Dust Division
Pittsburgh Safety and Health Technology Center

Mark Schultz
Senior Mining Engineer
Mine Ventilation

• Dust Control
Mine Ventilation is used to Dilute and Render Harmless

- All Noxious Gases
- Dusts!!!!
Dust Concentrations are Inversely Proportional to Air Quantity
(under ideal situations)

Double the Air Quantity, Dust Concentration is Cut in Half!!

N × Air Quantity = 1/N Concentration

• N=2
• 2 Quantity = ½ Concentration
• 20,000 cfm - 2.0 mg/m³ Concentration
• 40,000 cfm - 1.0 mg/m³ Concentration
• 10,000 cfm - 4.0 mg/m³ Concentration
Practical Ways To Increase Air Quantities

• Increase Fan Quantity
  • Mine Design
• Reduce Leakage
Fan Air Quantity

• Change Blade Setting
• May need more Motor HRSP.
  – Higher electrical costs
Mine Design

• Basic Mine Ventilation Equations

\[ H = R \cdot Q^2 \]

- \( H \) – Pressure Loss (Inches of Water)
- \( R \) – Resistance
- \( Q \) – Quantity of Air
Parallel Flow in Airways

- \( R_n = \frac{1}{n^2} \times R_1 \)

- \( R_1 \) is Original Resistance (1 entry)
- \( N \) is number of Entries
Multiple Entries

- One to Two Entries
  - $R_2 = \frac{1}{4} R_1$
  - You have reduced your resistance to $\frac{1}{4}$ original resistance

- One to Three Entries
  - $R_3 = \frac{1}{9} R_1$
  - You have reduced your resistance to $\frac{1}{9}$ original resistance
Single Entry (Intake and Return)

1" H₂O Pressure
30,000 cfm

1" H₂O Pressure
30,000 cfm
Triple Entry (Intakes and Returns)

1" H₂O Pressure
90,000 cfm
# Single Entry (Intake and Return)

<table>
<thead>
<tr>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="cell1.png" alt="Cell" /></td>
<td><img src="cell2.png" alt="Cell" /></td>
<td><img src="cell3.png" alt="Cell" /></td>
<td><img src="cell4.png" alt="Cell" /></td>
<td><img src="cell5.png" alt="Cell" /></td>
<td><img src="cell6.png" alt="Cell" /></td>
<td><img src="cell7.png" alt="Cell" /></td>
<td><img src="cell8.png" alt="Cell" /></td>
<td><img src="cell9.png" alt="Cell" /></td>
<td><img src="cell10.png" alt="Cell" /></td>
<td><img src="cell11.png" alt="Cell" /></td>
</tr>
</tbody>
</table>

**1” H₂O Pressure**

30,000 cfm

---

**1” H₂O Pressure**

30,000 cfm
<table>
<thead>
<tr>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image" alt="Triple Entry (Intakes and Returns)" /></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

0.1” H₂O Pressure
30,000 cfm

0.1” H₂O Pressure
30,000 cfm
Leakage

• Patch Holes in Stopping
• Lower Pressure Drop Across Entries
  – Multiple Entries
  – Do not locate Intakes and Returns side by side
  – One open air split
    • No Regulator
    • Also reduces energy costs
Face Ventilation

- Get the Air where you Need it!
  - Tight Check Curtains
  - Good Run Through Curtains
  - Curtain tight to the roof
  - Do not Park Equipment in Last Open Entries
  - Keep curtains close to the face
Exhaust or Blowing Ventilation

- Blowing is better for Methane Control
- Exhaust is better for dust Control
Blowing Curtain

• Blowing curtain is easier to maintain
  – Less manpower to hang curtain
  – No need for frame work
  – “Cheap Man’s Ventilation!”

• Miner Operator should always be in fresh air!

• Higher possibility for Roof Bolters, Shuttle Car and Ram Operators to be out!
  – Especially Important in high silica faces!!!!

• Better for Methane Control!

• Scrubber must be used with Blowing Curtain and the use of Scrubber results in less return float dust!
Exhaust Ventilation

• Better for Dust Control
  – May be necessary in high silica areas

• Allows most workers to always be in intake air
  – Exception may be the roof bolters

• At same curtain set back distances, exhaust ventilation is not as efficient in removing methane

• Scrubber not required
  – More float dust in returns when scrubber is not used
Airflow Patterns Blowing Vrs. Exhausting

Airflow patterns independent of air volume

- Turbulence
- Primary airflow
- Secondary airflow

A  BLOWING

B  EXHAUSTING
Blowing Face Ventilation

• Line Brattice air quantity is based on the scrubber air quantity
• Must first determine your scrubber air quantity
Pitot Tube Air Measurements made to Measure Scrubber Air Velocity and Ventilation Tubing Velocity

- A Pitot Tube Traverse must be used to accurately measure airflow in ventilation tubing and the duct work of dust scrubbers; especially where there are greater than 3000 fpm velocities.
Why not use a Vane Anemometer?

- According to the ACGIH Industrial Ventilation Recommended Practice
  - This instrument is accurate to determine air flow through large supply and exhaust openings
  - The cross-sectional area of the instrument should not exceed 5% of the measured area
  - Generally, useful range is below 3,000 fpm
  - Standard 4” anemometer is unsuited for measurements in ducts below 20” diameter
  - Velocities vary dramatically throughout scrubber
  - Pitot tube has less error at higher velocities!
Pitot Tube used to Measure Air Speed (Velocity)
Proper Scrubber Air Quantity

• Full Pitot Tube Traverse
  – Machine is New (baseline)
  – Clean
  – Water is on
• Pitot tube faces direction of Air Flow
• Get a Proper Area
• Scrubber Exhaust Clear
Full Pitot Tube Traverse
Blowing Ventilation - What Should the Line Brattice Air Quantity Be

Minimum Line Brattice Air Quantity Is equal to Scrubber Air Quantity with Maximum of 1,000 cfm over or 15% over scrubber quantity

Minimum assures adequate intake air is delivered to face

• Maximum Quantity prevents Overpowering of Scrubber (dust laden air bypasses scrubber and goes directly into return from face)
  – Occurs when
    • Line Brattice Air Quantity exceeds Scrubber Air Quantity and
      – Curtain too close to cutting head
      – Line Brattice air velocities over 400 fpm
Higher Air Quantities can overpower the scrubber if

Line Brattice Air Velocity is too high and Line Curtain hung too close to Cutterhead

Effects Ram Car Operators & Downwind Personnel (Roof Bolters)

Higher air quantity than the scrubber AND
Curtain to close to cutting head OR
Velocity exceeds 400 fpm
How to Stop Over Powering of Scrubber

Balanced Airflow
Or
Higher Air Quantities with

Low Air Velocity (below 400 fpm)
-increasing curtain area

Keep curtain away from cutterhead

Additional Step cuts allow curtain be held back!
- the deeper your sump cut the closer the curtain will be to your cutterhead on slab cut
On Blowing Ventilation Systems, MSHA has been requiring the line brattice air quantity be the minimum of the scrubber capacity measured with the scrubber off

Why????

This assures adequate Intake Air is being supplied to the face

Prior to this change, recirculation of return air was contaminating the intake curtain and causing dust overexposures to the continuous miner operator
Face Airflows

Scrubber Rating
7,500 cfm

Inadequate Intake Air

What happens when we have Inadequate Intake Air

Inby End of Curtain
- Scrubber Off: 3,000 cfm
- Scrubber On: 7,500 cfm

Outby End of Curtain
- Scrubber Off: 4,000 cfm
- Scrubber On: 4,300 cfm

20,000 cfm
• Amount of Recirculation will depend on
  – Air Quantity in the curtain area
  – Scrubber Air Quantity
  – Length of curtain
  – Integrity of hung curtain
How was this recirculation identified (4 ways)

1. Air Measurements of the Line curtain
2. Inby and outby line curtain dust concentrations
3. Use of Chemical Smoke on the curtain for air currents
4. By CMO’s going out of compliance!
# Air Measurements from a Dust Face Study

<table>
<thead>
<tr>
<th>Date</th>
<th>Cut No.</th>
<th>Curtain Length (feet)</th>
<th>Scrubber (on/off)</th>
<th>Airflow (cfm)</th>
<th>Section Main Intake</th>
<th>Section Main Return</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Miner Line Curtain</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Outb</td>
<td>Inby</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>151</td>
<td>on</td>
<td>6,200</td>
<td>7,800</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>off</td>
<td>7,100</td>
<td>movement inby</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>145</td>
<td>on</td>
<td>7,900</td>
<td>7,900</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>off</td>
<td>8,300</td>
<td>3,300</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>1</td>
<td>192</td>
<td>on</td>
<td>8,300</td>
<td>8,900</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>off</td>
<td>7,400</td>
<td>movement inby</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>2</td>
<td>161</td>
<td>on</td>
<td>7,000</td>
<td>6,000</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>off</td>
<td>8,000</td>
<td>movement inby</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>159</td>
<td>on</td>
<td>7,900</td>
<td>10,700</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>off</td>
<td>6,200</td>
<td>3,600</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>204</td>
<td>on</td>
<td>10,00</td>
<td>6,200</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>off</td>
<td>8,800</td>
<td>movement inby</td>
<td></td>
</tr>
</tbody>
</table>
• Factors that affect inby vrs. Outby air Quantities
  – Scrubber
  – Line Brattice
    • Length of curtain
    • Condition of curtain
      – How well is curtain hung
    • Turning 90’s
      – Direction of scrubber exhaust
  – Other Section Variables
    • Equipment location
      – Ram Cars
Face Airflows

Scrubber Rating
7,500 cfm

Proper Intake Air

Inby End of Curtain
Scrubber Off 7,500 cfm
Scrubber On 7,900 cfm

Outby End of Curtain
Scrubber Off 9,000 cfm
Scrubber On 9,200 cfm

20,000 cfm
## Dust Concentrations from a Face Dust Survey

<table>
<thead>
<tr>
<th>Area</th>
<th>Dust Concentration (mg/m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>8/2/05</td>
</tr>
<tr>
<td>Section Main Intake</td>
<td>0.13</td>
</tr>
<tr>
<td>Section Main Return</td>
<td>0.67</td>
</tr>
<tr>
<td>Line Curtain Outby End</td>
<td>0.16</td>
</tr>
<tr>
<td>Line Curtain Inby End</td>
<td>2.81</td>
</tr>
<tr>
<td>CM Immediate Return</td>
<td>3.67</td>
</tr>
</tbody>
</table>
3. Artificial Smoke to determine airflows at the curtain

4. CMO going out of Compliance (should always be in intake air)
Summary - How do we Prove Curtain recirculation “Inadequate Intake Air”

- Inby curtain vrs. Outby curtain Air Quantity Readings
- Outby curtain to inby curtain dust area dust concentrations
- Smoke the curtain
- Continuous Miner Operator Samples
How Does MSHA Enforce Taking Readings with Scrubber Off?
What is the Purpose of the Scrubber?

• Scrubber main function is to control dust
  – Scrubber is a Dust collection Device
  – Recirculation does not apply

• But, if Scrubber is used to obtain the line brattice air quantity, it is a ventilation device and must meet Regulations!
  • 75.331(4) Located and Operated to avoid recirculation
  • 75.330(c) Maintaining line brattice for proper ventilation (no recirculation)

• Take the line brattice air reading with the scrubber off!!! Assures Adequate Intake Air!!!
2 Major Points
Blowing Ventilation

• **Minimum** Line Brattice air Quantity should be the Scrubber Capacity

• **Take Line Brattice Air Reading with the Scrubber Off!!!** Helps to assure Miner Operator is in fresh air!
  
  – Assures that Adequate Intake Fresh Air is Delivered to the Working Face
Exhaust Ventilation

• Line Brattice air quantity minimum of 3,000 cfm or enough to meet 60 mean air velocity

• Generally better for dust control
  – All employees (except possibly roof bolters) should always be in intake air
  – May be necessary in high silica mining

• If blowing sections can not obtain compliance, Exhaust ventilation is recommended
  – Removes many variables
    • Balancing scrubber and line brattice air quantities
    • Miner Operator Work position
    • Other Employees removed from return air
  – If non compliance occurs in exhaust vent., increase line brattice or tubing air quantity
Line Brattice Air Measurement
Intake or Exhaust

• Line Brattice Air Quantities are dynamic entities and may continually change depending on many conditions

• Air Quantities must be maintained throughout your cut
Factors Influencing Line Curtain Air Quantities

- Adding additional curtain
- Movement through Outby Curtains or mandoors
- Position of other Equipment
- Movement of Outby Equipment
- Scrubber on or off
- Scrubber Capacity changing
- Person taking the Air Reading
  - Bad Measurements
  - Accuracy of Data due equipment error
Changes in Curtain Airflows

Starting Air Quantity 7,000 cfm

Air Quantity at Inby End of Curtain

- 7,000 cfm
- 6,800 cfm
- 2,000 cfm
- 6,300 cfm
- 6,100 cfm
- 9,000 cfm

25,000 cfm
Need Accurate Line Brattice Air Quantity Measurements

• Human and Mechanical errors
• Calibrated Anemometer
• Accurate 1 minute timing
• Accurate Area Measurement
• Minimal movement of outby equipment and miners
• Keep you body out of measured area
Body Size can Affect Air Readings

Miner’s Size 1 foot wide by 6 feet high
Takes up an area of 6 square feet

\[ V = 300 \text{ fpm} \]
\[ A = 18 \text{ square feet} \]
\[ Q = 5400 \text{ cfm} \]

\[ V = 300 \text{ fpm} \]
\[ A = 12 \text{ square feet} \ (18 - 6) \]
\[ Q = 3600 \text{ cfm} \]

Foreman reports 5400 cfm when he actually only has 3600 cfm
Air Quantity Errors Will Add Up

- Scrubber Nameplate Rating 4,600 cfm
- Actual Scrubber Quantity 4,900 cfm
- Plan requires 4,600 cfm to + 1000 cfm (5,600 cfm) of the nameplate rating
• Foreman takes an air reading of 4,600 cfm. He is good to go!

• Actual Air Quantity
  - 4,600 cfm  Foreman’s Air Reading
  - 1,530  Foreman’s body increased area
  - 300  Adding 40 feet more curtain during cut
  - 460  Error in reading (10% error)

  2,310 cfm Actual Line Brattice Air Quantity

You actually have 2,310 cfm ventilating a 4,900 cfm scrubber!!!!!!
Recipe for recirculation and Poor Dust Control!!
Offset Cut

- CM takes a normal sump cut
- CM does not square face up on slab cut
- Cuts about 3 - 4 feet less than square face
- At the start of next sump cut, the CM cutterhead is boxed in and the scrubber efficiency is increased
Working downwind of CM is always discouraged!

When bolting downwind we actually ventilate roof bolter with the dirtiest air from the Continuous Miner.

Clean air bypasses roof bolter.
Add a curtain in LOX to mix dirty air!
Conclusions

• Dust Concentrations are Inversely Proportional to Air Quantity. Increase your face ventilation and utilize it properly and you will reduce your dust concentrations!
Questions?

• Mark Schultz, P.E.
• [Schultz.mark.j@dol.gov](mailto:Schultz.mark.j@dol.gov)
• 412 386 6807