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

Central Appalachian Section SME
West Virginia Coal Mining Institute
2017 Joint Spring Meeting
Friday, April 7, 2017

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SPONSOR AND TEAM

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  - 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

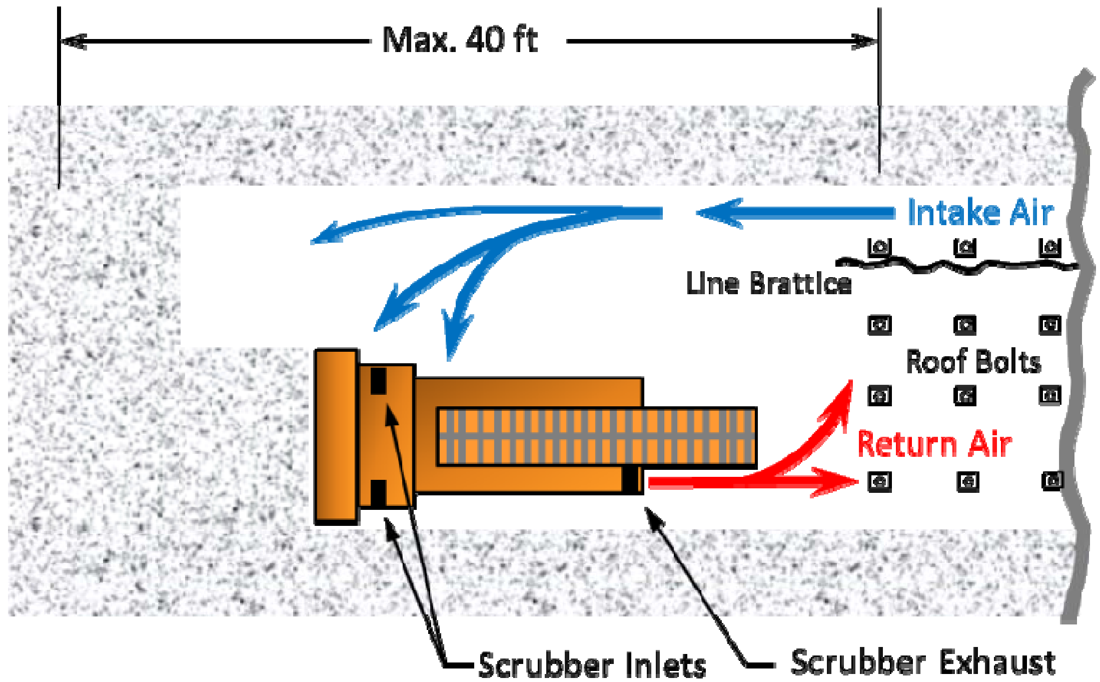
BACKGROUND

- Longwall dust mitigation measures
  - Dilution with ventilation air
  - Wetting and capture by water sprays
  - Confinement and isolation by water sprays

BACKGROUND

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



BACKGROUND

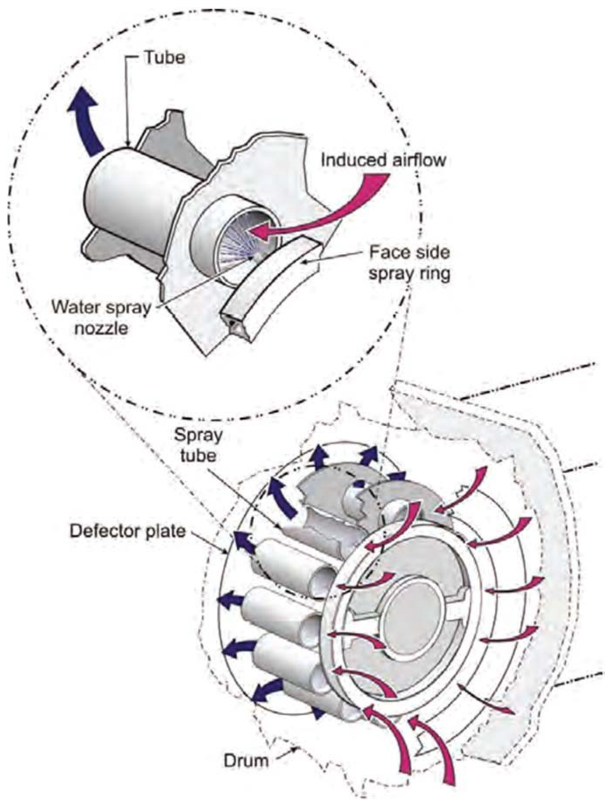
Problems with Applying Dust Scrubbers to Longwall Systems

- 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

BACKGROUND

Prior Attempts at Using Scrubbers on Longwalls

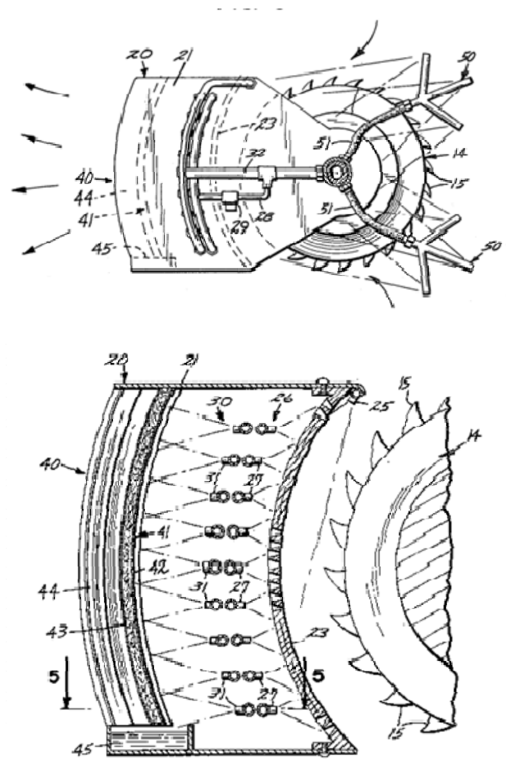
- Ventilated drum
- 3500 cfm airfow
- 50% capture with face airflow of 28,000 cfm
- Maintenance issues



BACKGROUND

Prior Attempts at Using Scrubbers on Longwalls

- Ventilated cowl
- 50% reduction in dust
- Reliability and maintenance issues

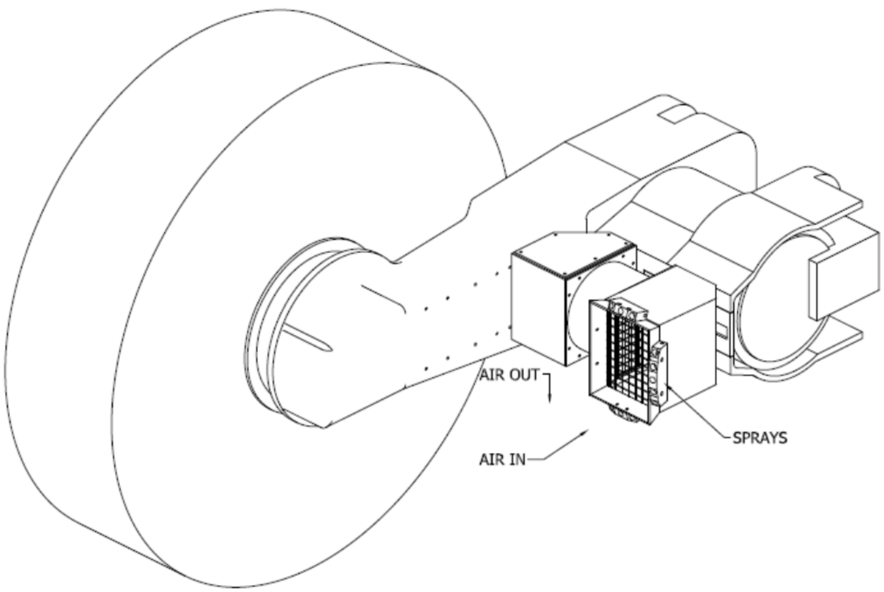


14. Cutter Drum
15. Cutter Bit
20. Scrubber
21. Housing
23. Scree-Like Barrier
25. Surface Sprays
26. Back-Flush Sprays
27. Back-Flush Nozzles
28. Piping
29. Pressure Switch
30. Jet-Spray Air-Movement Section
31. Jet-Spray Nozzles
32. Piping
40. Mist Consolidator and/or Eliminator Element
41. Fibrous Media Panel
42. Fibrous Media Surface
43. Rearward Side of Fibrous Panel
44. Wave Blade Demister
45. Sump
50. Water Spray Means
51. Flexible Spray Supports

BACKGROUND

Prior Attempts at Using Scrubbers on Longwalls

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

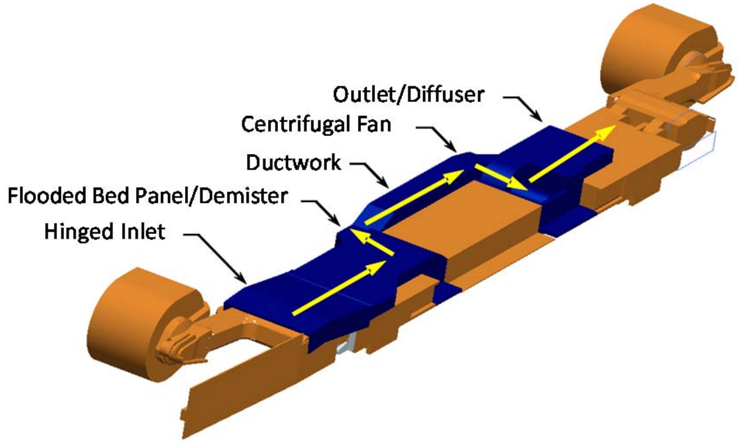


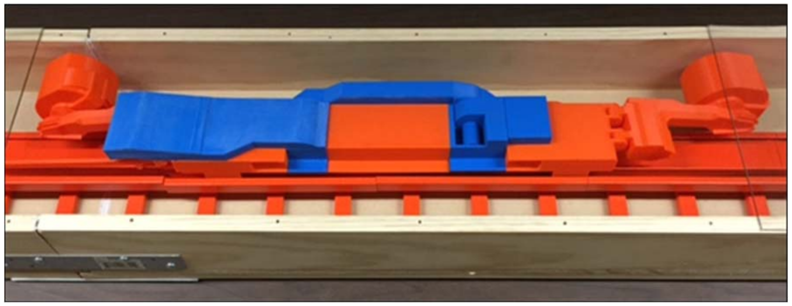
PROJECT OBJECTIVE

- 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

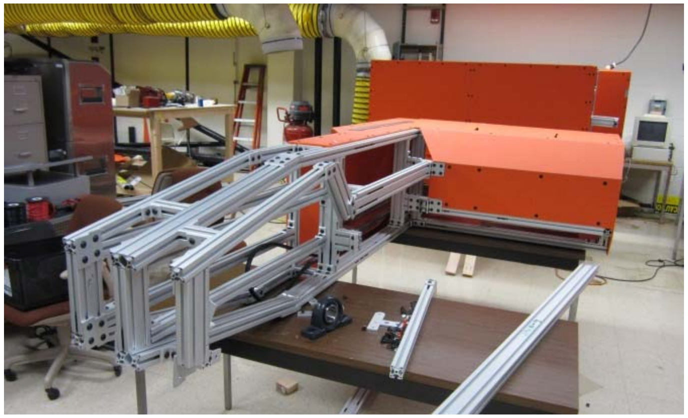


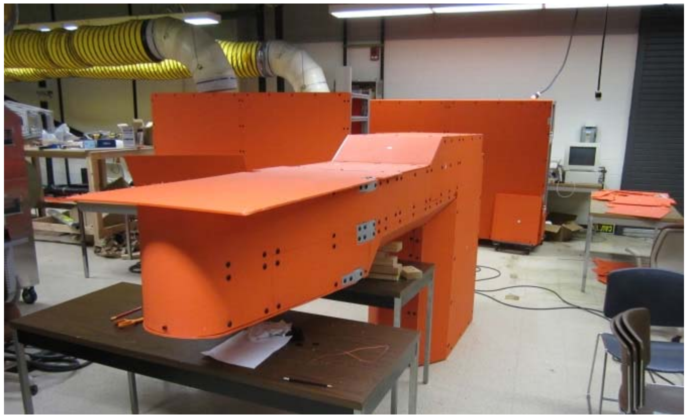


FABRICATION OF FULL-SCALE MOCKUP

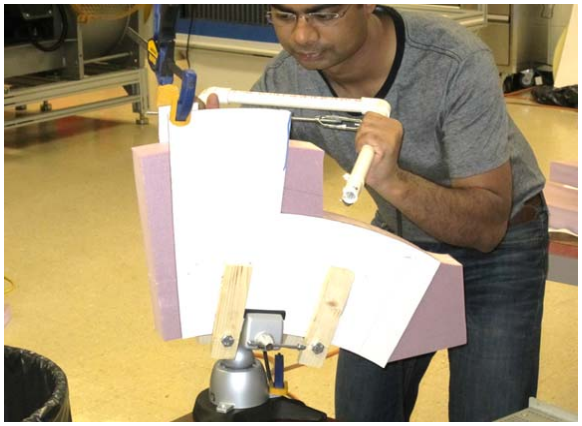
- Frame - Constructed with 80/20 T-slotted framing system
- Covering – high-density polyethylene sheets
- Scrubber – Scrubber and demister designed for continuous miner but with 50-hp fan driven by VFD
- Controls – Programmable Automation Controller (PAC)
- Rotating headgate drum with water sprays

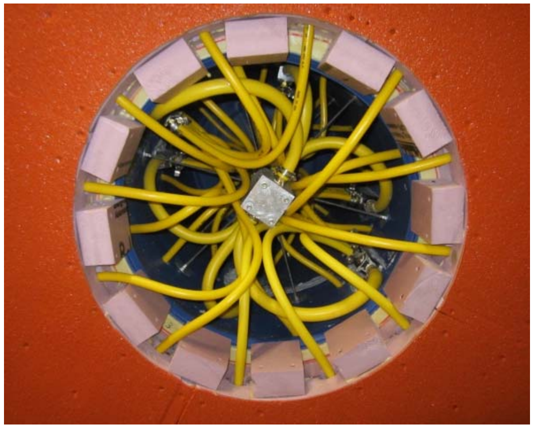
FRAME AND COVERING



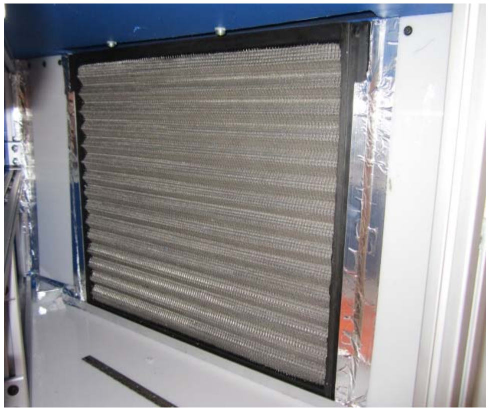


HEADGATE CUTTING DRUM

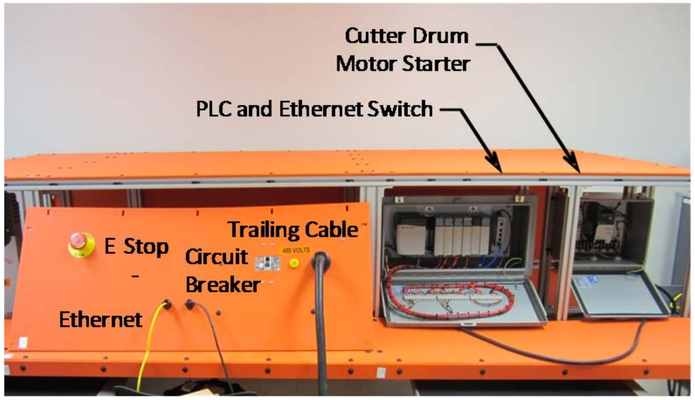




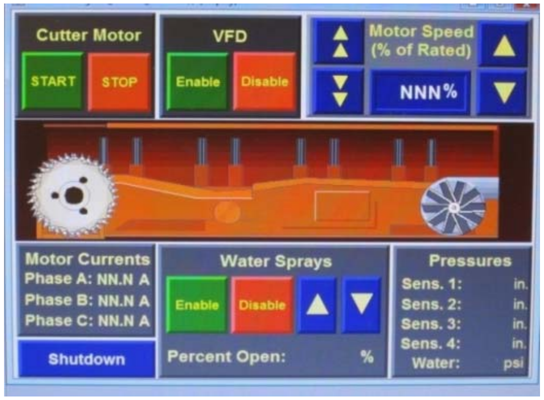
SCRUBBER SYSTEM



CONTROLS


Cutter Drum
Motor Starter
PLC and Ethernet Switch
E Stop
Trailing Cable
Circuit
Breaker
Ethernet


E-Stop
ON/OFF


Cutter Motor
START
STOP
VFD
Enable
Disable
Motor Speed
(% of Rated)
NNN%
Motor Currents
Phase A: NN.N A
Phase B: NN.N A
Phase C: NN.N A
Shutdown
Water Sprays
Enable
Disable
Percent Open: %
Pressures
Sens. 1: in.
Sens. 2: in.
Sens. 3: in.
Sens. 4: in.
Water: psi

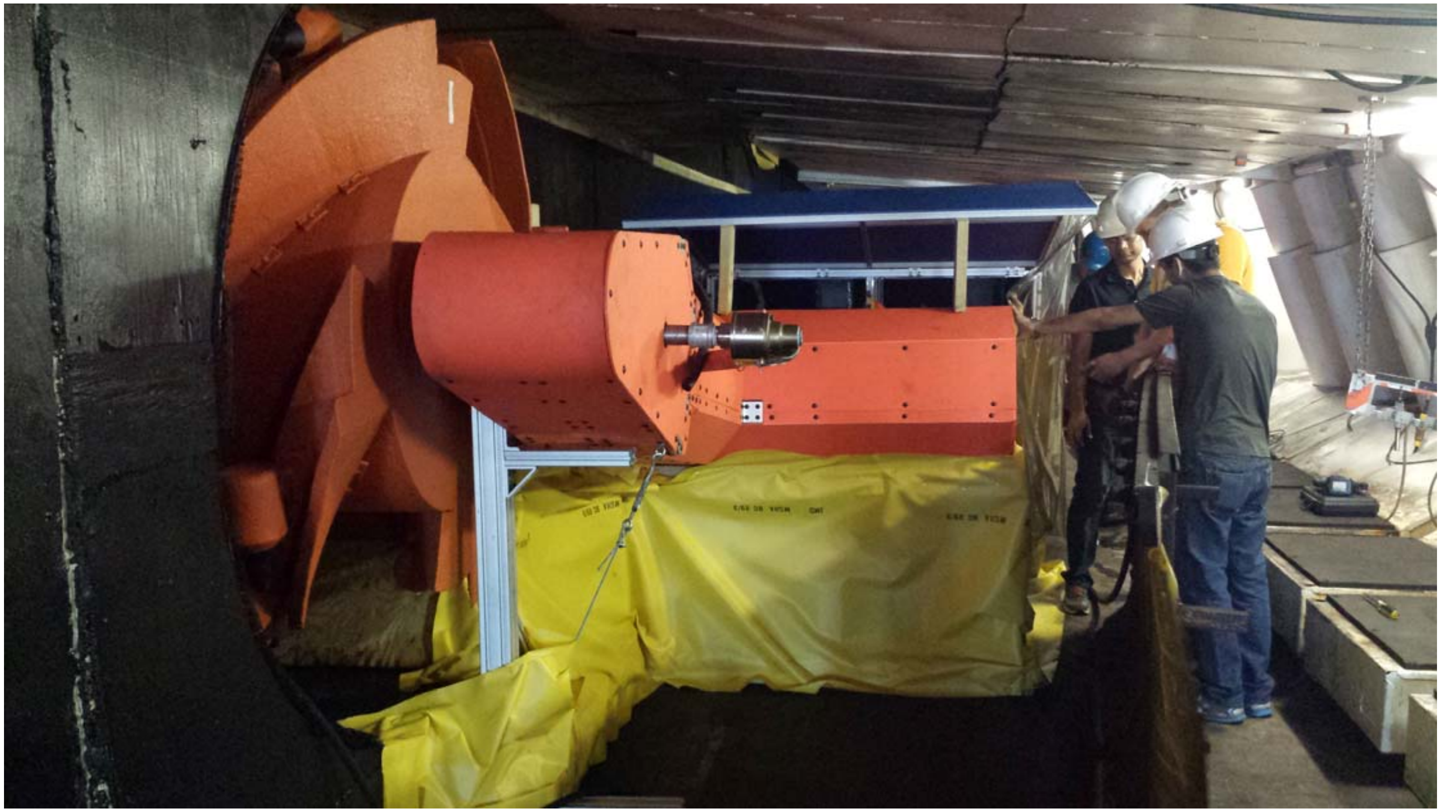
COMPLETED MOCKUP

TESTING – NIOSH PRL LONGWALL GALLERY

Location: CDC NIOSH Pittsburgh Research Laboratory

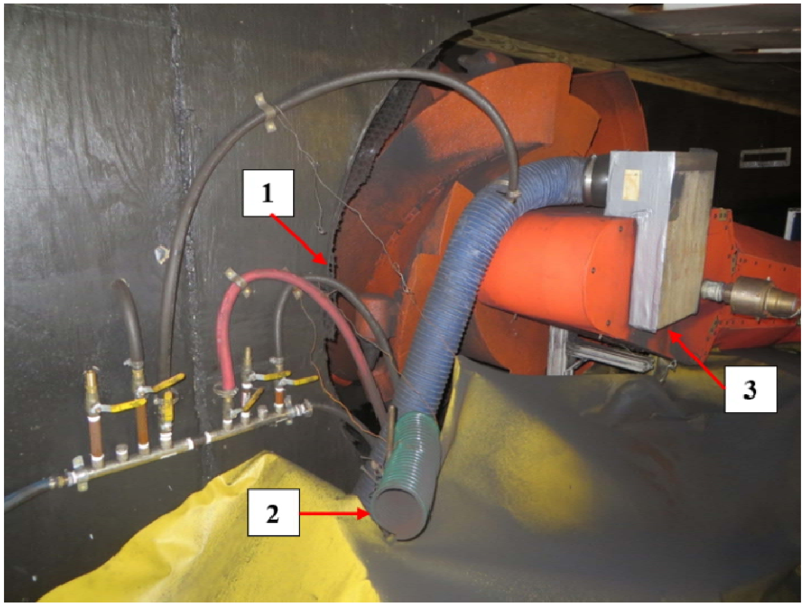
- 125 ft-long longwall gallery
- Adjustable ceiling/shield height
- Air velocity up to 700 fpm
- Ability to inject respirable dust (Keystone Mineral Black 325BA)

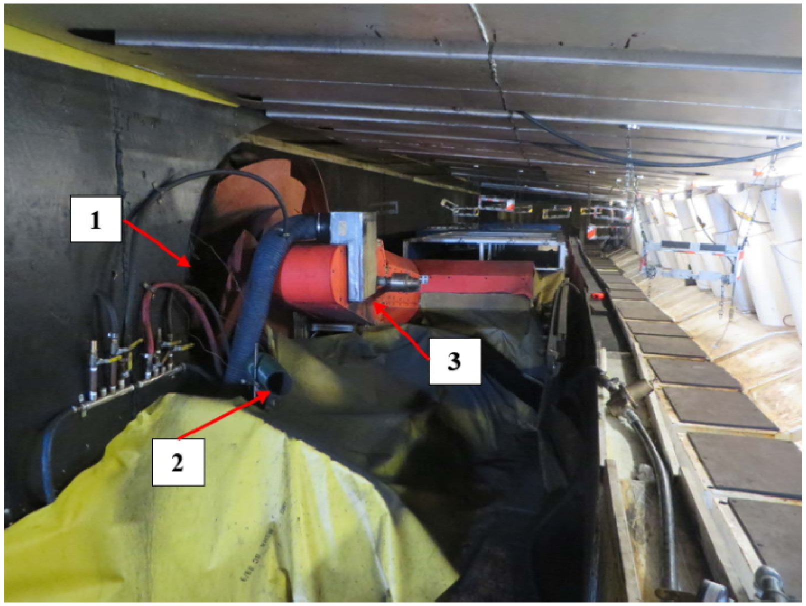
INSTALLATION AT PRL LONGWALL GALLERY



DUST INJECTION

- Dust injected at three locations near headgate drum

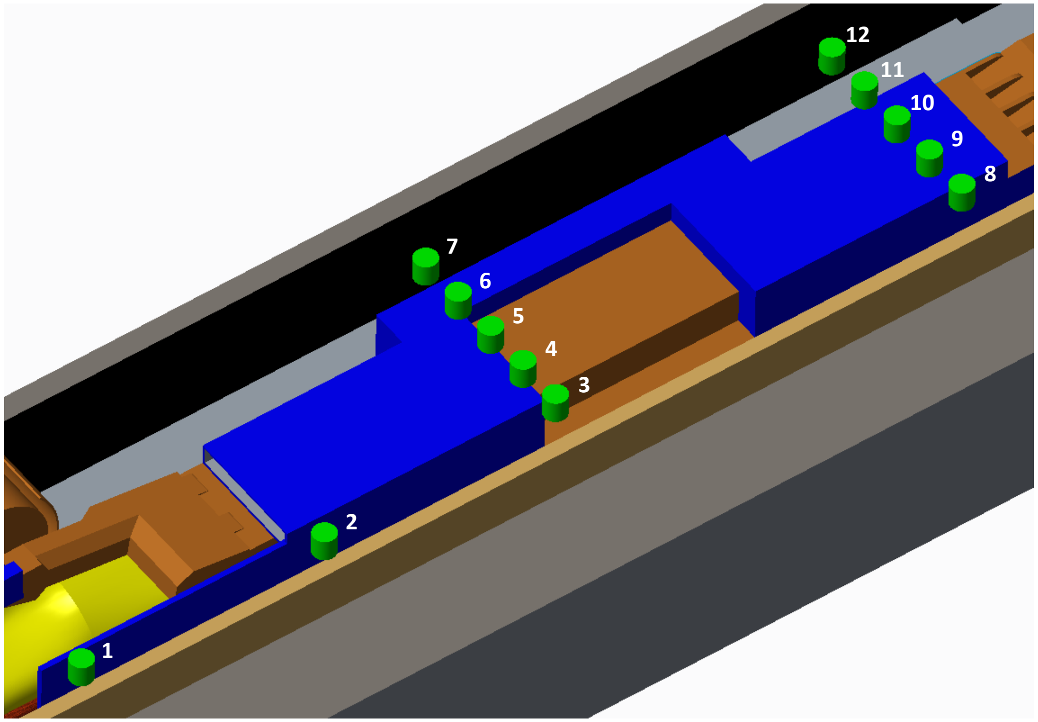




DUST MEASUREMENT LOCATIONS

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

Factor	Low Level	High Level
Scrubber inlet extension	Removed	Included
Scrubber capacity	6300 cfm (2.97 m^3/s)	13,700 cfm (6.47 m^3/s)
Face air velocity	500 fpm (2.54 m/s) 40,800 cfm (19.3 m^3/s)	700 fpm (3.56 m/s) 57,200 cfm (27.0 m^3/s)

OPERATING CONDITIONS

Step	Operating Condition
1	Dust only
2	Dust + scrubber fan
3	Dust + scrubber fan + scrubber sprays
4	Dust + scrubber fan + scrubber sprays + splitter arm sprays
5	Dust only

DETERMINING DUST REDUCTION

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

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

Treatment Combinations	Design Factors			Reduction in Dust Concentration (%)						
	A	B	C	Run 1	Run 2	Run 3	Run 4	Run 5	Averages	Totals
(1)	-1	-1	-1	17.84	27.05	19.27	22.07	19.60	21.17	105.83
a	1	-1	-1	17.53	19.86	18.91	31.34	21.73	21.87	109.37
b	-1	1	-1	42.41	45.36	37.62	40.64	48.96	43.00	214.99
c	-1	-1	1	21.54	24.46	27.67	24.82	19.35	23.57	117.83
ab	1	1	-1	52.53	47.11	48.87	54.49	46.16	49.83	249.17
ac	1	-1	1	31.70	32.39	33.88	35.45	32.56	33.19	165.97
bc	-1	1	1	50.95	51.05	47.05	45.78	53.29	49.63	248.13
abc	1	1	1	56.31	60.43	56.02	54.76	57.41	56.99	284.93

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

ANALYSIS-EXAMPLE

Regression model parameter estimates for return airway-splitter arm sprays OFF

$R^2 = 0.95$					
Term	**Estimate**	**Std Error**	**t-ratio**	**Critical Value**	**P-Value**
Intercept	37.4054	0.5643	66.28	2.739	< 0.0001*
A	3.0667	0.5643	5.43	2.739	< 0.0001*
B	12.4549	0.5643	22.07	2.739	< 0.0001*
C	3.4374	0.5643	6.09	2.739	< 0.0001*
AB	0.4824	0.5643	0.85	2.739	0.3990
AC	1.1807	0.5643	2.09	2.739	0.0444
BC	0.0074	0.5643	0.01	2.739	0.9896
ABC	-1.0495	0.5643	-1.86	2.739	0.0721

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

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

SUMMARY OF RESULTS

Summary of scrubber performance with shearer clearer sprays ON

General Location	Dust Monitoring Stations	Treatments for best performance	Maximum Predicted Dust Reduction	Comments
Return	13-16	Inlet extension included 100% scrubber capacity Face air velocity 700 fpm	62.5%	Scrubber capacity is largest effect No face-air-velocity main effect
Walkway	1, 2, 3, 8	Inlet extension removed 100% scrubber capacity Face air velocity 500 fpm	97.4%	- 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

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