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A LABORATORY INVESTIGATION OF UNDERSIDE SHIELD SPRAYS WITH A SHEARER-CLEARER WATER SPRAY SYSTEM TO IMPROVE DUST CONTROL ON LONGWALL FACES

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ABSTRACT

Previous testing was performed by researchers at the National Institute for Occupational Safety and Health (NIOSH) to improve longwall dust control using underside shield sprays with a longwall directional spray system. This testing provided encouraging results toward respirable dust exposure reductions for longwall personnel, achieving as high as 99% dust reduction at some sampling locations along the longwall personnel walkway. Additional laboratory testing was conducted to test these underside shield sprays in conjunction with a shearer-clearer spray system located on the longwall shearer body. The purpose of this testing was to determine if the underside shield sprays interacted positively or negatively with the shearer-clearer sprays. Results from this testing indicate that while the shearer-clearer system influences where the respirable dust particles are directed, underside shield sprays can still lower respirable dust exposure for longwall personnel.

Keywords: Coal Mining; Health and Safety; Longwall Mining; Respirable Dust Control; Shearer Clearer; Underside Shield Sprays; Water Spray Systems

INTRODUCTION

NIOSH researchers previously tested the use of underside shield water sprays for improved longwall dust control to reduce underground coal mine personnel exposure to potentially harmful respirable dust [1]. Overexposure to respirable coal dust can lead to coal workers' pneumoconiosis (CWP), commonly known as black lung. CWP is a preventable occupational lung disease that is caused by respirable coal dust inhalation in underground coal mines. A person with CWP will develop lung damage over time, potentially causing respiratory failure and premature death [2-3]. In August 2016, the U.S. Mine Safety and Health Administration (MSHA) set a new respirable dust standard (CFR 70.100), which decreased the concentration limits allowed for respirable coal mine dust from 2.0 mg/m^3 over an eight-hour shift to 1.5 mg/m^3 over the full actual working shift [4]. This maximum allowable exposure for mine personnel can be challenging to maintain without proper underground engineering controls.

It has been shown that longwall personnel can face overexposure to respirable coal dust from several dust- generating sources. These sources include the intake entry, stage loader, shearer, and shield advance [5], with the longwall shearer being the highest contributor, comprising anywhere from 43% to 50% of respirable dust generated on the longwall face [3,5]. NIOSH researchers have observed that the fracturing and spalling of coal just upwind of the headgate drum of the shearer creates a cloud of dust that can migrate into the personnel walkway.

CFR 75.325 states that the required ventilation on a longwall face must be at least 14.2 m^3/s (30,000 ft^3/min) [4]. This requirement is to ensure proper respirable dust control on the longwall face. In addition to meeting this face ventilation requirement, longwall mines use water sprays to further improve dust control. Typically, a longwall will have water spray systems that include drum-mounted water sprays, splitter arm sprays, a shearer-clearer system, and tailgate manifolds in operation during mining [6-8]. These systems can help reduce respirable dust exposures, but further research and improvement may be necessary.

NIOSH researchers observed underside shield sprays in 2011 [5]. These sprays are mounted on the underside of the longwall shields and directed toward the mining face. Underside shield sprays can create a moving water curtain along the longwall face, preventing dusty air created by the shearer from reaching the mining personnel walkway. It was observed that there was no consistency in the use of these sprays; the alignment and sequencing of the underside shield sprays varied considerably among different longwall operations [5]. Improper sequencing and alignment can lead to negative interactions with other longwall sprays by allowing a cloud of dust and mist to enter the personnel walkway, so it is important to further study these sprays for improved use.

Underside sprays were observed and tested in a laboratory setting by NIOSH researchers and described in a paper published in January 2021 [1]. The goal of this research was to evaluate the underside shield sprays' ability to prevent the formation of a dust cloud, created due to coal spalling from the longwall face ahead of the shearer, from reaching the longwall personnel walkway [1]. These sprays were evaluated to determine the best operating parameters for reducing dust exposures of mining personnel. Results from this testing showed that certain operating parameters may be beneficial for maximizing these dust reductions. Most importantly, this previous study showed that underside shield sprays appeared to greatly decrease respirable dust exposures for mining personnel at several sampling locations along the longwall face [1].

A shearer-mounted water spray arrangement, termed a "shearer-clearer" system, was developed by the U.S. Bureau of Mines and Foster-Miller, Inc. to confine longwall-generated dust to the mining face [9]. These sprays were oriented towards the face and angled to the return. During field tests of tail-to-head passes, it was observed that clean air on the walkway remained separate from the dusty air at the mining face and resulted in a 75% reduction in dust concentrations at the mid-shearer location [9]. Further improvements to the system reduced the number of sprays (in turn reducing water consumption) and mounted them in a more practical position [10]. Since the 1980s, these spray arrangements have become standard on U.S. longwall installations. A variation of this system was fitted to the full-scale shearer model for these tests.

The previous underside shield spray testing significantly relates to this study. Previous testing did not include the use of shearer-clearer water sprays located on top of the shearer body [1]. This posed the question as to whether shearer-clearer sprays could have negative interaction with underside shield sprays or would these sprays work together to improve longwall dust control. Because shearer-clearer sprays are commonly used in underground longwall mines, it was important to further research this topic.

METHODOLOGY

The methodology for this study was developed for previous underside shield spray research, with several changes to incorporate the use of shearer-clearer sprays while using successful configurations from previous testing. Researchers performed laboratory testing in the NIOSH Pittsburgh Mining Research Division's longwall gallery (Figure 1). It is a full-scale laboratory that simulates a longwall operation. This lab has been successfully used to develop respirable dust control interventions and is described in previous literature [8, 11-12]. Additional details of the shearer size and specifications can be found within the methodology of the previous underside shield spray study [1]. The difference in this study is the addition of shearer-clearer sprays, which sit atop the shearer body in an S-shaped pattern and are directed toward the longwall face. These sprays would operate during all testing conditions, aside from when baseline dust concentrations were being established.

The underside shield sprays were located upwind of the splitter arm sprays for the headgate shearer drum. The three splitter arm sprays were spaced evenly along the splitter arm's 3.40-m (11.2-ft) length (from shearer body to end of splitter arm). The underside shield sprays were located 0.86 m (2.83 ft) in front of the splitter arm sprays. Figure 1 shows the splitter arm and underside shield sprays during operation and their location relative to the longwall shearer and personnel walkway.

Like in previous testing, several operating parameters were examined to determine the most effective approach in minimizing respirable dust concentrations while using the underside shield sprays with the shearer-clearer sprays. The first parameter examined was the pressure of the underside shield sprays to see if higher water pressures had a positive impact on minimizing dust exposures. The three water pressures examined were 690 kPa (100 psi), 1,034 kPa (150 psi), and 1,379 kPa (200 psi). The spray nozzles used in the underside shield sprays were Spraying Systems VeeJet H 3/8 U 65/15 flat pattern sprays (Spraying Systems Co.). Additionally, face ventilation was measured before and after each test by performing a vane anemometer traverse just upwind of the sampling area. The targeted face ventilation of each test was 3.56 m/s (700 ft/min).

To create an effective traveling water curtain, the underside shield sprays need to be properly aligned toward the longwall face at an optimal distance and angle. Previously, three different water spray locations were tested at distances of 1.37 m (4.5 ft), 1.52 m (5.0 ft), and 1.68 m (5.5 ft) measured from the mining face [1]. Sprays located too close to the mining face did not provide good protection from dust entering the personnel walkway. Sprays that were located further from the face resulted in water entering the walkway where mining personnel would be positioned. Additionally, three water spray orientations were examined for previous testing at 45, 60, and 75 degrees, measured from the mining roof [1]. Using too small of an orientation angle would allow dust to pass under the spray into the walkway, as well as not meeting the recommended spray angle for the model 65/15 sprays at the tested pressures. Using an orientation approaching 90 degrees would not direct the dust into the mining face as desired. From this testing, it was determined that the best combinations of distance and angle were a 75-degree angle located 1.37 m (4.5 ft) from the face and a 60-degree angle located 1.52 m (5.0 ft) from the face [1].

In addition to adding shearer-clearer sprays to this study, two different sets of tailgate sprays were tested to determine any differences in their effect on longwall dust control. One set was tailgate splitter bar sprays, and the other was tailgate manifold sprays. These sprays were analyzed with each set of testing parameters previously listed.

Dust was injected into the longwall gallery by an automatic dust feeder and through use of two blowers with attached tubing. The feeder (Schenck AccuRate) and blowers (American Fan AF-10) were all located outside of the longwall gallery with their attached tubing running through the longwall face. Figure 1 shows the outlets of the tubes placed near the shearer cutting drum. This was done to best simulate the dust cloud created by the fracturing and spalling of coal just upwind of the cutting drum. One blower tube contained dust injected from the dust feeder, with the second blower tube acting as a booster to push the dust cloud away from the cutting drum toward the personnel walkway, which has been observed in field studies of longwall operations. Dust feed rate, location, and blower pressure levels remained constant throughout testing.

Figure 1. NIOSH longwall gallery showing the dust injection system located near the shearer drum, with splitter arm and underside shield sprays in operation without dust injection.

Table 1 shows the testing sequence that was used for each individual test. This testing sequence included five 15-minute blocks for data collection, with a 3-minute stabilization period following each block to allow changing conditions to stabilize. The gallery was wetted each morning to ensure similar conditions for each test. Each sequence began with a dust-only (no sprays) testing condition. This was done to get a baseline dust concentration before beginning the use of water sprays. For each block using water sprays, the shearer-clearer sprays were operated along with the cutting drum rotating as it would be in an underground mine. The second block tested the use of splitter arm sprays without tailgate or underside shield sprays, operating at 1,034 kPa (150 psi). The third testing block ran the splitter arm sprays with the tailgate sprays. This would determine how these two sets of sprays interacted with the shearer-clearer sprays, but without the use of underside shield sprays. The fourth block of tests would introduce the underside shield sprays operated at that test's predetermined water spray pressure. The underside shield sprays would always operate with the shearer-clearer, splitter arm, and tailgate sprays. After completion of the underside shield sprays testing block, the final block would be another dust-only condition. This was done to ensure that the dust maintained a relatively equal injection rate throughout testing.

Table 1. Complete testing sequence for each test, where each block included a 3-minute stabilization period followed by a 15-minute test for capturing data.

Block #	Testing Conditions/Sprays Used
1	Dust Only (No Sprays)
2	Dust + Shearer Clearer + Splitter Arm Sprays
3	Dust + Shearer Clearer + Splitter Arm + Tailgate Sprays
4	Dust + Shearer Clearer + Splitter Arm + Tailgate + Underside Sprays
5	Dust Only (No Sprays)

As stated previously, two different combinations of underside shield spray angle and distance were used for this testing based on their successful results from previous testing. Each of these two combinations was tested with both the tailgate splitter arm and tailgate manifold sprays at three different underside spray pressures. This 2 x 2 x 3 testing matrix provided 12 unique tests that needed to be completed, which is shown in Table 2. Each unique combination of parameters would be tested at least three times for repeatability of results.

Dust concentration data was planned to be collected at five primary locations in the longwall gallery, shown in Figure 2, with two PDM-3700 (Thermo Fisher Scientific) sampling units at each location, one hung above the longwall shield spill plate and one over the foot of the longwall shields, known as the pontoon location. However, due to limitations with sampling equipment and unexpected conditions at one location, only seven of these sampling locations provided usable data for analysis. The PDMs were placed at a height approximated to be the average breathing zone of mining personnel standing in the walkway. The first three pairs of sampling locations were located in succession upwind of the splitter arm sprays, at the centerline of the shearer drum, and at the ranging arm motor. The other two pairs of sampling locations were located downwind along the shearer body and at the tailgate.

Table 2. List of tests completed for this study, where each test was completed a minimum of three times to obtain three dust concentrations at each sampling location for each testing parameter.

Test #	Spray Angle	Spray Distance	Spray Pressure	Tailgate Sprays
1	75 degrees	1.37 m (4.5 ft)	690 kPa (100 psi)	Splitter Arm
2	75 degrees	1.37 m (4.5 ft)	1,034 kPa (150 psi)	Splitter Arm
3	75 degrees	1.37 m (4.5 ft)	1,379 kPa (200 psi)	Splitter Arm
4	75 degrees	1.37 m (4.5 ft)	690 kPa (100 psi)	Manifold
5	75 degrees	1.37 m (4.5 ft)	1,034 kPa (150 psi)	Manifold
6	75 degrees	1.37 m (4.5 ft)	1,379 kPa (200 psi)	Manifold
7	60 degrees	1.52 m (5.0 ft)	690 kPa (100 psi)	Splitter Arm
8	60 degrees	1.52 m (5.0 ft)	1,034 kPa (150 psi)	Splitter Arm
9	60 degrees	1.52 m (5.0 ft)	1,379 kPa (200 psi)	Splitter Arm
10	60 degrees	1.52 m (5.0 ft)	690 kPa (100 psi)	Manifold
11	60 degrees	1.52 m (5.0 ft)	1,034 kPa (150 psi)	Manifold
12	60 degrees	1.52 m (5.0 ft)	1,379 kPa (200 psi)	Manifold

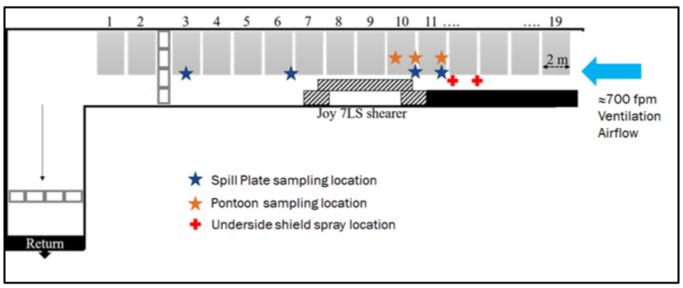

Figure 2. Longwall gallery setup showing the underside shield spray locations and the seven dust sampling locations used for this study.

Figure 2 shows the three locations where PDMs were not sampling. The shearer body pontoon location and the tailgate pontoon location were not sampled for enough tests to provide sufficient data for analysis. This occurred due to a shortage of PDMs for sampling. These locations were chosen to be removed first due to being a lesser focus of this study. The spill plate locations were generally of bigger concern due to their proximity to the mining face, and since this is generally where mining personnel would stand (and lean against). A third location also had to be removed due to the equipment shortage, so the ranging arm motor spill plate sampling location was removed. This location was selected for a different reason. When the shearer-clearer sprays were installed on the shearer body, a small gap was left between these sprays and the splitter arm sprays. This was not observed until several tests were already completed and could not be repeated. For some tests, this small gap allowed dust to funnel into the walkway, which was right at this ranging arm motor spill plate location, so this would occasionally overload the PDM. This is a notable observation during testing, like what has been mentioned with the alignment of underside shield sprays, a small alignment issue with any of these sprays can create issues with dust control. This can easily be avoided but was caught too late into the testing process, so this sampling unit was simply removed, and tests were continued. While this sampling location was affected negatively, no other sampling location saw effects from this.

RESULTS

For each test, there was a block of data collection with dust-only being injected into the gallery, with no water sprays in operation. This was done to gain baseline dust concentration data, which can vary between tests due to how the dust feeder system operates, as well as changes in face ventilation and overall air properties (humidity, barometric pressure, temperature, etc.). A face ventilation of 3.6 m/s (700 ft/min) was targeted for each test, with slight variations occurring from test to test. The baseline dust concentrations were also dependent on the sampling location, so this data needed to be normalized at each sampling location based upon that location's baseline dust concentration. Equation 1 shows the calculation for this ratio.

$$Ratio = \left[\frac{Parameter\ concentration}{Dust\ baseline\ concentration}\right] \quad (1)$$

Where:

Parameter concentration = the respirable dust concentration (mg/m^3) during measurement at the splitter arm, tailgate spray, 690 kPa (100 psi), 1,034 kPa (150 psi), or 1,379 kPa (200 psi) parameter.

Dust baseline concentration = the dust concentration (mg/m^3) during respirable dust baseline measurement

This calculation produced a ratio that allows for simpler comparison of the three underside shield spray pressures tested with the splitter arm and tailgate spray testing blocks, as well as to the baseline dust-only testing block (1.0 ratio). A ratio < 1.0 meant there was a reduction in the respirable dust concentration at that sampling location. A ratio > 1.0 meant there was an increase (negative reduction) in respirable dust concentration at that sampling location when compared to the baseline dust-only block.

Figures 3-6 show the calculated dust concentration ratios at the spill plate sampling locations. Each of these figures show the dust concentration ratios during operation of splitter arm sprays, tailgate sprays, and underside shield sprays operating at 690 kPa (100 psi), 1,034 kPa (150 psi), and 1,379 kPa (200 psi). These figures do not show data at the ranging arm motor spill plate location. This data was determined to be insufficient for comparative purposes as described previously in the Methodology section. Figure 3 and Figure 4 show tests at a 75-degree spray angle and distance of 1.37 m (4.5 ft) with the tailgate splitter arm and manifold spray configurations, respectively. Figure 5 and Figure 6 show tests at a 60-degree spray angle and distance of 1.52 m (5.0 ft) with the tailgate splitter arm and manifold spray configurations, respectively.

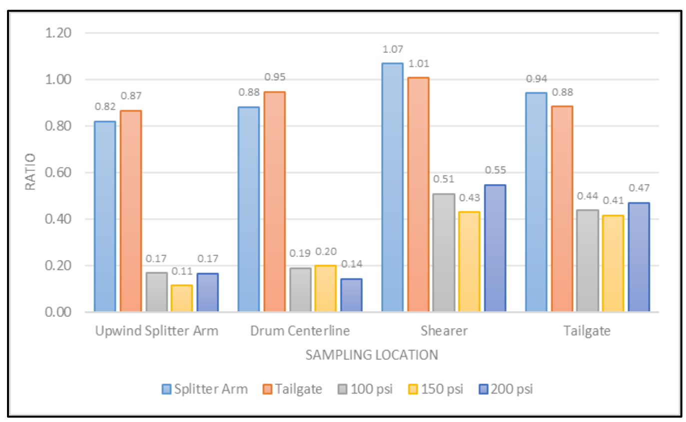

Figure 3. Spill plate concentration ratios with the splitter arm tailgate sprays at a 75-degree spray angle and 1.37 m (4.5 ft) from the face.

As in previous testing, Figures 3-6 show that operation of the splitter arm sprays without the use of underside shield sprays did not greatly reduce respirable dust concentrations. In several instances, the use of splitter arm sprays increased the respirable dust levels at some sampling locations (> 1.0 ratio). Additionally, this testing examined the use of tailgate water sprays with two different options: the tailgate splitter arm and tailgate manifold sprays. The use of tailgate sprays in conjunction with the splitter arm sprays did not produce a noticeable reduction in respirable dust concentrations at any of the sampling locations. The visual representation of this comparison is easily seen in Figures 3-6, where the tailgate sprays follow a similar trend to use of just the splitter arm sprays, even producing increased dust concentrations at several sampling locations.

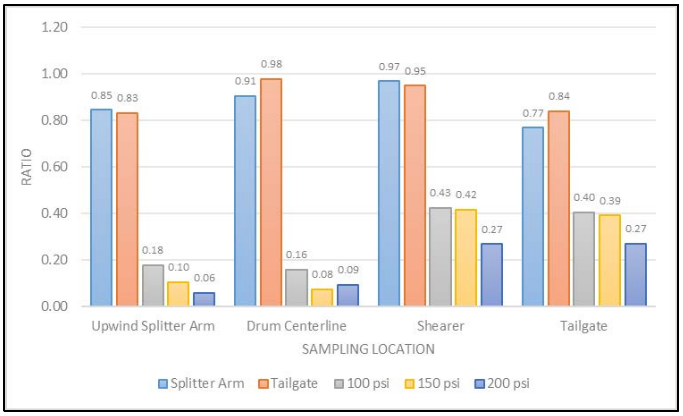

Figure 4. Spill plate concentration ratios with the manifold tailgate sprays at a 75-degree spray angle and 1.37 m (4.5 ft) from the face.

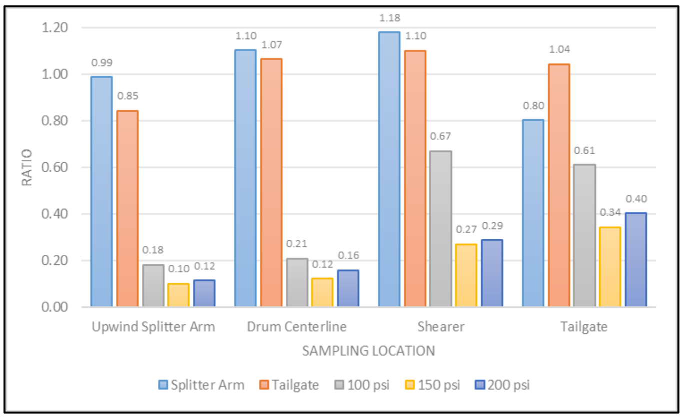

Figure 5. Spill plate concentration ratios with the splitter arm tailgate sprays at a 60-degree spray angle and 1.52 m (5.0 ft) from the face.

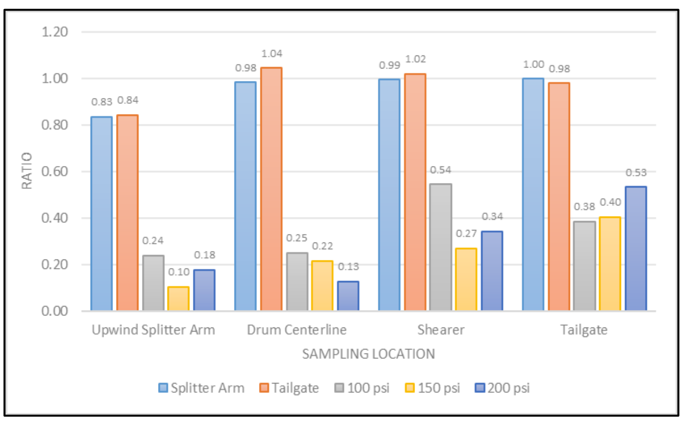

Figure 6. Spill plate concentration ratios with the manifold tailgate sprays at a 60-degree spray angle and 1.52 m (5.0 ft) from the face.

Figures 3–6 show the use of underside water sprays in conjunction with splitter arm and tailgate water sprays at three pressures of 690 kPa (100 psi), 1,034 kPa (150 psi), and 1,379 kPa (200 psi). At each sampling location, the use of underside shield sprays, at any pressure, reduced the respirable dust concentration. This was particularly true at the upwind splitter arm and drum centerline sampling locations along the spill plate, where dust reductions were at least 75% and as high as 94%. At the shearer and tailgate spill plate locations, dust reductions were seen while using underside shield sprays, but some dust was still able to enter the walkway at these downwind sampling locations, resulting in dust reductions between 33% and 73%. These locations are not intended to be as crucial for reducing respirable dust concentrations, as mining personnel are less likely to be standing at these areas for prolonged periods. It is expected that the mining personnel would be near the upwind splitter arm and drum centerline locations while operating the longwall shearer.

Figures 7–10 show the calculated dust concentration ratios at the pontoon sampling locations. Each of these figures show the dust concentration ratios during operation of splitter arm sprays, tailgate sprays, and underside shield sprays operating at 690 kPa (100 psi), 1,034 kPa (150 psi), and 1,379 kPa (200 psi). These figures do not show data at the shearer and tailgate pontoon locations. Like the ranging arm motor spill plate location, this data was determined to be insufficient for comparative purposes as described previously in the Methodology section. Figure 7 and Figure 8 show tests at a 75-degree spray angle and distance of 1.37 m (4.5 ft) with the tailgate splitter arm and manifold spray configurations, respectively. Figure 9 and Figure 10 show tests at a 60-degree spray angle and distance of 1.52 m (5.0 ft) with the tailgate splitter arm and manifold spray configurations, respectively.

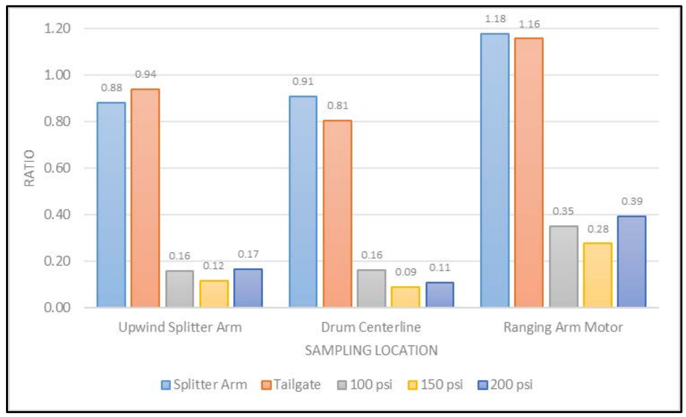

Figure 7. Pontoon concentration ratios with the splitter arm tailgate sprays at a 75-degree spray angle and 1.37 m (4.5 ft) from the face.

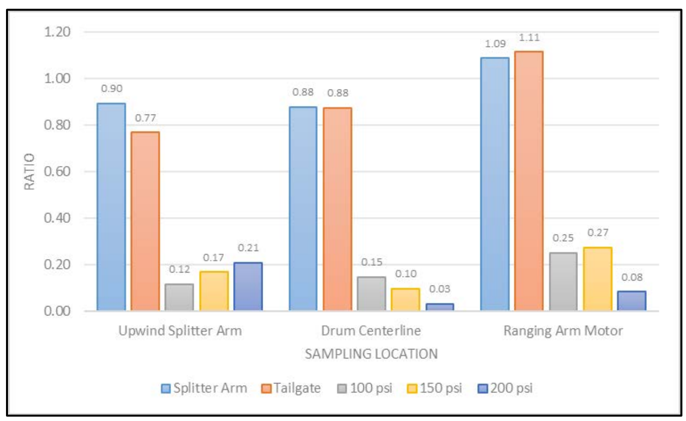

Figure 8. Pontoon concentration ratios with the manifold tailgate sprays at a 75-degree spray angle and 1.37 m (4.5 ft) from the face.

The pontoon sampling data follows the same general trend as was observed for the spill plate sampling locations. When the splitter arm was operated without the underside shield sprays, the dust concentrations at the three pontoon locations did not dramatically decrease from the dust-only sampling. In some cases, the measured dust concentrations increased. The same trend was seen when the tailgate sprays were operated with the splitter arm sprays, but without use of underside shield sprays. The dust concentrations remained high, with some dust concentration ratios measuring above the 1.0 baseline. As was the case at the spill plate locations, use of the splitter arm sprays and tailgate sprays did not appear to help with reducing respirable dust concentrations at any sampling location.

Again, similarly to the spill plate sampling locations, the pontoon sampling locations saw noteworthy reductions in respirable dust with the use of underside shield sprays in conjunction with the splitter arm and tailgate sprays. These dust reductions were seen at every pontoon sampling location for each testing condition, with a minimum 73% dust reduction and a maximum 97% reduction. Although there was not usable data at the ranging arm motor spill plate location, it is shown that the ranging arm motor pontoon location did follow a similar trend to every other sampling location in terms of respirable dust concentration reduction with use of underside shield sprays, especially at the highest 1,379- kPA (200-psi) pressure. Dust reductions at the ranging arm motor pontoon location varied between 41% and 92% reduction.

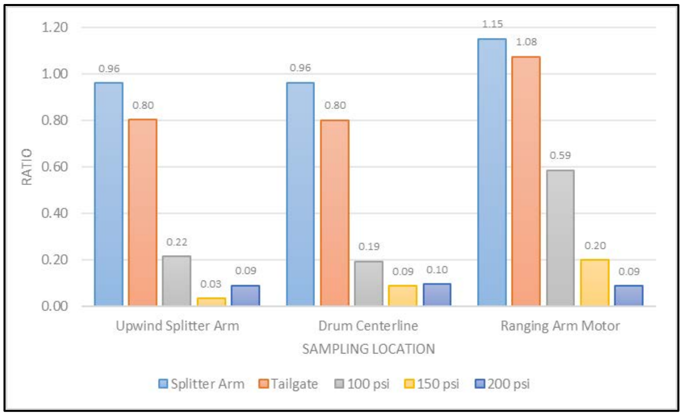

Figure 9. Pontoon concentration ratios with the splitter arm tailgate sprays at a 60-degree spray angle and 1.52 m (5.0 ft) from the face.

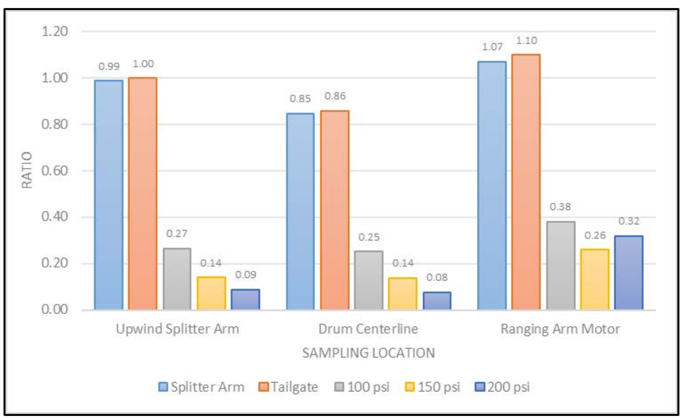

Figure 10. Pontoon concentration ratios with the manifold tailgate sprays at a 60-degree spray angle and 1.52 m (5.0 ft) from the face.

CONCLUSIONS

NIOSH researchers performed further research of previous testing that investigated the impact of underside shield sprays on longwall dust control in a laboratory setting. These tests included the use of shearer- clearer water sprays located on the longwall shearer body in conjunction with the overall longwall water spray system. The use of shearer-clearer sprays is a typical method for longwall dust control, so it was necessary to determine if the use of underside shield sprays would work as effectively while also operating shearer clearer sprays.

As was the case without the shearer-clearer sprays, the use of underside shield sprays with shearer-clearer sprays continued to provide encouraging laboratory results towards decreasing respirable dust exposure for mining personnel working along the longwall face. Proper alignment and positioning of the underside sprays, as well as the shearer-clearer sprays, continues to be extremely important towards the effectiveness of these sprays. Improper positioning of underside sprays can dramatically decrease dust control effectiveness. Additionally, there can be no gaps between all water sprays used within the overall longwall water spray system. A gap between sprays can cause a funnel effect where the dirty air is forced to that gap and potentially to the personnel walkway and exposing mining personnel. Positioning the mining personnel behind underside shield sprays can help minimize exposure to respirable dust.

For this testing, 75-degree and 60-degree spray angles were used for comparison, since these were the better performing spray angles observed during previous testing. These spray angles were set at 1.37 m (4.5 ft) and 1.52 m (5.0 ft) from the face, respectively, since these were the best performing combinations observed. This testing also introduced a comparison of different tailgate sprays—the tailgate splitter arm sprays and the tailgate manifold sprays. These were used in conjunction with the splitter arm sprays located near the shearer cutting drum and then also operated during the use of the underside shield sprays. Respirable dust sampling occurred at four spill plate and three pontoon sampling locations along the personnel walkway.

Overall, this testing provided positive results for the use of underside shield sprays in conjunction with shearer- clearer sprays. The use of splitter arm sprays at the cutting drum did not provide substantial dust reductions at any of the seven sampling locations, which was seen in previous testing as well. It appears the dust is still able to roll around the splitter arm and move down the personnel walkway, providing similar dust concentrations as when just dust was injected into the longwall gallery with no sprays operating.

In addition to the general ineffectiveness of the splitter arm sprays, these sprays were operated with two different combinations of tailgate sprays. These sprays were compared to determine if there would be any additional effects of tailgate spray systems on the overall longwall water spray system. These sprays did not appear to impact the dust concentrations observed during testing, as there were no dramatic decreases in dust levels at any sampling location while operating either set of tailgate sprays with the splitter arm sprays.

Finally, the underside shield sprays were operated with both the tailgate sprays and splitter arm sprays. The underside sprays were operated at 690 kPa (100 psi), 1,034 kPa (150 psi), and 1,379 kPa (200 psi) for each test. While a higher pressure is typically preferred, this did not seem to be as important of a testing parameter as previously seen. All three pressures resulted in substantial dust reductions at every sampling location at both the spill plate and pontoon. This was especially true at the upwind splitter arm and drum centerline locations, where mining personnel are typically expected to be located during operation of the longwall shearer. Dust reductions were as high as 94% at the spill plate upwind splitter arm location, and 92% at the spill plate drum centerline location. For the pontoon locations, dust reductions were as high as 97% at both the upwind splitter arm and drum centerline locations. While future testing in an underground setting would be beneficial for determination of the true effectiveness of underside shield sprays, this laboratory study has provided further evidence that underside shield sprays can be effective for reducing respirable dust exposure for mining personnel if positioned, aligned, and operated effectively.

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DISCLAIMER

The findings and conclusions in this report are those of the author(s) and do not necessarily represent the official position of the National Institute for Occupational Safety and Health (NIOSH), Centers for Disease Control and Prevention (CDC). Mention of any company or product does not constitute endorsement by NIOSH.

CONFLICTS OF INTEREST

On behalf of all authors, the corresponding author states that there is no conflict of interest.

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