Evaluating tailgate spray manifolds to reduce dust exposures for shearer face personnel

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Abstract

Technical advances in longwall mining over the last several years have resulted in much larger and faster shearers that have the capability of mining at speeds over 30 m/min (100 fpm). This has resulted in a substantial increase in the amount of dust that is generated at the shearer and during shield advances. Meanwhile, increased underground coal production has put a greater demand on longwall dust control systems as some operators have had difficulty maintaining consistent compliance with federal dust standards. To address this need, the U.S. National Institute for Occupational Safety and Health (NIOSH) is investigating the effectiveness of a water spray manifold mounted on the tailgate end of the shearer body. The sprays are oriented parallel to the tailgate ranging arm, and these sprays create a water curtain confining the dust plume near the face, preventing the dust from drifting into the walkway. This redirection of dust provides a clean air envelope for the tailgate shearer operator and jacksetters working near the tailgate drum. Three different tailgate spray manifold designs were tested and evaluated at the Office of Mine Safety and Health Research (OMSHR) Pittsburgh Longwall Test Facility. Manifolds were equipped with hollow cone or flat fan water spray nozzles and evaluated at three face air velocities — 152, 213 and 274 m/min (500, 700 and 900 fpm)— and at water pressures of 689, 1,034 and 1,379 kPa (100, 150 and 200 psi). Reductions in dust concentrations were observed at six face sampling locations for all the tailgate manifold systems at each of the tested spray pressures and face velocities. Average reduction efficiencies of at least 90 percent were seen at the three sampling locations closest to the shearer for all three manifold systems at nozzle spray pressures greater than 689 kPa (100 psi). Based on results from the laboratory tests showing reductions in dust concentrations at sampling locations downwind of the shearer, a spray manifold was fabricated and evaluated at an underground operation.

Key words: Dust control, Longwall, Spray manifold

2016 *Transactions of the Society for Mining, Metallurgy & Exploration,* Vol. 340, pp. 53-60.
https://doi.org/10.19150/trans.7327

Introduction

In 2012, underground coal mining in the United States produced a total of 310 Mt (342 million st) of coal, with longwall mining accounting for over 53 percent of this production (Energy Information Administration, 2013). The longwall mining industry continues to see remarkable and significant improvements in longwall mining equipment and mining practices. Average shift production during compliance dust sampling has increased from 3,500 tons per shift in 1994 to approximately 6,000 tons per shift in 2012. A dramatic decrease in working longwall faces from 80 to 49 has occurred over the same period (Fiscor, 2013). Factors specific to longwall mines that supported productivity improvement include: higher capacity shearers, improved shield hydraulics and control, higher horsepower for equipment, wider face conveyors and larger faces. Today, the average face width has increased to 362 m (1,188 ft), with one longwall operation reporting a face width of 503 m (1,650 ft) compared with an average of 229 m (750 ft) in 1994 (Fiscor 2009, 2014). Panel lengths in 2013 averaged 3,446 m (11,307 ft) compared with 2,134 m (7,000 ft) in 1994. Overall production from U.S. longwalls has increased by nearly four percent from 2007 to 2012 with more than 182 million tons mined annually (Energy Information Administration, 2013). Given the volume and rate of coal produced on longwall faces, the potential to generate large quantities of respirable coal mine dust also exists.

Overexposure to respirable coal mine dust can lead to coal workers' pneumoconiosis (CWP). CWP is a fibrotic lung disease that is irreversible and can be debilitating, progres-

Paper number TP-15-025. Original manuscript submitted August 2015. Revised manuscript accepted for publication February 2016. Discussion of this peer-reviewed and approved paper is invited and must be submitted to SME Publications Dept. prior to Sept. 30, 2017.

sive, and potentially fatal. Coal miners may also be exposed to high levels of respirable silica/quartz dust, leading to the development of silicosis, another disabling and sometimes deadly lung disease. Once contracted there is no cure for CWP or silicosis. CWP contributed to the deaths of 73,022 U.S. miners during the period of 1970 through 2010 (Centers for Disease Control and Prevention, 2014). In the years 1990 to 1999, 2,407 deaths were attributed to silicosis, according to the U.S. National Institute for Occupational Safety and Health (NIOSH, 2012). Today, CWP continues to be a persistent and significant health threat to underground coal mine workers. Results from the most recent NIOSH Coal Worker's X-ray Surveillance Program survey indicate that approximately eight percent of the examined miners with at least 25 years of mining experience show evidence of CWP (Storey and Laney, 2014).

Historically, longwall shearer operators and jacksetters have had the greatest difficulty in meeting the applicable respirable dust standard during compliance sampling by the Mine Safety and Health Administration (MSHA). From 2008 through 2012, 7.6 percent of tailgate shearer operator samples and 5.0 percent of jacksetter samples collected by MSHA inspectors exceeded the applicable dust standard (MSHA, 2013). These samples were obtained with the MSHA maximum permissible exposure limit (PEL) set at 2.0 mg/m^3. Recently, MSHA has enacted a more stringent permissible exposure limit, reducing the previous standard from 2.0 mg/m^3 to 1.5 mg/m^3, under the 79 Federal Regulation 24814 final rule (MSHA, 2014). For the same five-year time span, the percentage of dust samples exceeding a 1.5 mg/m^3 PEL was 20.8 and 14.2 percent for tailgate shearer operators and jacksetters, respectively.

The persistence of CWP cases in underground coal miners and the magnitude of respirable dust overexposures in longwall coal mining occupations illustrate the need for improved dust control technologies. The long-term objective of NIOSH's longwall dust control program is to protect mine workers' health by developing control technologies that will reduce respirable dust on the longwall face. One phase of this program involved laboratory tests to research a blocking water spray system in the area around the tailgate drum, which has the potential to reduce dust levels for the tailgate shearer operator and jacksetter by preventing dust from drifting into the walkway. This paper describes a series of laboratory tests that evaluated spray manifolds mounted on the tailgate side of a longwall shearer and describes the underground evaluation of the NIOSH fabricated spray manifold.

Experimental setup

The simulated longwall gallery of NIOSH's Office of Mine Safety and Health Research (OMSHR) uses a full-scale wooden model of a Joy 4LS double ranging arm shearer (Joy Global, Milwaukee, WI), where the center of the tailgate drum is 0.9 m (3 ft) from the end of the shearer body (Rider, Colinet and Prokop, 2002). In the last decade, significant improvements in longwall mining equipment have occurred and today the majority of the longwall operations in the United States use Joy 7LS shearers (Joy Global, Milwaukee, WI) where the distance from the shearer body to the tailgate drum centerline varies between 1.5 and 2.4 m (5 and 8 ft). To better represent dust generated by the tailgate drum in today's underground longwall environment, this series of tests used four dust inlets (Fig. 1) located from 46 cm to 3.05 m (18 to 120 in.) downwind of the end of the shearer body. The two inlets furthest away from the shearer represent the dust generated by a projected tailgate drum located approximately 2.1 m (7 ft) from the shearer, similar to Joy 7LS shearers. Simulated shield advance took place four shields (approximately 6 m or 20 ft) downwind of the projected tailgate drum location. The relative position of the tailgate shearer operator usually ranges between one shield downwind of the tailgate drum and two to three shields upwind of the tailgate drum. This area is equivalent to the area between shields 14 and 17 in the longwall test gallery. The tailgate jacksetter usually walks between one and four shields downwind of the tailgate drum, or from shields 17 to 20 as shown in Fig. 1.

Three different tailgate spray manifolds systems were evaluated. The manifold sprays were equipped with either Spraying Systems (SS) WhirlJet BD3 hollow cone sprays, SS VeeJet 40-20 flat fan sprays with 40° spray angle and flow capacity of 2 gpm at 40 psi, or SS VeeJet 65-15 flat fan sprays with 65° spray angle and flow capacity of 1.5 gpm at 40 psi (Spraying Systems Co., Wheaton, IL). In dust control ap-

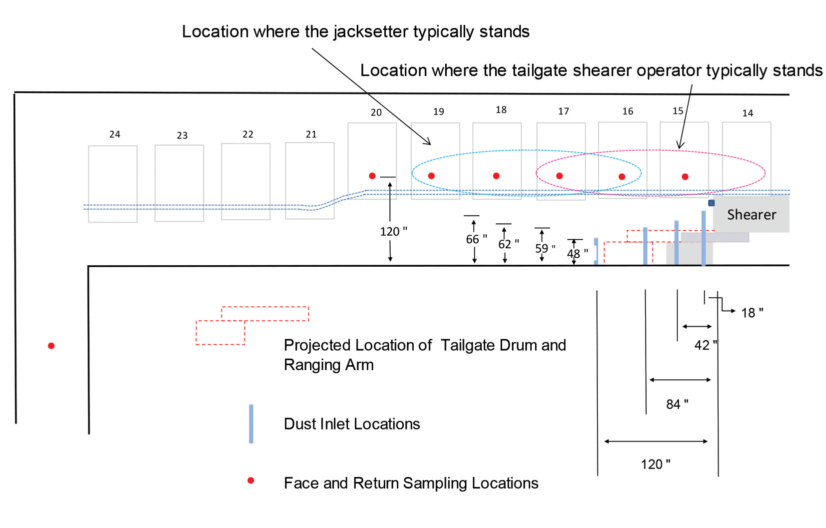


Figure 1 — Diagram of sampling positions for dust inlet locations for tailgate manifold testing in longwall test facility.

Table 1 — (a) Flow capacities at the three tested spray pressures and (b) total water usages for the three manifold systems.

	(a) Spray capacity (gpm)			(b) Water usage (gpm)			
	100 psi	150 psi	200 psi		100 psi	150 psi	200 psi
BD3	0.95	1.16	1.34	Manifold with seven SS BD3 sprays	6.65	8.14	9.40
SS 40-20	3.2	3.92	4.53	Manifold with two SS 40-20 sprays	6.40	7.84	9.05
SS 65-15	2.4	2.94	3.39	Manifolds with four SS 65-15 sprays	9.60	11.76	13.58

plications, hollow cone sprays are commonly used to knock down airborne dust and they can also redirect dust, while flat fan sprays are primarily used to redirect or confine dust away from a longwall operator. Each of the spray manifolds were fabricated from ¼-in. steel plate channels measuring 10 cm wide, 5 cm deep and 91 cm high (4 in. wide, 2 in. deep and 36 in. high). They were positioned near the back corner of the tailgate end of the shearer body near the spill plate (Figs. 2a and 2b). The first spray manifold system, referred to as the BD3 in subsequent text, was attached to the shearer body 1.07 m (42 in.) from the tailgate drum and angled approximately 25° toward the tailgate. It consisted of seven SS BD3 sprays located on 10-cm (4-in.) centers with the first spray placed 56 cm (22 in.) off the floor and the last spray 1.17 m (46 in.) from the floor. The second manifold system, referred to as SS 40-20 in subsequent text, had two SS 40-20 flat fan sprays located 1.17 and 0.76 m (46 and 30 in.) off the floor. The manifold was attached to the shearer body 1.2 m (47 in.) from the tailgate drum and was angled approximately 15° toward the face. The final spray manifold configuration, referred to as SS 65-15 in subsequent text, consisted of two 10 by 91 cm (4 by 36 in.) manifolds with two SS 65-15 flat fan sprays on each manifold. The manifolds were positioned parallel to the tailgate cutting drum. The first of the two spray manifolds was attached to the shearer body 81 cm (32 in.) from the tailgate drum, and sprays were 86 cm and 1.17 m (34 and 46 in.) from the floor. The second manifold in this system was attached to the shearer body 94 cm (37 in.) from the tailgate drum and the sprays were positioned 76 cm and 1.07 m (30 and 42 in.) off the floor. Each of the three spray manifold systems was evaluated at three face air velocities — 152, 213 and 274 m/min (500, 700 and 900 fpm) — and spray pressures of 689, 1,034 and 1,379 kPa (100, 150 and 200 psi). Table 1 shows the flow capacities of the nozzles at each of the tested spray pressures as well as the water usages for each of the three manifold systems.


(a)
(b)

Figure 2 — (a) Spray plume from the SS 65-15 spray manifold system and (b) BD3 spray manifold system attached to the tailgate end of the shearer.

Sampling methodology

An A-B-A assessment of the effectiveness of each manifold system was used for all tests. Test conditions — air velocity, water pressure and dust concentration — were established and held constant throughout the duration of the testing period. Manifolds sprays were off for the initial phase of the test, then activated during the second phase, and turned off again for the final phase of the test. Respirable dust sampling packages consisting of a nephelometer and two gravimetric samplers were located at six shields — shields 15 through 20 — along the face and one in the return (Fig. 1). Gravimetric dust samplers, identical to those used in compliance sampling under Title 30 Code of Federal Regulations (30 CFR) Part 90 (MSHA, 2015), were operated at 2 L/min in conjunction with a 10-mm Dorr-Oliver cyclone and a 37-mm 5-µm pore polyvinyl chloride (PVC) filter combined with an MSA pump (MSA Safety Inc., Cranberry Township, PA). The respirable dust fraction was deposited onto preweighed 37-mm PVC filters. All filters were pre- and post-weighed in an environmentally controlled NIOSH laboratory in Pittsburgh, PA, and respirable dust concentrations were calculated. The nephelometer was a personal DataRAM (pDR) real-time dust sampler (Thermo Fisher Scientific, Waltham, MA). The pDR is an MSHA-approved, instantaneous dust measuring device where dust-laden air passes through a sampling chamber and a light source. The amount of light deflection in the chamber is measured and provides a relative measure of the dust concentration. The pDR provides a continuous record of dust concentrations that can be evaluated over any time interval during the sampling period. Each face sampling package was positioned approximately 3 m (120 in.) from the simulated face and suspended from the underside of the shields in the approximate breathing zone of the longwall operators.

Prior to the start of each test, the desired face ventilation quantities were established, and dust injection (Rider, Colinet and Prokop, 2002) into the longwall face was initiated. A baseline period of 5 to 10 min was sampled with the pDR instantaneous samplers to verify that the dust concentrations had stabilized. After the baseline test was completed, the gravimetric samplers were activated, and phase one of the test was initiated. At the conclusion of the 20-min phase one, the gravimetric filters at each sampling location were collected and replaced with a new set of filters. Manifold sprays were activated, and the second 20-min phase of the test was started. At the end of phase 2, the manifold sprays were deactivated, and the gravimetric filters were once again collected.

The final phase of the test was initiated to determine if the dust concentrations during the third 20-min period returned to near the levels observed in the first phase of the test. Using data acquisition software, real-time pDR concentrations were downloaded to a multichannel data acquisition system for monitoring throughout the test and recorded for later analysis. In addition, average gravimetric dust concentrations were calculated from the samplers at all the face sampling locations, along with an average return concentration for each test. These concentrations were compared with the associated pDR data, and correction factors were calculated by dividing the concentrations from the gravimetric samplers by the pDR average concentration at each sampling location. The correction factors were then applied to the instantaneous readings from the pDRs, as recommended by the pDR manufacturer.

Table 2 — Dust reduction efficiencies of the three manifold systems for each test condition at the six sampling locations downwind of the shearer.

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
150	BD3	500	0.9461	0.9351	0.9421	0.8776	0.8446	0.7699
		700	0.9633	0.9415	0.9406	0.9253	0.8798	0.8133
		900	0.9631	0.9323	0.9471	0.8655	0.7646	0.6162
	SS 40-20	500	0.8727	0.9502	0.9698	0.9583	0.9250	0.8156
		700	0.7705	0.8638	0.9089	0.9127	0.8799	0.8309
		900	0.8908	0.9046	0.9387	0.9240	0.9216	0.8599
	SS 65-15	500	0.9955	0.9861	0.9900	0.9704	0.9603	0.8775
		700	0.9907	0.9872	0.9768	0.9738	0.9403	0.8810
		900	0.9670	0.9887	0.9807	0.9790	0.9526	0.9505
200	BD3	500	0.9646	0.9654	0.9609	0.8949	0.8250	0.7265
		700	0.9675	0.9576	0.9687	0.9493	0.8987	0.8300
		900	0.9940	0.9852	0.9801	0.9547	0.9051	0.8348
	SS 40-20	500	0.9454	0.9580	0.9812	0.9795	0.9552	0.8851
		700	0.9625	0.9557	0.9686	0.9528	0.9526	0.8981
		900	0.9419	0.9461	0.9701	0.9466	0.9491	0.9061
	SS 65-15	500	0.9976	0.9954	0.9948	0.9843	0.9562	0.8686
		700	0.9798	0.9808	0.9796	0.9729	0.9596	0.9239
		900	0.9864	0.9806	0.9827	0.9692	0.9695	0.9311

Laboratory results

Reductions in dust concentrations were observed at the six face sampling locations for all three tailgate manifold systems at each of the tested spray pressures and face velocities. Table 2 shows the dust reduction efficiency of gravimetric dust concentrations when the manifold nozzles were activated. A graphical representation of the data is shown using bar graphs in Fig. 3, which displays dust concentrations associated with the SS 65-15 manifold system. Average gravimetric dust concentrations with the manifold sprays off and activated are shown. Each graph represents a different set of test parameters. Face velocities are displayed in columns increasing from 152 to 274 m/min (500 to 900 fpm) from left to right, while spray pressures are shown in rows increasing from 689 to 1,379 kPa (100 to 200 psi) from top to bottom. The graphs display the six face sampling locations on the horizontal axis and dust concentrations in milligrams per cubic meter along the vertical axis.

Instantaneous dust concentrations measured by the pDR samplers at the shield sampling locations along the face and sampling location in the return for the SS 40-20 manifold system are shown in Fig. 4. Once again, each graph represents a specific test condition with face velocities displayed in columns increasing from 152 to 274 m/min (500 to 900 fpm) from left to right, and spray pressures shown in rows increasing from 689 to 1,379 kPa (100 to 200 psi) from top to bottom. Along the horizontal axis, each 20-min phase of the test is displayed. The first 20-min sequence illustrates dust concentrations with the manifolds sprays off, while the second 20-min progression shows dust concentrations observed with the manifold sprays activated. The final 20 min displays dust concentrations with the manifolds off. The vertical axis displays the dust concentrations in milligrams per cubic meter. Rapid and significant reductions in dust concentrations were observed at all six face sampling locations when the manifold sprays were activated for each test condition. Once the manifold sprays were deactivated, dust concentrations immediately returned to similar dust levels observed before the manifold sprays were activated.

A two sample t-test was used to determine if statistical significant differences in sampling location dust reduction efficiencies were evident when nozzle spray pressure increased. A two-tailed t-test with unequal variances was used with a level of significance of $\alpha = 0.05$ to test the null hypothesis that the mean ranks of the two sampling populations for a specific set of test parameters were equivalent. The six sampling location reduction efficiencies of each manifold system for the face velocities at 689 kPa (100 psi) were compared with the reduction efficiencies of the six sampling locations at 1,034 kPa (150 psi), and then 1,379 kPa (200 psi). Next, the reduction efficiencies of each manifold system at 1,034 kPa (150 psi) were compared with the reduction efficiencies at 1,379 kPa (200 psi). Table 3a shows the calculated p-values from the two-sample t-test when nozzle spray pressures were increased. Statistically, differences were evident for the BD3 and SS 40-20 manifold systems when nozzle spray pressure increased from 689 kPa (100 psi) to 1,379 kPa (200 psi). When increasing nozzle spray pressure from 689 kPa (100 psi) to 1,034 kPa (150 psi), significant differences were seen only in the BD3 manifold system. Examining the manifold

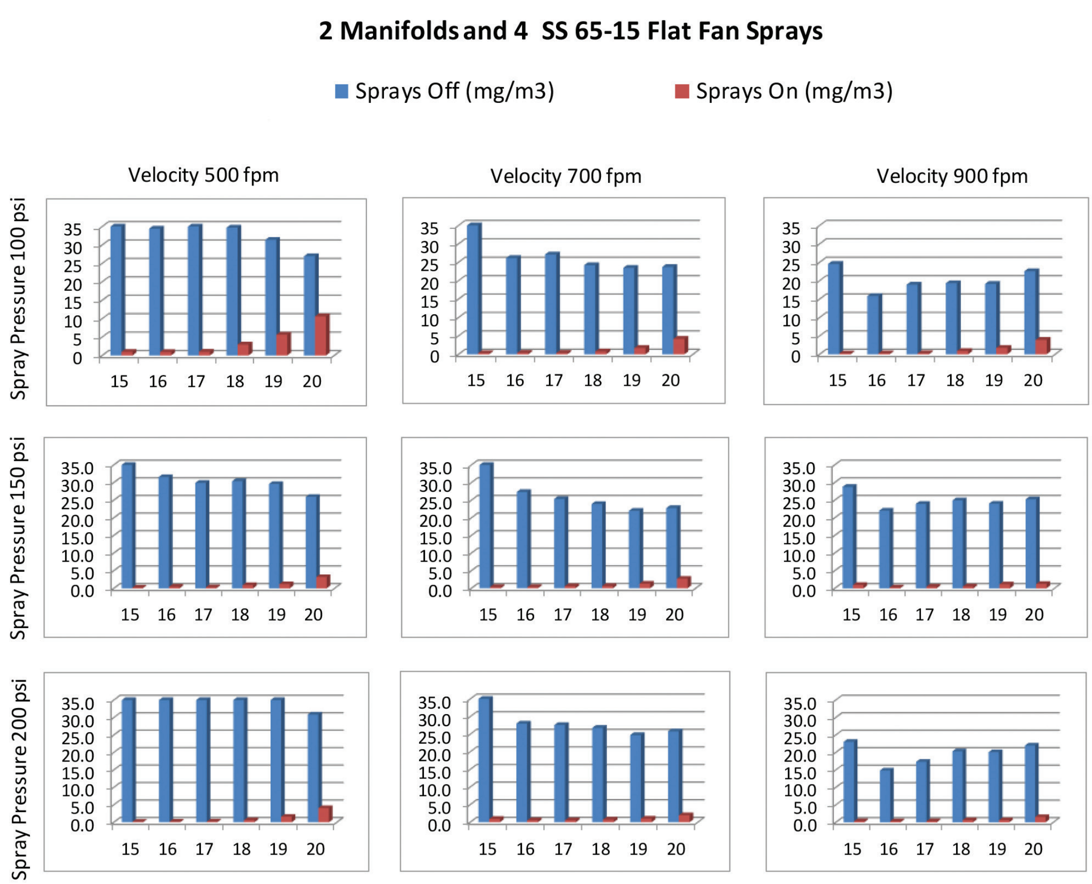


Figure 3 — Dust concentrations in mg/m[3] with spray nozzles off versus activated for tests conducted with two tailgate manifolds and four SS 65-15 flat fan sprays.

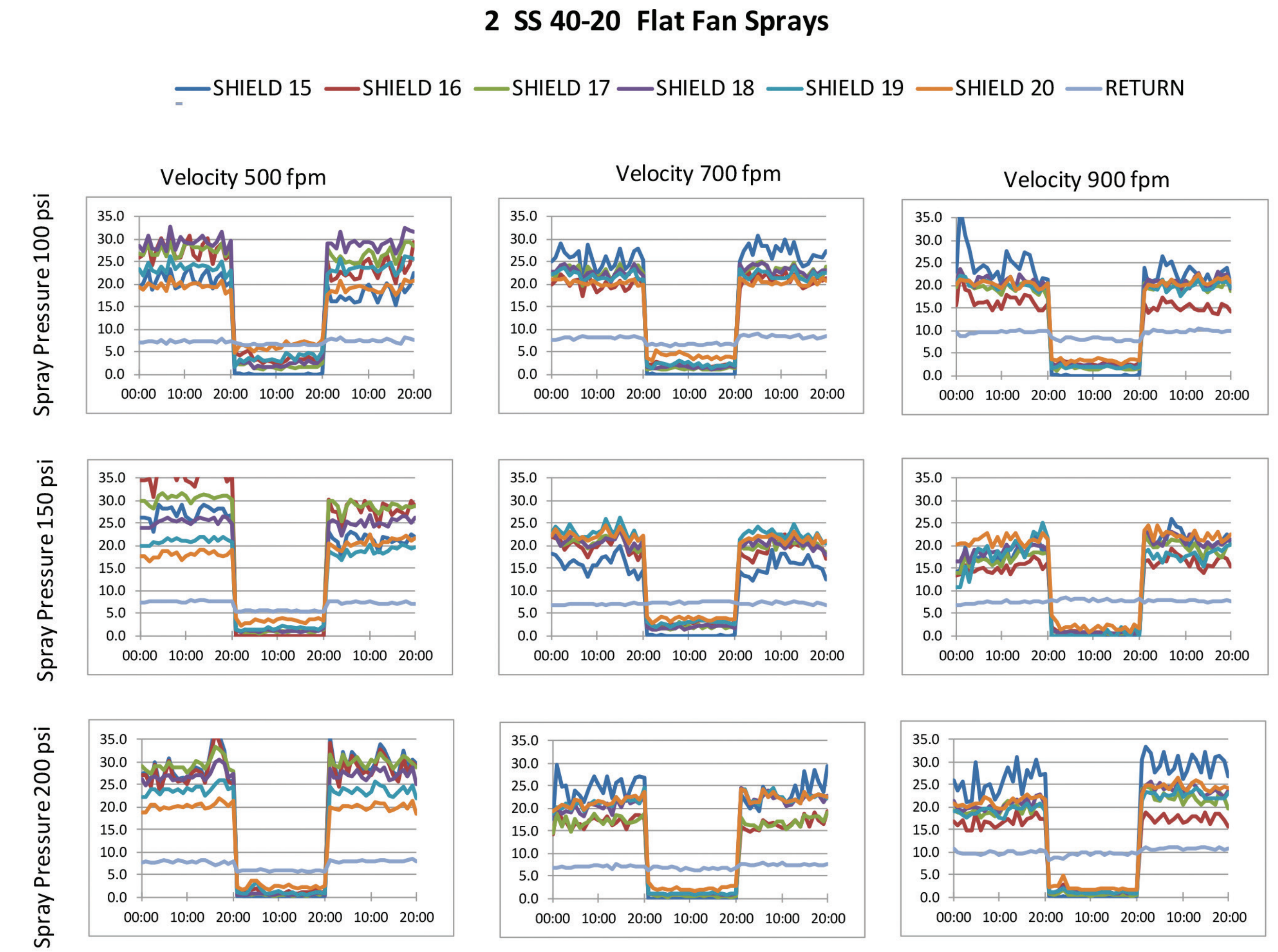


Figure 4 — Instantaneous dust concentrations in mg/m^3 for tests conducted with 40-20 spray nozzles.

systems when nozzle pressure increased from 1,034 kPa (150 psi) to 1,379 kPa (200 psi) showed significant differences in reduction efficiencies for the SS 40-20 manifold system. Although substantial reductions in dust levels were observed for each of the manifold systems, higher nozzle spray pressure were more effective at containing dust closer to the face especially when nozzle spray pressure was increased from 689 kPa (100 psi) to 1,379 kPa (200 psi).

Similar two-sample t-tests were completed to determine if statistical differences occurred in sampling location reduction efficiencies of each manifold system for the tested nozzle spray pressures when face velocities increased from 152 m/min (500 fpm) to 213 m/min (700 fpm), then to 274 m/min (900 fpm) and when face velocities increased from 213 m/min (700 fpm) to 274 m/min (900 fpm). Once again, a two-tailed test with unequal variances was used with a level of significance of α = 0.05 to test the null hypothesis that the mean ranks of the two sampling populations for a given set of test parameters were equivalent. As shown in Table 3b, the p-values from each of the t-test were greater than 0.05, indicating the observed differences in reduction efficiencies were not statistically different when face velocities increased.

Manifold systems were compared against each other to determine if one manifold system is more effective at reducing dust concentrations. Again, a two-sample t-test was used to test the null hypothesis that the mean ranks of the two sampling populations were equivalent. Sampling location reduction efficiencies of each manifold system were compared against the other two manifold systems at nozzle spray pressures of 689, 1,034 and 1,379 kPa (100, 150 and 200 psi) and at face velocities of 152, 213 and 274 m/min (500, 700 and 900 fpm). Results from the two-sample t-test are shown in Table 4a for nozzle spray pressures of 689, 1,034 and 1,379 kPa (100, 150 and 200 psi), while Table 4b displays the results of the two-sample t-test at face velocities of 152, 213 and 274 m/min (500, 700, and 900 fpm). Sampling location reduction efficiencies were statistically different at each nozzle spray pressure when comparing the SS 65-15 manifold system with the BD3 manifold. At nozzle spray pressures of 1,034 and 1,379 kPa (150 and 200 psi), the SS 65-15 manifold system was more efficient at confining dust close to the face than the SS 40-20 manifold system. These results indicate the SS 65 manifold system was more effective at reducing dust concentrations at the sampling location downwind of the shearer. Similar results from the two-sample t-test were seen at the face velocities of 152, 213 and 274 m/min (500, 700 and 900 fpm). Once again, significant differences were evident when sampling location reduction efficiencies of the SS 65-15 manifold system were compared with the other two manifold systems. Statistically, differences were not evident when the SS 40-20 manifold system was compared with the BD3 manifold system at the tested nozzle spray pressures and face velocities.

As shown in Table 2, reductions in dust concentrations when the manifold sprays were activated were substantial, especially at sampling locations closest to the shearer. As expected, the magnitude of dust reductions decreased for all nozzles with increasing distance downwind from the spray manifold. Examination of the reduction efficiencies populations at the three sampling locations closest to the spray manifolds — shields 15, 16 and 17 — compared with the reduction efficiencies population at the sampling locations at shields 18, 19 and 20 was determined with a two-sample t-test for statistical significance. The two-sample populations were analyzed at each of the three nozzle spray pressures and face velocities for each manifold system. Results for the two-sample t-test showed that statistically significant differences in the sample populations were evident when the BD3 and SS 65-15 manifold systems were analyzed for each nozzle spray pressure and face velocity. Dust concentrations at the first three sampling locations were confined closer to the face than those at the three sampling locations farthest from the shearer. Average reduction efficiencies of at least 90 percent were seen at sampling locations 15, 16 and 17 for all three manifold systems at nozzle spray pressure greater than 689 kPa (100 psi). Although statistical differences in reduction efficiencies were evident at the farthest three sampling locations when compared with the three closer sampling locations, substantial dust reductions of between 55 and 95 percent were still achieved at shield 20. Statistically, differences in two sample populations were not found with the SS 40-20.

NIOSH researchers observed dust migrated into the walkway starting at shield 18, especially with the manifold fitted with the BD3 hollow cone sprays. Manifolds using the flat fan water sprays were somewhat more effective at keeping respirable dust confined to the face area and out of the walkway, with spray pressures at 1,034 and 1,379 kPa (150 and 200 psi) and face velocities at 213 and 274 m/min (700 and 900 fpm). Water mist was observed in the walkway starting at shield 18 for the tests conducted with the two-manifold systems with SS 65-15 flat fan sprays. These sprays were located close to the spill plate and oriented parallel to the cutting drum, allowing the velocity stream to push the spray mist into the walkway where the shearer operator and jacksetters are located. For the longwall personnel to benefit from any dust control system it is critical to keep water mist out of walkway. Spray mist was observed on the spill plate at shield 20 but not in the walkway for the other two manifold systems that were angled toward the cutting drum.

Discussion

The laboratory data showed that all spray nozzles substantially reduced dust under all test conditions, and reductions in dust concentrations ranged between 60 and 95 percent. Test results showed average reduction efficiencies of at least 90 percent were seen at the three sampling locations closest to the shearer for all three manifold systems at nozzle spray pressures greater than 689 kPa (100 psi). The SS 65-15 flat fan spray manifold system was somewhat more effective than the BD3 and SS 40-20 manifold systems at confining dust close to face. This might be explained by the area of the spray plume created by the SS 65-15 manifold system and the increase in water quantity when compared with the other two manifold systems. Higher nozzle spray pressure was more effective at containing dust closer to the face, especially when nozzle spray pressure was increased from 689 kPa to 1,379

Table 3 — Calculated p-values from two-sample t-tests comparing (a) nozzle spray pressures and (b) face velocities for each manifold system.

(a) Nozzle spray pressures

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

(b) Face velocities

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

Table 4 — Calculated p-values from two-sample t-tests comparing (a) manifold systems at 100, 150 and 200 psi and (b) face velocities at 500, 700 and 900 fpm.

(a) Manifold systems at 100, 150 and 200 psi

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

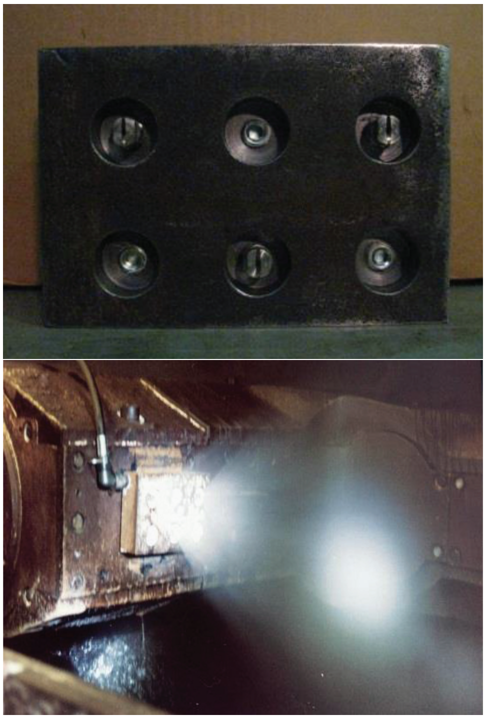
(b) Face velocities at 500, 700 and 900 fpm

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

kPa (100 psi to 200 psi). There did not appear to be any relation between the ventilation air velocity and reduction in dust concentration for any of the nozzle types. Considering dust reduction by water consumption as percent reduction per gallon, better efficiency was seen at the lowest air velocity for all nozzles. The 40-20 nozzles were more effective at reducing dust levels than the other two nozzles in terms of water consumption.

The significance of dust overexposures to tailgate operators and jacksetters along with laboratory data showing substantial reductions in dust concentrations at locations downwind of the shearer warranted an underground evaluation of a spray manifold. Therefore, a mine-specific manifold (Fig. 5a) was fabricated measuring 24 by 17 by 6.4 cm (9.5 by 6.5 by 2.5 in.) and was mounted on the tailgate side of a CAT EL3000 shearer (Caterpillar, Peoria, IL), parallel to the tailgate drum, 59 cm (22 in.) from the ranging arm and 1.04 m (41 in.) from the armoured face conveyor (AFC), as shown in Fig. 5b. Three SS VeeJet 65-15 flat fan sprays were mounted in the top left, bottom middle and top right hole locations. The SS VeeJet 65-15 spray produces a spray angle of 65° with a capacity of 1.5 gpm at a pressure of 28 kPa (40 psi). Increasing the pressure to 689 kPa (100 psi) produces a spray angle of 70° with a capacity of 2.4 gpm.

The longwall operation used a unidirectional cutting sequence. Shields were consistently advanced five to six shields behind the trailing drum. The positioning of the tailgate shearer operator was consistent throughout the sampling period. During headgate-to-tailgate cuts the tailgate shearer operator was located between the end of the shearer and the center of the tailgate cutting drum. On tailgate-to-headgate cuts, the tailgate shearer operator was positioned between the center of the tailgate cutting drum and the end of the ranging arm, and the jacksetter was positioned between three and four shields downwind of the tailgate drum. Mobile dust sampling was conducted to isolate and quantify dust generation by the shearer when the tailgate manifold spray nozzles were on and off. Average dust samples observed, within two to three shields of the tailgate side of the shearer and approximately two to three shields downwind of the tailgate drum, were extremely low, ranging between 0.762 and 1.053 mg/m^3. Face velocities of approximately 396 m/min (1,300 fpm) and an average spray nozzle pressure of 827 kPa (120 psi) were observed during mobile dust sampling.



(a)

(b)

Figure 5 — (a) NIOSH fabricated spray manifold. (b) The spray manifold mounted on the tailgate side of the shearer.

NIOSH researchers believe the velocity and volume of air observed along the face was the dominant dust control factor that kept excessive dust from migrating into the walkway at the dust sampling locations. Because dust concentrations were low, quantitative dust sampling data showed small differences in dust concentrations with the manifold spray nozzles on versus off. Although the differences in dust levels were inconclusive from a quantitative standpoint, lower dust concentrations were observed on tailgate-to-headgate and especially on headgate-to-tailgate cuts with the tailgate spray manifold operational. Average dust concentration observed near the tailgate end of shearer was 0.949 mg/m^3 with the manifold spray nozzles off and 0.762 mg/m^3 with the manifold spray nozzles operational. At the downwind sampling location, average dust concentrations were 1.053 mg/m^3 when the spray nozzles were off and 0.828 mg/m^3 with the sprays nozzles on.

The tailgate spray manifold appeared to have a positive influence on keeping the dust cloud confined close to face levels in the tailgate area. Feedback from the tailgate shearer operators indicated they responded positively to the spray manifold and thought it helped keep dust out of the walkway in the tailgate area.

Disclaimer

Mention of a company name or product does not constitute an endorsement by NIOSH. The findings and conclusions in this report are those of the authors and do not necessarily represent the views of NIOSH.

References

Centers for Disease Control and Prevention (CDC), 2014, "National occupational respiratory mortality system (NORMS): National database," U.S. Department of Health and Human Services, Centers for Disease Control and Prevention.

Energy Information Administration (EIA), 2013, "Annual Coal Report 2012," U.S. Department of Energy, Washington, DC.

Fiscor, S.J., 2009, "Total number of longwall drop below 50, U.S. longwall census," *Coal Age*, February 2009.

Fiscor, S.J., 2013, "America's longwall operations demonstrate stability during an uncertain period," *Coal Age*, March 2013.

Fiscor, S.J., 2014, "The landscape for U.S. longwalls changes," *Coal Age*, March 2014.

Mine Safety and Health Adminstration (MSHA), 2013, "MSHA Standardized Information System," U.S. Department of Labor, Arlington, VA.

Mine Safety and Health Administration, 2014, "79 Fed. Reg. 24814: Lowering miners' exposure to respirable coal mine dust, including continuous personal dust monitors; final rule," to be codified at Title 30 Code of Federal Regulations (30 CFR) Parts 70, 71, 72, 75 and 90.

Mine Safety and Health Adminstration (MSHA), 2015, "Code of Federal Regulations (CFR)," U.S. Government Printing Office, Office of the Federal Register, Washington, DC.

National Institute for Occupational Safety and Health (NIOSH), 2012, "Work-Related Lung Disease Surveillance System (eWoRLD): Reference Number 2012F03-01," U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, Washington, DC.

Rider, J.P., Colinet, J.F., and Prokop, A.E., 2002, "Impact of control parameters on shearer-generated dust levels," *Transactions of the Society for Mining, Metallurgy & Exploration*, Vol. 312, pp. 28-34.

Storey, E., and Laney, A., 2014, "Respiratory disease in US coal miners," 2014 SME Annual Conference & Expo, Feb. 23-26, 2014, Society for Mining, Metallurgy & Exploration Inc.. Englewood, CO.