12th U.S./North American Mine Ventilation Symposium 2008 – Wallace (ed)
ISBN 978-0-615-20009-5

Effectiveness of a water curtain utilized for dust control on continuous miner sections

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ABSTRACT: The Mine Safety and Health Administration (MSHA) conducted a respirable dust survey to evaluate the effectiveness of a water curtain utilized for dust control on continuous miner sections. The purpose of this survey was to determine if the water curtain was effective in reducing respirable dust concentrations, since several mines currently use water curtains to control miners' respirable dust exposures. The survey was conducted on a supersection of an underground coal mine, which utilized two continuous miners on the same split of air. Each continuous miner alternated taking a cut so that both continuous miners would not operate at the same time. The underground coal mine is located in Knox County, Indiana. The water curtain evaluated in this survey was located in the last open crosscut between the intake side continuous miner and the return side continuous miner. When the intake side continuous miner cuts coal, its exhaust air would be used to ventilate the return side of the section. The intent of the water curtain was to reduce the intake air respirable dust concentration (generated by the intake side continuous miner) before the air stream ventilated the return side of the section. To determine the effectiveness of the water curtain in reducing respirable dust concentrations, respirable dust sampling pumps were placed on both the intake side and the return side of the water curtain. Additional respirable dust sampling pumps were placed farther downstream from the water curtain to monitor dust levels downstream of the water curtain, but in an area where respirable dust would not be created by anything other than the intake side continuous miner or additional section air. The water curtain and the respirable dust sampling pumps were operated only when the intake side continuous miner was cutting coal. The samples were analyzed for respirable dust and quartz content. The water curtain showed minimal effect in controlling respirable dust and respirable quartz dust, but the reduction was so negligible that this survey could not quantify the reduction. The measured reductions are within the accuracy of the sampling equipment.

1 Introduction

On March 14 and 15, 2006, a respirable dust survey was conducted at a coal mine located in Knox County, Indiana. The purpose of the survey was to evaluate the effectiveness of a water curtain used for respirable dust control on one of the two continuous mining units of a supersection operating on a single split of air. MSHA personnel from the Pittsburgh Safety and Health Technology Center, Dust Division and Coal Mine Safety and Health participated in the survey.

The water curtain consists of two 2.44 m (8 ft) sections of stainless steel line and contains 16 mist nozzles that are hung across the top of the crosscut. Amusement parks use a similar device to cool guests during the hot weather. Mine management believed that the downwind operator's dust exposures are reduced by utilizing the water curtain. Miners expressed to mine management that the water curtain produced a more comfortable working environment due to the added moisture the water curtain places in the air. The respirable dust survey would determine if the water curtain is actually reducing respirable dust in the ventilation air stream.

2 Background

The underground coal mine has been in operation since April 1993. The mine operates two 9½-hour production shifts per day, 5½ days per week, with the midnight shift responsible for maintenance. Two hundred and sixty-seven people were employed at the mine with 220 miners working underground. Mine production for 2005 was approximately 1.9×10^9 kg (2.1 million tons) raw material. Coal is removed from the Danville #7 coal seam. Most of the coal produced is used for power plant generation of electricity.

The survey was conducted on mechanized mining unit 002-0 in the #2 Unit section. The #2 Unit section consisted of eight entries. A blowing line curtain was used to ventilate the faces. Each continuous miner alternated

taking a cut while operating in the same split of air. Only one continuous miner is permitted to operate at any time because of the single-split ventilation. The main intake air entered from Entries #7 and #8 and measured an average airflow of 25.1 m^3/s (53,200 cfm). The return section airflow exited Entries #1, #2, and #3. The belt was located in Entry #4. Average entry height was approximately 1.8 m (6 ft) and the average entry width cut by both continuous miners surveyed was 5.5 m (18 ft). Equipment operated on the #2 Unit section included two remote-controlled Joy[1] 14CM continuous miners, three DBT[1] battery-operated coal haulers, and two double-boom Fletcher[1] roof bolters. The roof bolting was conducted on 1.52 m (5 ft) centers. A diagram of the #2 Unit section map is shown in Figure 1.

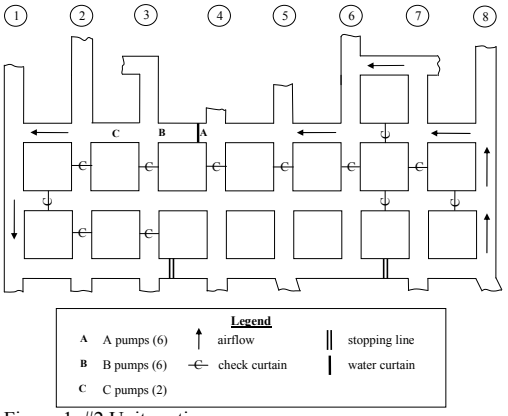

Figure 1. #2 Unit section map.

The water curtain is a Rapid Cool Mist Line[1] (www.rapidcoolusa.com) that is typically used in amusement parks to cool guests during hot weather. It consists of two 2.44 m (8 ft) sections of stainless steel line with a 9.53 mm (0.375 in) outside diameter that are connected. This line is hung across the top of the crosscut and contains 16 mist nozzles that are aimed into the airflow. Figure 2 is a close-up picture of two mist nozzles. Water is fed from the right side (intake side) continuous miner's water supply via a high pressure hose through a 5 micron Shroeder[1] Water Filter assembly. Direct water feed to the water curtain is controlled by a ball valve. The water curtain operates at 2,410 kPa (350 psi) water pressure.

The mine has been utilizing two water curtains as dust control devices since approximately August 2005. The sampled water curtain is located in the last open crosscut between the right side (intake side) continuous miner and the left side (return side) continuous miner. See Figure 1 for a section map showing the water curtain location. During the right side continuous miner cutting sequence, return air from this continuous miner is carried through the crosscut before it ventilates the left side of the section. The intent of this water curtain is to reduce respirable dust generated by the right side continuous miner before the return air ventilates the left side of the section. The mine typically operated an additional water curtain located in the main intake entries. It was not operated during this survey.

Figure 2. Close-up of mist nozzles.

3 Sampling and Analytical Procedure

Fourteen area respirable dust samples were collected on each day of sampling to determine respirable dust levels and quartz content. Twelve area respirable dust samples were collected in the same open crosscut where the water curtain was located. Of these twelve area samples, six area respirable dust samples were collected on the intake side of the water curtain (labeled A pumps 1 through 6) and six area respirable dust samples were collected on the return side of the water curtain (labeled B pumps 1 through 6). Two additional area respirable dust samples (labeled C pumps 1 and 2) were collected farther downstream from the water curtain to sample dust away from the water curtain, but in an area where dust would not be created by anything other than the right side continuous miner or additional section air. This area excluded the dust from the left side roof bolter or coal haulers. On the first day of sampling, the two C pumps were positioned in Crosscut 3 to 2 for the first three cuts of the right side continuous miner sampled and then moved to the straight of Entry #3 for the last three cuts sampled on that day. Because of face advancement on the second day of sampling, all pumps were positioned one crosscut inby with the C pumps positioned in Crosscut 3 to 2. Figure 1 shows the positioning of the pumps.

The water curtain and respirable dust sampling pumps were operated only when the right side (intake side) continuous miner was cutting and loading coal. During this cutting sequence, return air was carried through the crosscut containing the water current to the left side of the section. The intake air travels through this crosscut when the left side (return side) continuous miner operated.

To determine the effectiveness of the water curtain in reducing respirable dust concentrations, respirable dust sampling pumps were placed on both the intake side and the return side of the water curtain. Sampling only occurred when the upwind continuous miner was

operating. The samples for both the six A pumps (intake side of water curtain) and six B pumps (return side of water curtain) were evenly positioned in the crosscut of the water curtain. Three pumps were placed across the entry approximately 0.533 m (21 in) from the roof of the mine and three pumps were placed approximately 0.533 m (21 in) from the floor of the mine for each sample side of the water curtain. There was approximately 1.52 m (5 ft) between two samples, and approximately 1.52 m (5 ft) between the rib and sample. The A pumps were approximately 1.22 m (4 ft) from the intake side of the water curtain. The samples collected on the return side of the water curtain paralleled the intake samples. These return side samples were located approximately 12.8 m (42 ft) from the water curtain. A schematic of the location of the water curtain and the samples from the intake side of the water curtain for pumps 1 through 6 (A pumps) is shown in Figure 3. The two C pumps were located in the upper left side and upper right side of the ribs in the next crosscut to allow for the traveling of equipment.

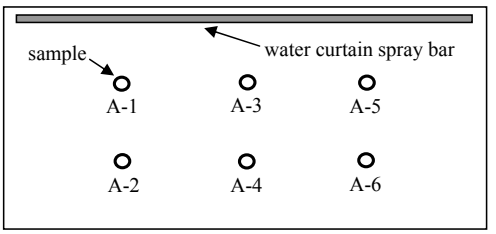

Figure 3. Cross-sectional view of A pumps with water curtain located 1.22 m (4 ft) downwind.

Respirable dust samples were collected using approved MSA Elf® constant-flow personal respirable coal mine dust sampling instruments operated at a flow rate of 2.0 liters per minute (Lpm). The samples were collected on polyvinyl chloride filters. The filters are 37 mm in diameter and have a 5.0 micron pore size. All filter cassettes were pre-weighed and post-weighed on an analytical balance to 0.001 milligram. A control filter was used to adjust post-weights for variability associated with day-to-day changes in laboratory conditions or introduced during storage and handling of the filter capsules.

Respirable dust concentrations were determined by dividing the sample mass by the volume of air sampled. Fixed-point or area respirable dust concentrations were then converted to Mining Research Establishment (MRE) equivalent concentrations by multiplying by the constant factor 1.38. Dust concentrations were calculated using the following formula:

$$Dust\ Conc.\left(\frac{mg}{m^3}\right)=\frac{Dust\ Weight\ (mg)\times 1{,}000\ \frac{L}{m^3}\times 1.38\ (MRE)}{2.0\ Lpm\times Sample\ Time\ (minutes)} \quad (1)$$

All of the respirable dust samples were analyzed to determine quartz content using low temperature ashing and Fourier Transform Infrared Spectroscopy analysis (MSHA P-7 Method). Quartz concentrations were determined by dividing the sample mass by the volume of air sampled. Fixed-point concentrations were then converted to MRE equivalent concentrations by multiplying by the constant factor 1.38. Quartz concentrations were calculated by the following formula:

$$Quartz\ Conc.\left(\frac{\mu g}{m^3}\right)=\frac{Quartz\ Weight\ (\mu g)\times 1{,}000\ \frac{L}{m^3}\times 1.38\ (MRE)}{2.0\ Lpm\times Sample\ Time\ (minutes)} \quad (2)$$

Velocity readings were taken at each respirable dust sampling pump location using a vane anemometer. Velocity readings were taken at each sampling location twice during the first day of sampling and once during the second day of sampling.

4 Results and Discussion

Table 1 shows the results of the area respirable dust concentrations and velocity readings from March 14 and 15, 2006. The concentrations are based on the actual sampling time. Sampling pumps operated for approximately 4 hours on the first day of sampling and approximately 1 hour on the second day of sampling.

The average weighted dust concentrations were calculated by multiplying the individual concentrations by the associated velocity then dividing the sum of these two products by the total velocity. The air quantities at the locations of the A pumps and B pumps must be the same, since both sampling locations were in the same crosscut. The velocities varied at each sampling location throughout each cross-sectional area. Due to the variance in velocities of the cross-sectional area, all velocities and concentrations in each cross-sectional area of the A pumps and B pumps were weighted to obtain an average weighted dust concentration. This average weighted dust concentration would represent one dust concentration for each of the sampling locations of the A pumps and B pumps in order to evaluate the water curtain.

On the first day of sampling, the average weighted dust concentrations were 2.42 mg/m^3 for the respirable dust prior to entering the water curtain at the A pumps and 2.35 mg/m^3 for the B pumps located 12.8 m (42 ft) from the water curtain indicating a 2.9% reduction from the location of the A pumps. The average weighted dust concentration from the two C pumps located downwind of the water curtain in the next crosscut was 2.45 mg/m^3 indicating a 1.2% increase from the location of the A pumps. On the second day of sampling, the average weighted dust concentrations were 1.90 mg/m^3 for the A pumps and 1.84 mg/m^3 for the B pumps indicating a 3.2% reduction from the location of the A pumps. The average weighted dust concentration for the C pumps was 1.85 mg/m^3 indicating a 2.6% reduction from the location of the A pumps. The average weighted dust concentrations were lower the second day of sampling than the first day, but total sampling time from the first day of sampling was four times the amount of the second day sampling time. The comparison between the average weighted dust

concentrations from the A pumps and B pumps resulted in a slight reduction for each day of sampling. The measured reductions are within the accuracy of the sampling equipment. The water curtain may have a minimal effect in controlling respirable dust, but the percent reduction is so negligible that this survey could not quantify the reduction.

Table 1. Respirable dust concentrations and velocity readings.

Date	Location	Dust Conc. (mg/m^3)	Average Velocity m/s (fpm)	Average Weighted Conc. (mg/m^3)/ Percent Reduction from A
3/14	A1	2.07	1.483 (292)	2.42 ---
	A2	2.01	1.524 (300)	
	A3	2.56	1.910 (376)	
	A4	2.50	1.854 (365)	
	A5	2.70	1.387 (273)	
	A6	2.63	1.626 (320)	
	B1	2.11	1.631 (321)	2.35 2.9%
	B2	1.97	1.488 (293)	
	B3	2.44	1.768 (348)	
	B4	2.38	1.803 (355)	
	B5	2.61	1.463 (288)	
	B6	2.59	1.478 (291)	
	C1	2.46	1.626 (320)	2.45 -1.2%
	C2	2.43	0.752 (148)	
3/15	A1	1.82	1.544 (304)	1.90 ---
	A2	1.88	1.250 (246)	
	A3	1.82	2.027 (399)	
	A4	1.84	1.544 (304)	
	A5	1.98	1.793 (353)	
	A6	2.04	1.595 (314)	
	B1	1.97	1.483 (292)	1.84 3.2%
	B2	1.90	1.214 (239)	
	B3	1.88	1.676 (330)	
	B4	1.86	1.407 (277)	
	B5	1.73	1.915 (377)	
	B6	1.76	1.798 (354)	
	C1	1.92	1.280 (252)	1.85 2.6%
	C2	1.78	1.387 (273)	

The quartz concentrations from the first day of sampling averaged 54 $\mu g/m^3$ prior to entering the water curtain at the A pumps, 46 $\mu g/m^3$ for the B pumps located 12.8 m (42 ft) from the water curtain, and 50 $\mu g/m^3$ for the two C pumps located downwind of the water curtain in the next crosscut.

The average quartz percentages were 2.3% for the A pumps, 2.0% for the B pumps, and 2.1% for the C pumps.

From the location of the A pumps to the location of the B pumps, the average quartz concentrations resulted in an 8 $\mu g/m^3$ reduction and the average quartz percentages resulted in a 0.3% reduction. On the second day of sampling, the average quartz concentrations were 60 $\mu g/m^3$ for the A pumps, 58 $\mu g/m^3$ for B pumps, and 64 $\mu g/m^3$ for the C pumps. The average quartz percentages were 3.2% for the A pumps, 3.1% for the B pumps, and 3.4% for the C pumps. From the location of the A pumps to the location of the B pumps, the average quartz concentrations resulted in a 2 $\mu g/m^3$ reduction and the average quartz percentages resulted in a 0.1% reduction. The comparison between the average quartz concentrations and average quartz percentages from the A pumps and B pumps resulted in a slight reduction for each sampling day. The measured reductions are within the accuracy of the sampling equipment. The water curtain may have a minimal effect in controlling respirable quartz dust, but the reduction is so negligible that this survey could not quantify the reduction.

Table 2 shows the results of the quartz concentrations and quartz percentages from March 14 and 15, 2006.

Table 2. Quartz concentrations and quartz percentages.

Date	Location	Quartz Conc. ($\mu g/m^3$)	Percent Quartz (%)	Avg. Conc. ($\mu g/m^3$)/ Avg. Percent
3/14	A1	51	2.5	54 2.3%
	A2	48	2.4	
	A3	52	2.0	
	A4	55	2.2	
	A5	54	2.0	
	A6	63	2.4	
	B1	43	2.0	46 2.0%
	B2	37	1.9	
	B3	46	1.9	
	B4	37	1.6	
	B5	55	2.1	
	B6	58	2.2	
	C1	48	2.0	50 2.1%
	C2	51	2.1	
3/15	A1	70	3.8	60 3.2%
	A2	58	3.1	
	A3	58	3.2	
	A4	58	3.2	
	A5	58	3.0	
	A6	58	2.9	
	B1	58	3.0	58 3.1%
	B2	58	3.0	
	B3	58	3.1	
	B4	58	3.1	
	B5	58	3.3	
	B6	58	3.3	
	C1	69	3.6	64 3.4%
	C2	58	3.2	

Table 3 shows the production measured while both the right side continuous miner and sampling pumps were operating.

Table 3. Production.

Cut Number	3/14/06		3/15/06	
	Footage Mined m (ft)	Prod. kg (tons)	Footage Mined m (ft)	Prod. kg (tons)
1	6.1 (20)	122,500 (135)	6.1 (20)	122,500 (135)
2	10.7 (35)	214,100 (236)	6.1 (20)	122,500 (135)
3	10.7 (35)	214,100 (236)	---	---
4	6.1 (20)	122,500 (135)	---	---
5	6.1 (20)	122,500 (135)	---	---
6	7.6 (25)	153,300 (169)	---	---
Total	47.3 (155)	949,000 (1,046)	12.2 (40)	245,000 (270)

On the first day of sampling, 6 cuts out of 11 cuts were made by the right side continuous miner. Sampling pumps operated the entire time the right side continuous miner was operating. The footage mined ranged from 6.1 m (20 ft) to 10.7 m (35 ft) resulting in approximately 47.3 m (155 ft) mined and 949,000 kg (1,046 tons) of production. Average production for both the left side and right side continuous miners is approximately 1,728,000 kg (1,905 tons) per shift indicating that there was normal production on this sampling day.

On the second day, the sampling pumps operated for 6.1 m (20 ft) out of 9.1 m (30 ft) for each cut from the right side continuous miner. The total distance mined was approximately 12.2 m (40 ft) and production was approximately 245,000 kg (270 tons). The level of production on the second day was approximately 26% of that produced on the first day.

5 Findings and Conclusions

The respirable dust survey was conducted to evaluate the effectiveness of a water curtain utilized for dust control on continuous miner sections. The mine operator considered the water curtain as a dust control device, but the water curtain had no appreciable effect on reducing dust levels on the downwind side.

For each day of sampling, the average weighted dust concentrations resulted in a slight reduction from the A pumps to the B pumps. Results from the A pumps to B pumps indicated a 2.9% reduction in average weighted dust concentration for the first day of sampling and 3.2% reduction for the second day of sampling. The measured reductions are within the accuracy of the sampling equipment. The water curtain may have a minimal effect in controlling respirable dust, but the percent reduction is so negligible that this survey could not quantify the reduction.

For each day of sampling, the average quartz concentrations and average quartz percentages indicated a slight reduction from the A pumps to the B pumps. Comparing the results from the A pumps to B pumps on the first day of sampling indicated an 8 $\mu g/m^3$ reduction in average quartz concentration for the first day of sampling and 0.3% reduction in average quartz percentage. Comparing the results from the A pumps to B pumps on the second day of sampling indicated a 2 $\mu g/m^3$ reduction in average quartz concentration for the second day of sampling and 0.1% reduction in average quartz percentage. The measured reductions are within the accuracy of the sampling equipment. The water curtain may have a minimal effect in controlling respirable quartz dust, but the reduction is so negligible that this survey could not quantify the reduction.

References

MSHA. 2006. PS&HTC-DD-06-610.

Brand names used in this report are for purposes of clarity. MSHA does not endorse any equipment manufacturer.