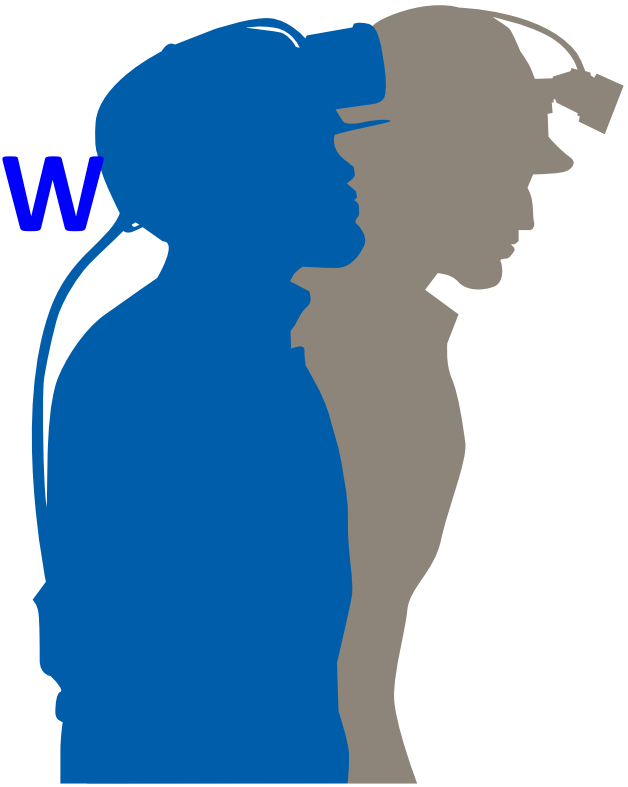
OMSHR

Office of Mine Safety and Health Research



An Improved Longwall System

Jim Rider

Lead Research Scientist

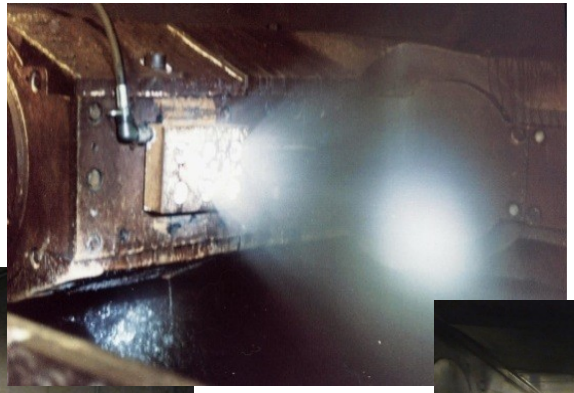
Acting Team Lead – Dust Control

Dust, Ventilation and Toxic Substances Branch

An Improved Longwall Water Directional Spray System

Outline

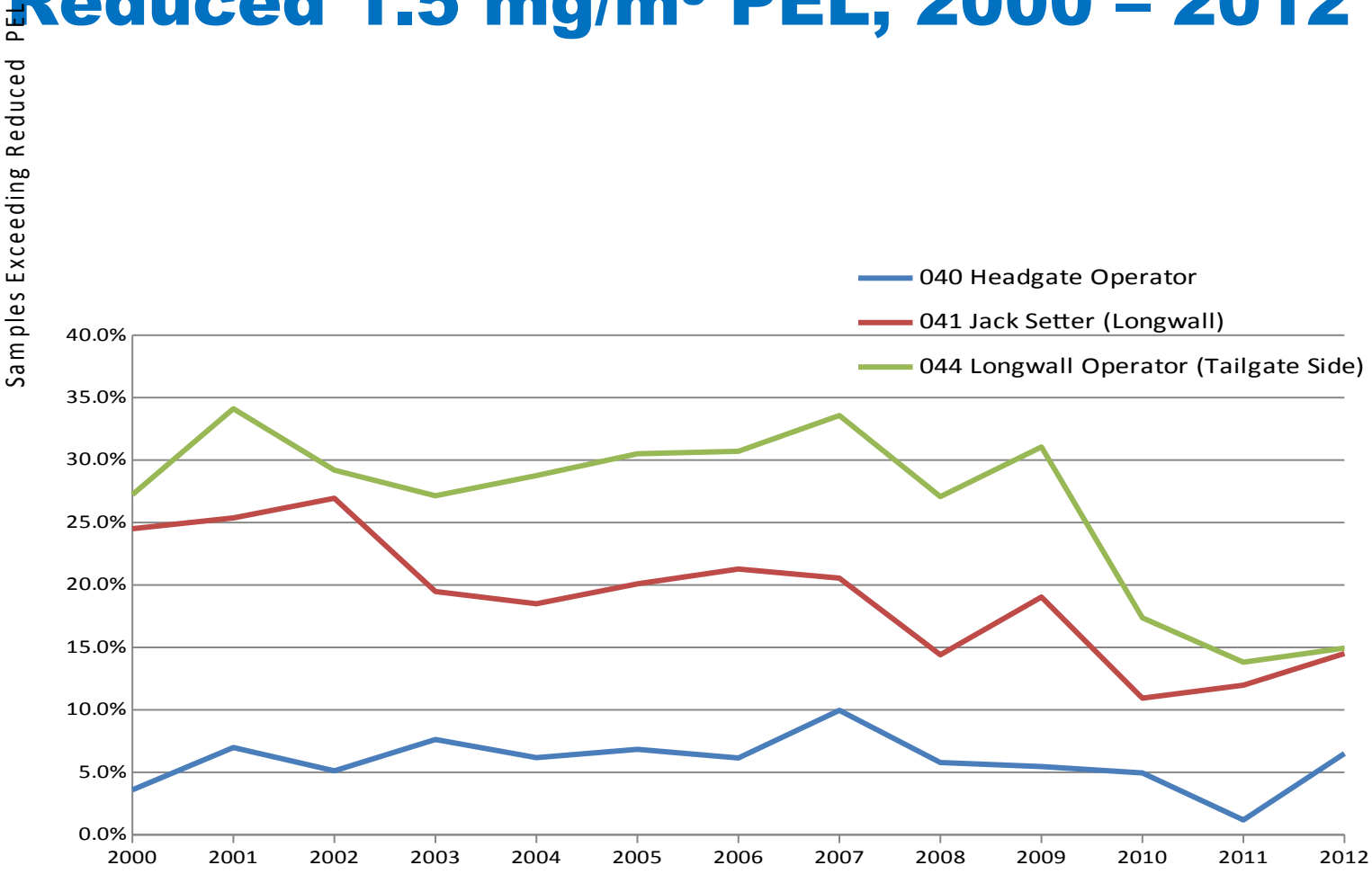
- Todays Longwall, Compliance Data
- Laboratory Assessment of 3 Tailgate Spray Manifolds
- Underground Evaluation of a Tailgate Manifold
- Traveling Water Curtain and Underside Shield Sprays
- Summary



Longwall Statistics

- 2008 – 179.2 million tons
- 2013 – 185.0 million tons
- 53 % of underground production
- Working Faces
  - 1994 – 80
  - 2008 – 46
  - 2013 – 48
- Average Shift Production
  - 1994 – 3,600 tons per shift
  - 2008 – 5,500 tons per shift
  - 2012 – 6,000 tons per shift
- Panel Widths
  - 2002 - 940 ft.
  - 2007 - 967 ft.
  - 2013 - 1,188 ft.
- Panel Lengths
  - 2002 - 10,000 ft.
  - 2007 - 10,132 ft.
  - 2013 - 11,307 ft.
- Average Cutting Height
  - 2013 - 91 inches

MSHA Inspector Samples Exceeding Reduced 1.5 mg/m³ PEL, 2000 – 2012



Respirable Dust in Coal Mining

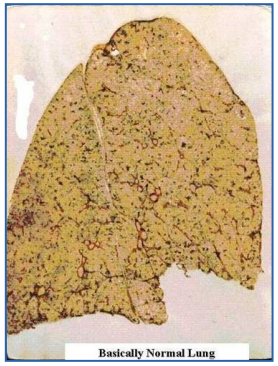
- Dust less than 10 microns in size (cannot be seen with the eye)
- Overexposure can cause lung disease
- 1969 Federal Coal Mine Health and Safety Act first regulated miners' exposures
  - Established 2.0 mg/m^3 respirable coal mine dust limit
  - Required occupational dust sampling by MSHA and mine operators
  - Established an X-ray surveillance program for underground coal miners
  - Established a federal black lung benefits program
- Control technologies are implemented to reduce worker exposures

Diseases Caused by Inhalation of Coal Dust

- Fibrotic diseases – damage/destroy lung tissue
  - Coal workers' pneumoconiosis "CWP"
  - Silicosis
- Airflow diseases "COPD" – block movement of air in and out of lungs
  - Bronchitis
  - Emphysema
  - Mineral dust airway disease

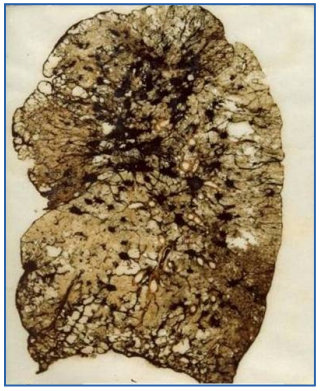
Overexposure to Respirable Dust in Mining

- Coal Workers' Pneumoconiosis (CWP) results from inhalation of respirable coal dust and is commonly called "Black Lung"
- Silicosis results from inhalation of respirable silica dust
- Both lung diseases can be disabling or fatal
- Simple and severe forms (Progressive Massive Fibrosis – PMF)
- **No cure**…so diseases must be prevented



Healthy lung

CWP



Silicosis

Progressive Massive Fibrosis (PMF)

- Fibrous tissue develops in larger area of lungs
- Lungs become stiff and cannot expand fully
- Breathing becomes difficult
- Lips and fingernails may have bluish tinge
- Fluid retention and signs of heart failure

Respirable crystalline silica (quartz)

- Silica is more toxic than coal (exposure limited to 1/20th that of coal in 1969 Act)
- Freshly fractured silica is more toxic than aged silica
- Smaller particles are more toxic
- Consequences of overexposure:
  - Silicosis
  - Airways diseases
  - Pulmonary tuberculosis
  - Chronic renal disease
  - Lung cancer

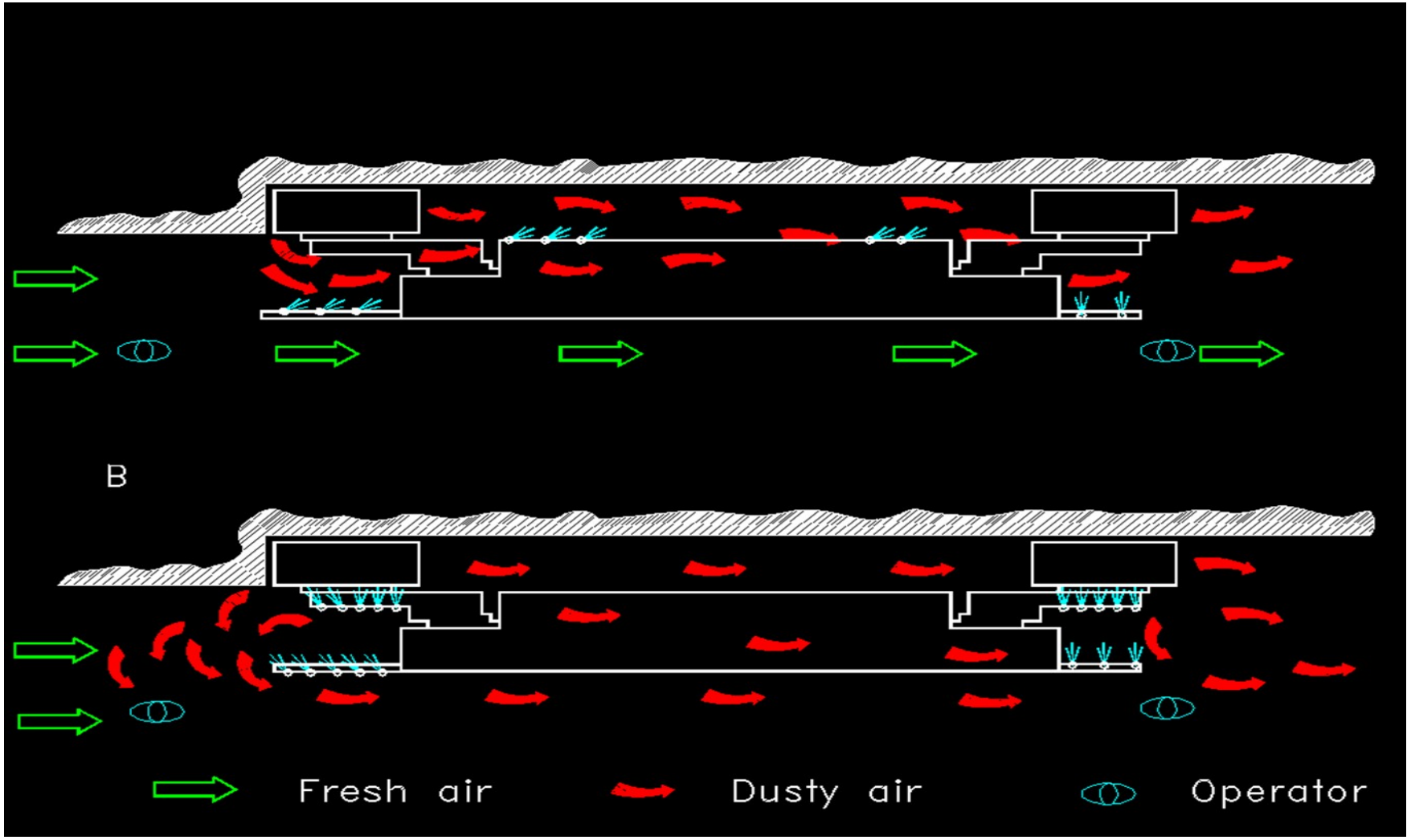
Silicosis

- Chronic
  - Occurs after 10 or more years of exposure
  - Swelling in lungs
  - Troubled breathing similar to COPD
- Accelerated
  - Develops in 5 to 10 years
  - Symptoms occur faster than in chronic silicosis
- Acute
  - Develops in less than 5 years
  - Lungs become inflamed and fill with fluid
  - Severe shortness of breath and low blood oxygen

Underground Observations

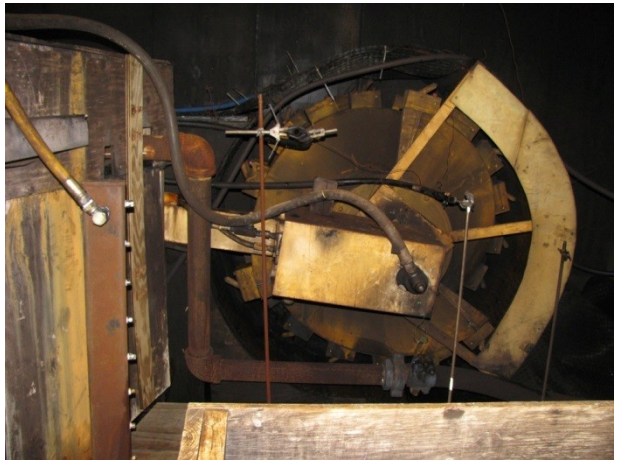
- Shield sprays interacting with splitter arm sprays creating turbulence
- Dust and mist cloud rolled into walkway
- Shield sprays interacting with splitter arm sprays creating turbulence
- Spalling upwind of headgate drum and dust rolling around splitter arm
- Elevated dust levels for the tailgate shearer operator and jacksetter

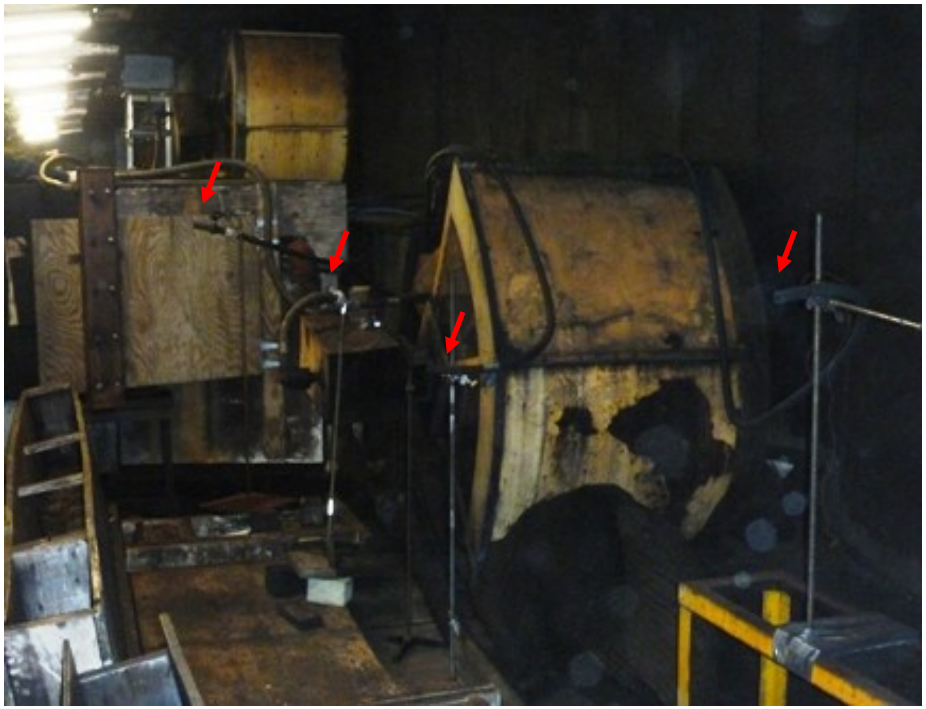
Expanding the Directional Spray System



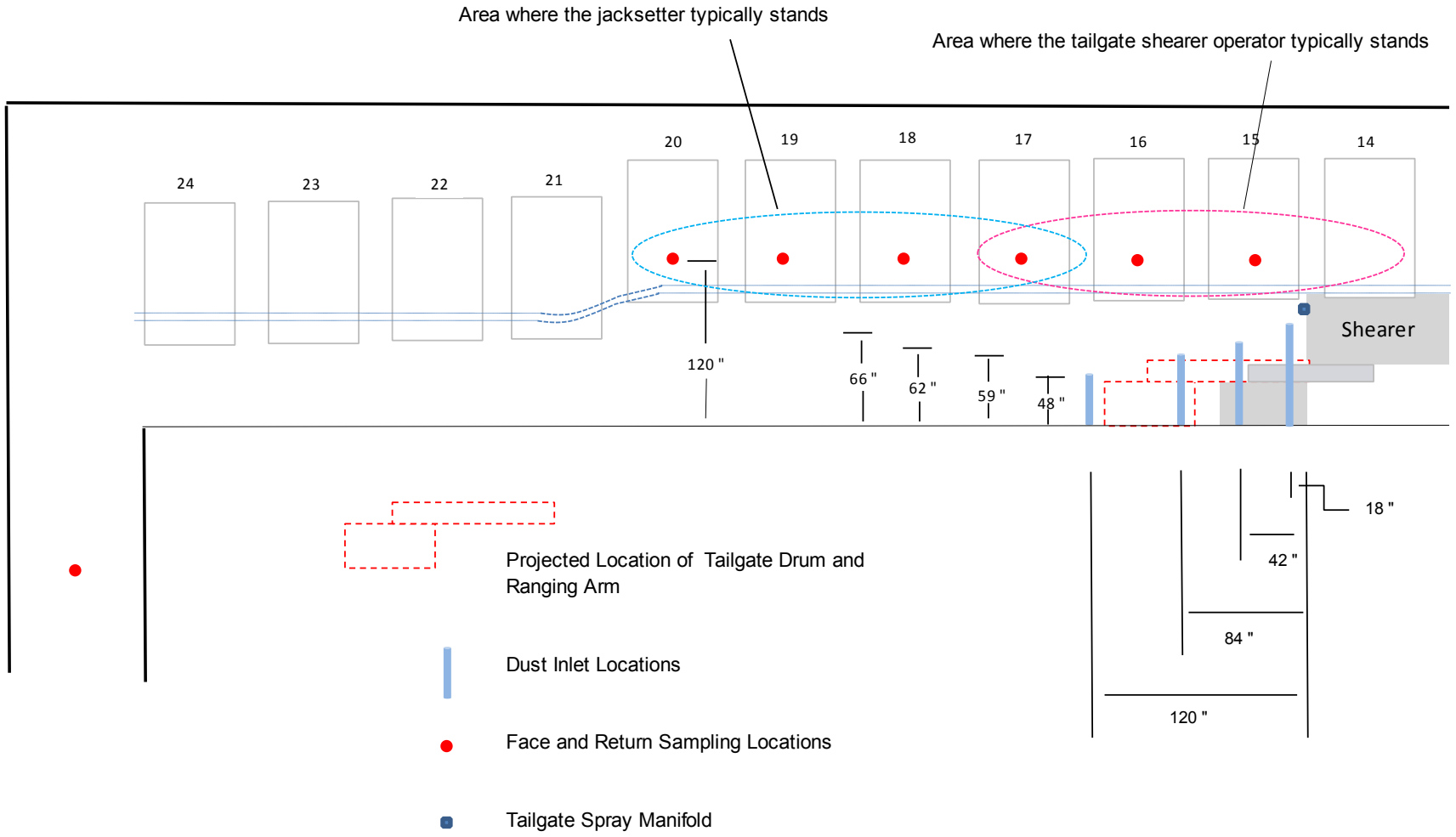
Laboratory Testing of Tailgate Spray Manifolds

Underground vs Laboratory





Laboratory Testing of Tailgate Spray Manifolds



Laboratory Testing of Tailgate Spray Manifolds

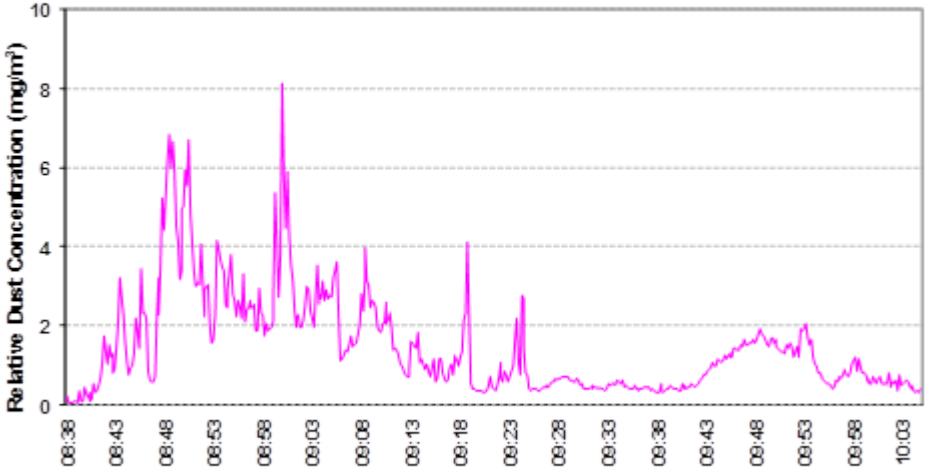
Sampling Strategy - Gravimetric Dust Sampler

- Provides time-weighted-average respirable dust concentration
- 10 –mm Dorr-Oliver cyclone separates respirable and oversize dust
- 37 mm PVC filter
- Pump operated at 2.0 liters per minute

Laboratory Testing of Tailgate Spray Manifolds

Sampling Strategy – personnel DataRAM (pDR)

- Uses light scattering as measurement technology
- Instantaneous readings correlated with time and stored in internal memory
- Relative concentrations impacted by:
  - size distribution of dust
  - composition of dust
  - water mist in air
- Adjust readings with ratio obtained from adjacent gravimetric samplers



Laboratory Testing of Tailgate Spray Manifolds

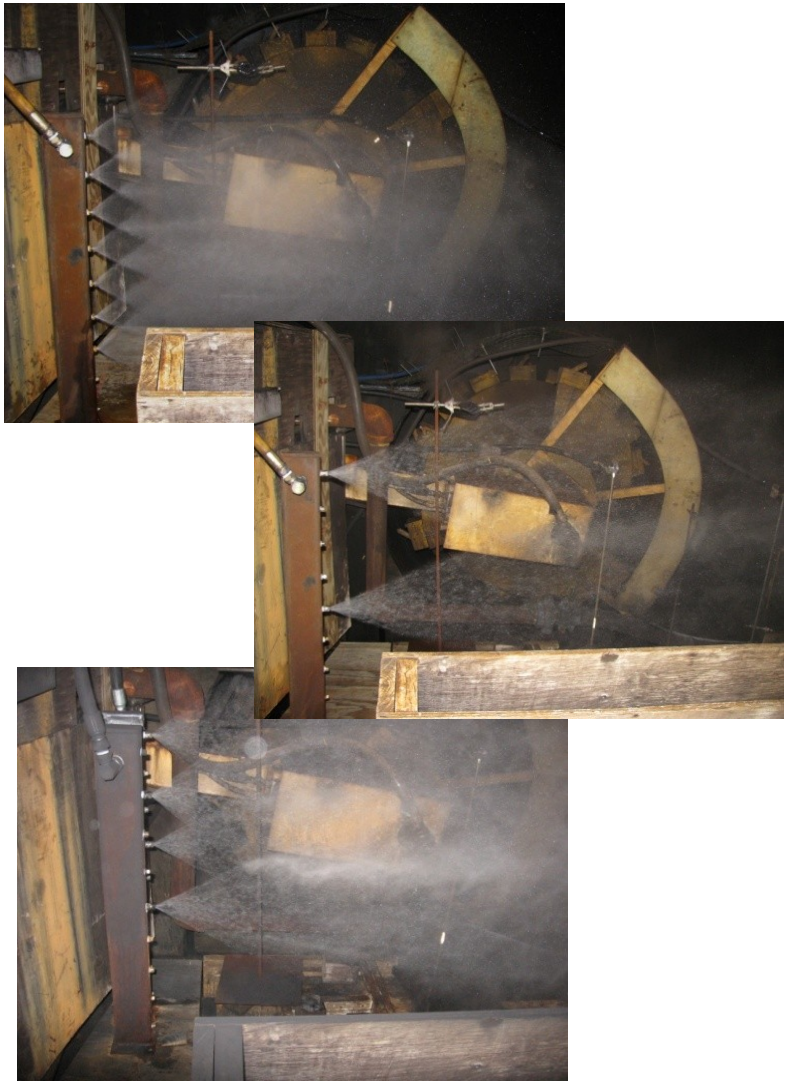
Laboratory Evaluation

- A-B-A Test
- 3 Tailgate manifolds
- 6 Face Sampling Stations
- Face Velocity - 500, 700, 900 fpm
- Spray Pressure - 100, 150, 200 psi

Laboratory Testing of Tailgate Spray Manifolds

Manifolds

- BD3 Manifold
  - Single spray bar
  - SS BD3 hollow cone – 7 sprays
  - 42” from TG drum – 25 degree angle toward the face
- 40-20 Manifold
  - Single spray bar
  - SS 40-20 flat fan spray – 2 sprays
  - 47” from TG drum – 15 degree angle toward the face
- 65-15 Manifold
  - Two spray bar
  - SS 65-15 flat fan spray – 2 sprays
  - 32” and 37” from TG drum – parallel to face



Laboratory Testing of Tailgate Spray Manifolds

Dust Reduction Efficiencies at 100 psi

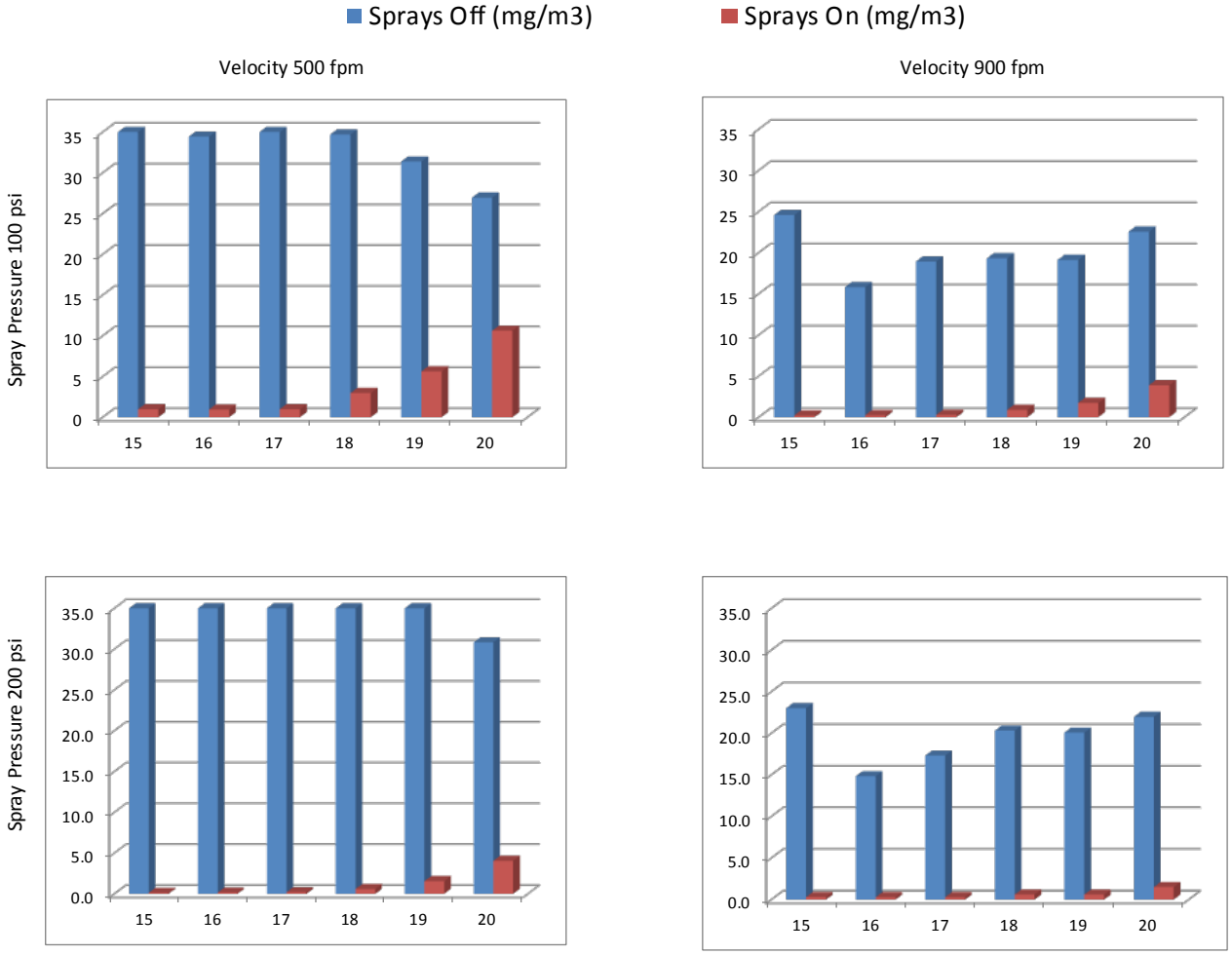
- All 3 manifolds systems substantially reduced dust under all test conditions.
- Reductions in dust concentrations ranged between 55% and 99%.

Spray Pressure (psi)	Manifold System / Nozzle	Velocity (fpm)	Sampling Location					
			15	16	17	18	19	20
100	BD3	500	0.9414	0.8949	0.9058	0.7400	0.6885	0.5492
		700	0.9691	0.9177	0.9141	0.8412	0.7181	0.6434
		900	0.9276	0.8791	0.8239	0.7660	0.6874	0.5792
	SS 40-20	500	0.8202	0.8738	0.9380	0.9238	0.8492	0.6788
		700	0.8570	0.8956	0.9479	0.9301	0.9022	0.8025
		900	0.8152	0.8467	0.9190	0.8937	0.9051	0.8383
	SS 65-15	500	0.9802	0.9728	0.9726	0.9146	0.8207	0.6056
		700	0.9918	0.9857	0.9871	0.9685	0.9270	0.8234
		900	0.9913	0.9842	0.9855	0.9540	0.9097	0.8276

Laboratory Testing of Tailgate Spray Manifolds

Gravimetric Dust Concentrations

2 Manifolds and 4 SS 65-15 Flat Fan Sprays



Instantaneous (pDR) Dust Concentrations

2 SS 40-20 Flat Fan Sprays

Laboratory Testing of Tailgate Spray Manifolds

- Determine if statistical differences exist when nozzle spray pressure and velocity increase
- Two-tailed t-test; unequal variances; level of significance of α = .05

Nozzle Spray Pressure

Manifold / Nozzle	Pressure (psi)	Pressure (psi)	
		150	200
BD3	100	0.0146	0.0021
	150	**X**	0.2283
SS 40-20	100	0.2036	0.0001
	150	**X**	0.0009
SS 65-15	100	0.1083	0.0805
	150	**X**	0.7433

Velocity

Manifold / Nozzle	Velocity (fpm)	Velocity (fpm)	
		700	900
BD3	500	0.2968	0.7729
	700	**X**	0.4609
SS 40-20	500	0.8275	0.5158
	700	**X**	0.2818
SS 65-15	500	0.3998	0.3242
	700	**X**	0.8135

Laboratory Testing of Tailgate Spray Manifolds

- Determine if statistical differences exist between the manifold systems
- Two-tailed t-test; unequal variances; level of significance of α = .05

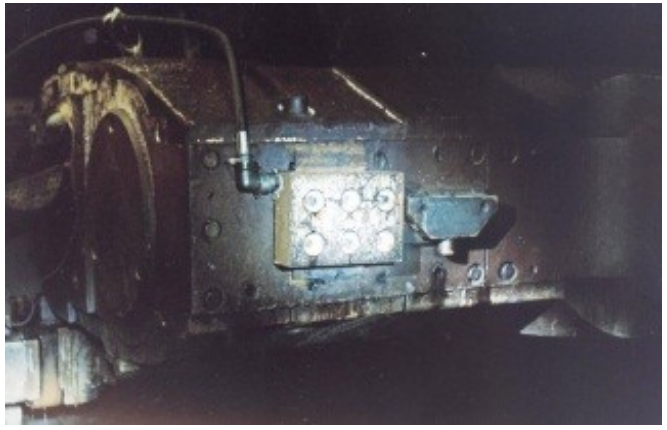
Nozzle Spray Pressure

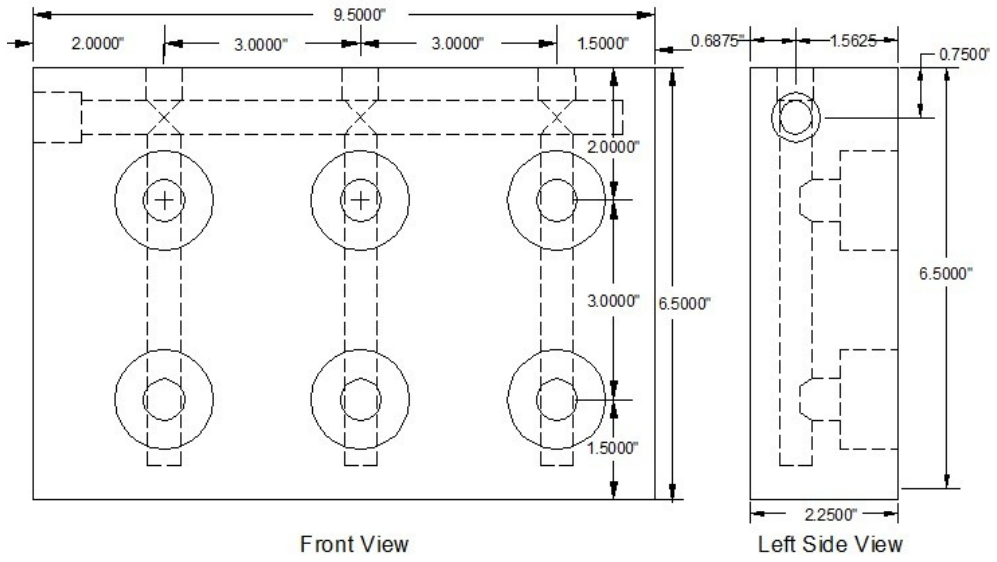
Pressure (psi)	Manifold / Nozzle	Manifold / Nozzle	
		SS 40-20	SS 65-15
100	BD3	0.0551	0.0033
	SS 40-20	X	0.0648
150	BD3	0.8741	0.0005
	SS 40-20	X	0.0001
200	BD3	0.1616	0.0189
	SS 40-20	X	0.0453

Velocity

Velocity (fpm)	Manifold / Nozzle	Manifold / Nozzle	
		SS 40-20	SS 65-15
500	BD3	0.1361	0.0288
	SS 40-20	X	0.2928
700	BD3	0.7416	0.0107
	SS 40-20	X	0.0019
900	BD3	0.0815	0.0032
	SS 40-20	X	0.0058

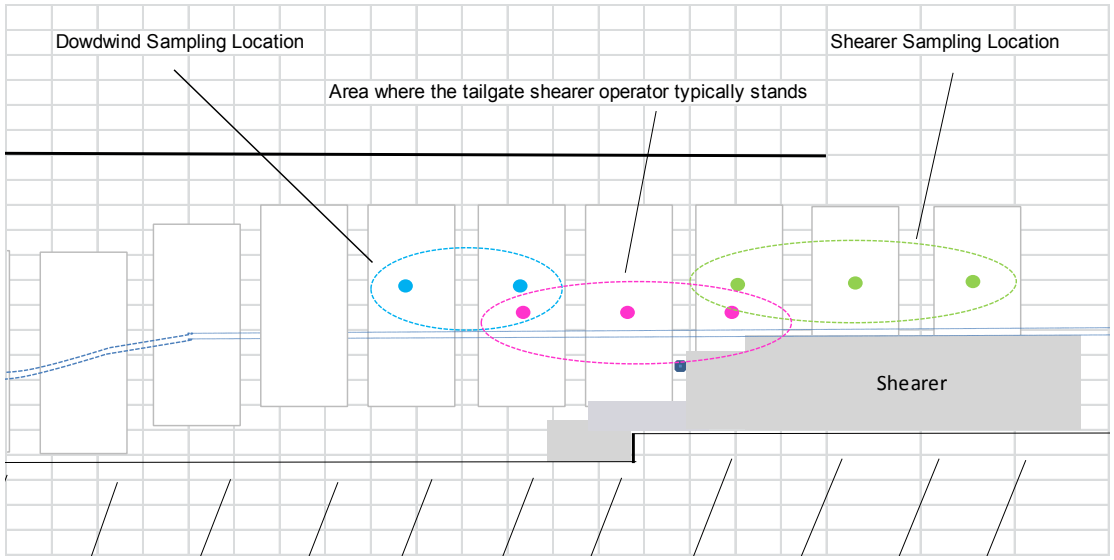
Tailgate Manifold Underground Evaluation





Tailgate Manifold Underground Evaluation

Sampling strategy and mining conditions



Tailgate shearer operator exposures from tailgate-side dust rollback can be calculated by subtracting the dust levels observed at the Shearer sampling location from dust levels at the Downwind sampling location.

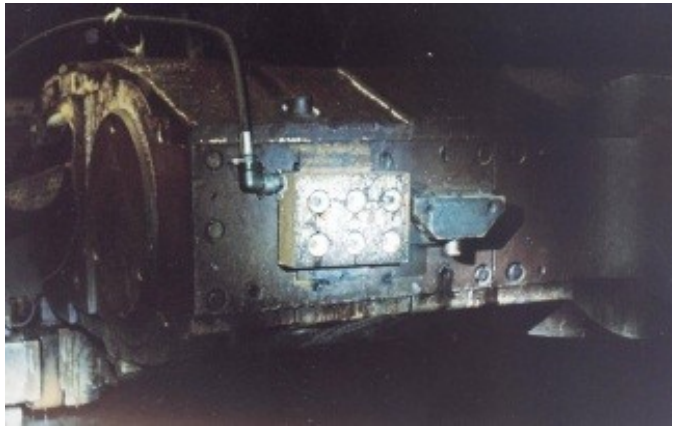
Mining Conditions

Seam height : 8 ft.
Face Velocity : 1300 fpm
Tailgate Spray Pressure : 120 – 130 psi

for Laboratory Comparison

Seam Height : 10 ft.
Face Velocity : 600 - 800 fpm
Tailgate Spray Pressure : 150 psi

Tailgate Manifold Underground Evaluation



GRAVIMETRIC SAMPLING DATA
AVERAGE DAILY PASS CONCENTRATIONS [mg/m³]

Tuesday		Wednesday		Thursday			Survey Average	
Manifold Off	Manifold On	Manifold Off	Manifold On	Manifold Off	Manifold On	Sampling Location	Manifold Off	Manifold On
0.478	0.862	0.773	0.536	1.256	0.492	**Upwind**	0.836	0.630
0.634	0.988	0.810	0.600	1.403	0.698	**Shearer**	0.949	0.762
0.609	1.218	1.038	0.657	1.513	0.610	**Downwind**	1.053	0.828
				Tailgate rollback	(Downwind-Shearer)		**0.104**	**0.066**

Tailgate Manifold Underground Evaluation

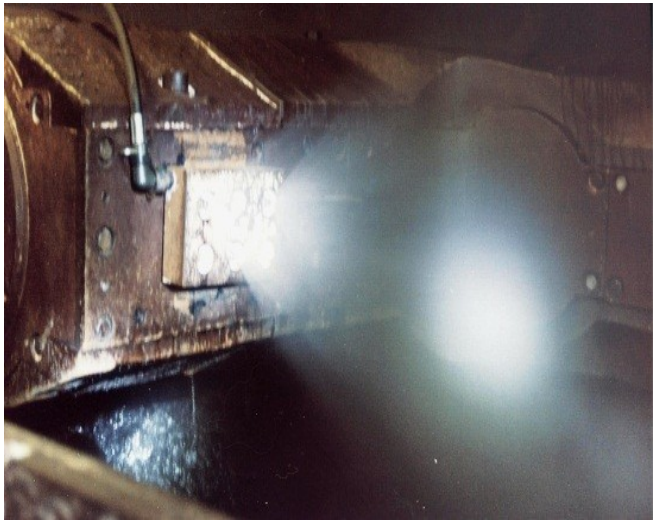
INSTANTANEOUS (pDR) SAMPLING DATA
AVERAGE H -> T ; T -> H CUT CONCENTRATIONS [mg/m³]

	Upwind Sampling Location				Shearer Sampling Location				Downwind Sampling Location			
	Manifold Off		Manifold On		Manifold Off		Manifold On		Manifold Off		Manifold On	
	H -> T	T -> H	H -> T	T -> H	H -> T	T -> H	H -> T	T -> H	H -> T	T -> H	H -> T	T -> H
Tuesday	0.362	0.358	1.263	1.196	0.589	0.396	1.973	0.891	0.571	0.448	2.227	1.064
Tuesday	0.673	0.482	0.482	0.651	0.906	0.673	0.639	0.471	0.740	0.676	0.875	0.666
Wednesday	0.774	0.505	0.650	0.434	0.776	0.651	0.693	0.474	1.015	0.820	0.444	0.432
Wednesday	1.043	0.792	0.616	0.498	0.980	0.848	0.719	0.473	1.317	0.983	1.030	0.623
Thursday	1.795	1.733	0.695	0.285	2.088	2.008	0.921	0.449	2.424	2.048	0.789	0.394
Thursday	0.657	0.516	0.567	0.326	0.858	0.487	0.859	0.468	0.982	0.487	0.745	0.404
Average	0.884	0.731	0.712	0.565	1.033	0.844	0.967	0.538	1.175	0.910	1.018	0.597
Tailgate rollback							(Downwind-Shearer)		**0.142**	**0.067**	**0.051**	**0.059**
OFF vs ON											64.01%	11.06%

%

Tailgate Manifold Underground Evaluation

- Face velocity (approximately 1300 fpm) was the dominating dust control factor resulting in very low dust levels at the sampling locations.
- Dust levels observed with gravimetric samplers : 0.856 mg/m^3 (SHEARER) ; 0.941 mg/m^3 (DOWNWIND).
- Quantitative dust sampling data showed little differences in dust levels with the manifold on versus manifold off conditions. Lower dust levels were observed with the tailgate spray manifold operational.
  - T->H : .067 mg/m^3 OFF vs .059 mg/m^3 ON
  - H->T : .142 mg/m^3 OFF vs .051 mg/m^3 ON
- The tailgate spray manifold appeared to have a positive influence on keeping dust the cloud confined close to face levels in the tailgate area.
- Both tailgate operators liked the spray manifold and thought it helped keep dust out of the walkway in the tailgate area.
- Further underground evaluations are warranted for faces that have air velocities below 1,000 fpm.



Traveling Water Curtain / Shield Sprays

Observed shield sprays interacting with splitter arm sprays creating turbulence

- Dust and mist cloud rolled into walkway
- Spalling upwind of headgate drum and dust rolling around splitter arm
- Research Study
  - Proper Sequencing
  - Effectiveness of shield sprays upwind of splitter arm

Traveling water curtain/shield sprays

Laboratory tests to evaluate dust suppression capabilities of underside shield spray sequencing

Traveling water curtain/shield sprays

Test conditions

- Splitter arm interaction
- Outby Spalling

Test parameters

- Face velocity – 600, 800 fpm
- Spray types – Hollow Cone, Flat Fan (2 spray angles)
- Spray pressure – 150, 200, 250, psi
- Activated shield sprays – 2, 4
- Nozzle distance – 97” and 80”
- Spray direction – 30 and 45 degrees
- Spalling simulated upwind of headgate drum

Traveling water curtain/shield sprays

Testing – ongoing, preliminary findings

- Spalling outby sprays – dust levels in walkway are elevated with sprays activated vs off
- Spalling contained within underside canopy sprays – dust levels are reduced over the spill plate and in walkway with sprays activated vs off

Traveling water curtain/shield sprays

- Optimize spray characteristics and synchronization in laboratory
- Test optimized system underground

An Improved Longwall Water Directional Spray System

Summary – Tailgate Manifold

- All 3 manifolds systems substantially reduced dust under all laboratory test conditions.
- Reductions in dust concentrations ranged between 55% and 99%.
- Flat fan sprays compared to the hollow cones sprays were more effective at reducing dust concentrations.
- No apparent relation between air velocity and reduced dust concentration for any of the nozzle types.
- Lower dust levels were observed during underground testing with the tailgate spray manifold operational
- Both tailgate operators liked the spray manifold and thought it helped keep dust out of the walkway in the tailgate area.
- Further underground evaluations are warranted for faces that have air velocities below 1,000 fpm.

An Improved Longwall Water Directional Spray System

Summary – Underside Shield Sprays

- Observed shield sprays interacting with splitter arm sprays creating turbulence
- Dust and mist cloud rolled into walkway
- Spalling upwind of headgate drum and dust rolling around splitter arm
- Laboratory tests to evaluate dust suppression capabilities of underside shield spray sequencing
- Preliminary findings
  - Spalling outby sprays – dust levels in walkway are elevated with sprays activated vs off
  - Spalling contained within underside canopy sprays – dust levels are reduced over the spill plate and in walkway with sprays activated vs off

Thank you!

Questions??

Jim Rider
412-386-4727
jrider@cdc.gov

Office of Mine Safety and Health Research
NIOSH
626 Cochrans Mill Road
Pittsburgh, PA 15236