Establishing and Ensuring Effective Filtration System Performance in Enclosed Cabs, Operator Booths and Control Rooms

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Research Goal
Assessing optimal filtering efficiency along with evaluating the use of a pressure monitoring device for determining filtration and pressurization system performance.
What Level of Improvement is Achieved with the Filtration System?
Relative Performance Measures
Protection Factor; Efficiency; Penetration

\[ PF = \frac{C_O}{C_I} ; \quad \eta = \frac{C_O - C_I}{C_O} ; \quad Pen = 1 - \eta \]

\[ PF = \frac{C_O}{C_I} = \frac{1}{1 - \eta} = \frac{1}{Pen} \]
Field Studies

Cooperative Efforts with Cab Filtration Manufacturers, OEMs, Mining Companies, & Government Agencies
## Results from Field Studies

<table>
<thead>
<tr>
<th>Cab Evaluation</th>
<th>Mining Type</th>
<th>New vs. Retrofit</th>
<th>Cab Pressure, Inches w.g.</th>
<th>Average Inside Cab Dust Level, mg/m³</th>
<th>Average Outside Cab Dust Level, mg/m³</th>
<th>Protection Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rotary Drill</td>
<td>Surface</td>
<td>Retrofit</td>
<td>None Detected</td>
<td>0.08</td>
<td>0.22</td>
<td>2.8</td>
</tr>
<tr>
<td>Haul Truck</td>
<td>Underground</td>
<td>Retrofit</td>
<td>0.01</td>
<td>0.32</td>
<td>1.01</td>
<td>3.2</td>
</tr>
<tr>
<td>Roof-bolter</td>
<td>Underground</td>
<td>New</td>
<td>0.05 - 0.10</td>
<td>0.12</td>
<td>0.92</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>Surface</td>
<td>Retrofit</td>
<td>0.015</td>
<td>0.03</td>
<td>0.30</td>
<td>10</td>
</tr>
<tr>
<td>Front-end Loader</td>
<td>Surface</td>
<td>Retrofit</td>
<td>0.05 - 0.20</td>
<td>0.19</td>
<td>2.43</td>
<td>28</td>
</tr>
<tr>
<td>Face Drill</td>
<td>Underground</td>
<td>New</td>
<td>0.07 - 0.12</td>
<td>0.70</td>
<td>6.125</td>
<td>89.3</td>
</tr>
<tr>
<td>Rotary Drill</td>
<td>Surface</td>
<td>Retrofit</td>
<td>0.20 - 0.40</td>
<td>0.05</td>
<td>2.80</td>
<td>56</td>
</tr>
</tbody>
</table>
These are gravimetric results right? Not particle counting?
Key Components for Effective Cab Filtration and Pressurization Systems
Effective Filtration

1. Pressurized Intake
2. Recirculated Cab Air
Health and Safety Professional

**Assumption:**
The greater the filtering efficiency of filters being used in filtration and pressurization systems, the greater the protection afforded to the miners’ inside of enclosed cabs/enclosures/operator booths.
Filtering Efficiency Terms

- **MERV Ratings**
  American Society of Heating, Refrigerating, and Air-Conditioning Engineers Handbook (ASHRAE)  
  “Minimum Efficiency Reporting Value”

- **HEPA**
  Established by the United States Department of Energy, (DOE)  
  High-Efficiency Particulate Arrestance  
  High-Efficiency Particulate Arresting  
  High-Efficiency Particulate Air
# MERV Rating Efficiency

Minimum efficiency reporting values (MERV) according to the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE)

<table>
<thead>
<tr>
<th>Group</th>
<th>MERV Rating</th>
<th>Average particle size efficiency (PSE) 0.3–1.0 microns</th>
<th>Average particle size efficiency (PSE) 1.0–3.0 microns</th>
<th>Average particle size efficiency (PSE) 3.0–10.0 microns</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td></td>
<td>&lt; 20%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2</td>
<td></td>
<td>&lt; 20%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>3</td>
<td></td>
<td>&lt; 20%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>4</td>
<td></td>
<td>&lt; 20%</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>5</td>
<td></td>
<td></td>
<td>20–34.9%</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td></td>
<td></td>
<td>35–49.9%</td>
</tr>
<tr>
<td></td>
<td>7</td>
<td></td>
<td></td>
<td>50–69.9%</td>
</tr>
<tr>
<td></td>
<td>8</td>
<td></td>
<td></td>
<td>70–84.9%</td>
</tr>
<tr>
<td>3</td>
<td>9</td>
<td></td>
<td>&lt; 50%</td>
<td>≥ 85%</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td></td>
<td>50–64.9%</td>
<td>≥ 85%</td>
</tr>
<tr>
<td></td>
<td>11</td>
<td></td>
<td>65–79.9%</td>
<td>≥ 85%</td>
</tr>
<tr>
<td></td>
<td>12</td>
<td></td>
<td>80–89.9%</td>
<td>≥ 90%</td>
</tr>
<tr>
<td>4</td>
<td>13</td>
<td>&lt; 75%</td>
<td>≥ 90%</td>
<td>≥ 90%</td>
</tr>
<tr>
<td></td>
<td>14</td>
<td>75–84.9%</td>
<td>≥ 90%</td>
<td>≥ 90%</td>
</tr>
<tr>
<td></td>
<td>15</td>
<td>85–94.9%</td>
<td>≥ 90%</td>
<td>≥ 90%</td>
</tr>
<tr>
<td></td>
<td>16</td>
<td>≥ 95%</td>
<td>≥ 95%</td>
<td>≥ 95%</td>
</tr>
<tr>
<td>HEPA</td>
<td></td>
<td>≥99.97%</td>
<td>≥99.97%</td>
<td>≥99.97%</td>
</tr>
</tbody>
</table>
Testing

Single-boom Face Drill and Roof-bolter Machine

MERV16 Testing – May thru November 2013
HEPA Testing – May thru November 2014
Filtration and Pressurization
Setup both Enclosed Cabs
Airflow Measurements

Both Intake and Recirculation
Static Test Mode

Mobile equipment was running without anyone in the enclosed cab to stir up or create any in-cab dust sources. Provides the highest PF for each of the enclosed cabs.

Note: HVAC Fan Operated on “High” Setting
Results

MERV16 vs. HEPA Filters
Average PF Comparing MERV 16 and HEPA Filters
Comparing Intake Airflow and Positive Cab Pressure on Face Drill
Roof-bolter Performance (PF) with Different Filters Used (Actual and Modeled Values) - MERV 16

Note: Model only included intake air leakage (>60 pct.)
Multiple Filtration System Leakages

Potential HVAC Leakage Areas

Leakage Around Filter
Retrofit Filtration and Pressurization System at Primary Crusher Operator Booth – Limestone Mine

Primary Crusher Operator’s Booth
Original System Effectiveness

Fan On: 6560 µg/m3
Fan Off: 530 µg/m3
Crusher Booth: System Upgrade

475 ft$^3$
Crusher Booth: Performance Monitoring
Crusher Booth: Airflows

- With fixed fan pressurization, airflow indicates filtration system restriction.
Crusher Booth: Protection Factors

Protection Factors with MERV 16 over **4X greater** compared to HEPA
Math Model of Enclosed Cabs

Mathematical model is useful for predicting PF

\[ PF = \frac{Q_I + Q_R - [Q_R(1 - \eta_I + l_I\eta_I)]}{Q_I(1 - \eta_I + l_I\eta_I)} \]

- Protection Factors @ Graymont; 1st 5 HEPA; last 6 MERV16

- Measured PF
- Predicted PF
Effect of intake leaks and filter efficiency

- Leaks matter – as important as the filter choice
Comparing Cab Pressure Monitors

- All gauges compared to reference standard (+/- 0.5% accuracy)
- Pressure varied between 0 and 0.5” H2O
- Horizontal (roll) and Vertical (pitch) varied up to 30 deg
- All data collected time synchronously
Comparing Cab Pressure Monitors

- Gauges within +/- 3% of true values (mean) and +/- 10% of (max)
Cab Pressure Monitors at Crusher Booth
Crusher Booth: Pressure Monitoring

- INSTALLED MERV16 FILTER
- FIXED LEAKY PLENUM
- FILTER LOADING
- HEPA FILTER
The Bottom Line

Miners’ Attention

“Where the dust meets the lungs”
Conclusions:

MERV 16 filters are less expensive, do not need to be changed as often, have lower maintenance and labor costs, have lower differential pressures across the filter resulting in higher airflow cleaning quantities and less contaminant leakage around the filter and into the enclosure. **MERV 16 filters were the preferred choice for these two studies** and we believe this would be consistent for almost all types of mining and construction type applications.
Questions?

Thank you.

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