EVALUATION OF THE WET HEAD CONTINUOUS MINER TO REDUCE RESPIRABLE DUST

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Abstract

The National Institute for Occupational Safety and Health (NIOSH) conducted field tests to evaluate the effectiveness of a wet head continuous mining machine for reducing dust exposure for continuous miner operators. Wet head technology delivers water via sprays to the continuous miner's cutter head as opposed to traditional standard sprays located on the boom and body of the mining machine. The sprays, positioned directly behind each bit on the cutter head, deliver water at the point of attack, serving to cool the bits during mining to reduce the potential for frictional ignitions. The sprays also flood the coal with water to potentially suppress dust generation. Dust surveys were conducted at several mines to evaluate the wet head's effectiveness to control respirable dust exposure at the continuous miner operator location and in the immediate return. Results show that the wet head miner improved air quality at both locations to varying degrees in some cases and not in others when compared to a continuous miner with a standard spray system.

Introduction

Under NIOSH's Coal Workers' X-Ray Surveillance Program, over 90,000 chest x-rays have been performed on underground coal workers from 1980 to 2008 to track and document the incidence of pneumoconiosis. Trends are evident from these x-rays and it can be shown that, after years of decline, pneumoconiosis has been increasing among underground coal miners since the year 2000. There is also evidence in these x-rays to suggest that the recent increase in pneumoconiosis cases is associated with coal workers exposure to excessive amounts of respirable crystalline silica (A. Scott Laney, et al., 2009). Many operations cut rock along with coal to create a more favorable working height for machinery and personnel. However, this rock is typically the source of the silica that often requires mines to be placed on a reduced dust standard lower than the current 2.0 mg/m^3 regulatory standard. Mine operations are placed on a reduced standard when the amount of silica on the dust filters exceeds 5% by weight. The dust standard is reduced using the expression, 10 divided by % silica. MSHA dust samples collected by inspectors from 2004 to 2008 show that 7.3 % of the samples from the continuous miner operator exceeds the permissible exposure limit (PEL) of 2.0 mg/m^3. However, when mines are placed on a reduced dust standard for silica content in respirable dust samples, nearly 20 % of the inspector samples are exceeded. (US Department of Labor, 2009).

Typically, respirable dust is controlled by water sprays mounted on the continuous miner (CM). This method has been an effective means of controlling respirable dust for CM operators for many years, but the increase in the incidence of overexposure suggests that the use of water sprays is no longer consistently providing protection to operators. As new methods of controlling face hazards are developed and adopted by the mining industry, their potential for controlling respirable dust will continue to be evaluated.

Typical mining machines place water sprays on the cutting boom approximately 30-40 cm away from cutting bits to protect the spray manifolds. The wet head continuous miner introduces water via sprays located directly behind each cutting bit on the cutting drum (Figure 1a; Figure 1b). The spray angle of the nozzles over the bits keeps the bits cool during the cutting process increasing bit longevity and lessening the potential for frictional ignitions. In addition, these water sprays wet coal surfaces and have the potential to prevent airborne respirable dust generation by placing the water sprays as close as possible to the coal surfaces. It has been shown that the closer the water sprays are to the surface being

Figure 1a. Wet head bit block showing water spray behind the bit.

Figure 1b. Wet head sprays on continuous miner cutter head.

cut, the more effective they become (Foster-Miller, Inc, 1986). The wet head introduces water in close proximity to the point of attack of each bit and therefore has the potential for limiting dust generation while mining. However, several studies of wet head sprays versus standard machine mounted sprays have either not shown or could not prove a significant difference in dust reduction from one system to the other (Chugh, et al, 2006, Goodman, et al., 2006, Fields, et al., 2005). In an attempt to clarify the effectiveness of the wet head miner to limit coal and silica dust exposure of the CM operator and downwind personnel, NIOSH conducted five in-mine dust studies to measure respirable dust levels at the CM operator location and in the immediate return.

Mine Site Investigations

These studies took place in five mines that are located in four states: Virginia, West Virginia, Kentucky, and Illinois. The five mines will be identified by letters A through E to ensure anonymity of the mines that cooperated for this study. In three of the mines, sampling took place on the same continuous miner configured with either a wet head spray system or a regular system of boom sprays. When running the wet head, for example, most of the boom sprays were plugged and a valve thrown to send water to the wet head sprays. Two studies took place on a super section that utilized two machines, one with standard boom sprays and one with a wet head. Dust samples were taken concurrently; as each miner unit was ventilated with its own air split. Of the five mines, three used blowing ventilation schemes and two were exhausting. All but one mine took extended cuts and all but one used a scrubber. The mine that did not take extended cuts used exhausting ventilation with a system of directional sprays called a sprayfan. No scrubber was used at this operation.

When possible, the ventilation and dust control plans were reviewed. Air velocity readings were taken before each cut and production was recorded at the end of the shift. Spray pressure, spray type, and number of sprays were noted on both standard and wet head spray systems.

Test Design

The sampling strategy for these studies consists of both area and personal sampling to evaluate the different spray system's affect on respirable dust levels at the miner operator location and in the immediate return of each cut (Figure 2). These samples were not collected for full shift and therefore the results cannot be correlated to compliance sampling.

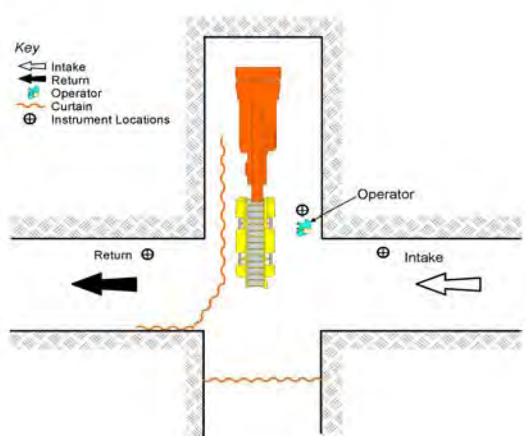

Figure 2. Sampling package locations for a typical cut on an exhausting ventilation scheme.

For area sampling, dust sampling packages were hung in the immediate intake and return of the individual continuous miner cuts. Dust generated in the cut and in the return can be directly related to the mining of that particular cut by subtracting the intake dust measurement from that at the operator and return. The sampling packages were repositioned at the start of each new cut (place change).

For personal sampling of dust exposure at the operator location, the CM operator wore a Personal Dust Monitor (PDM). The PDM provides data that allows for time periods to be extracted during the shift to calculate dust concentrations for individual cuts during the shift. The PDM data is downloaded at the end of the shift then reset for the next sampling day.

Area sampling packages for the sections consisted of two gravimetric samplers and a Personal Data RAM (pDR) (Thermo-Fisher) hung in the immediate intake and return entries. Gravimetric samplers use a cyclone, filter, and vacuum pump to collect dust particles. The permissible sampling pumps were calibrated at 2 liters/minute before the study. These pumps draw dust-laden air through 10-mm nylon cyclones to deposit the respirable dust fraction onto pre-weighed 37-mm PVC filters. All filters were pre- and post-weighed at the Pittsburgh Research Laboratory and respirable dust concentrations calculated for the total shift dust concentration. The filters were then sent to a third party to determine silica content of the dust. The MSHA P-7 method was used to measure the silica content in the samples.

The pDRs measure respirable dust particles by light scattering techniques and provide a relative dust concentration. The pDRs sample every 10 seconds and give a real-time reading of the relative dust concentrations over the entire shift. The pDR's are used in conjunction with the gravimetric samplers to monitor dust levels instantaneously. The instantaneous readings can account for variations in dust levels during mining that the gravimetric samplers cannot provide. NIOSH researchers conducted time-studies during the mining operations in order to relate gravimetric and pDR data to the operations at that particular time. The calculated concentrations from the gravimetric samplers are compared to the associated total shift pDR concentration. The pDR total shift dust concentration is a relative measurement (based on a calibration dust) and will vary from the true measured dust concentration given by the gravimetric samplers. To correct for this difference, the total pDR dust concentration measurements are adjusted based on the total gravimetric concentration. The adjustment factor is determined by dividing the concentrations from the gravimetric samplers by the pDR total average concentration. After the adjustments are made, the adjustment factors can then be applied to the instantaneous readings from the pDRs to determine the true concentrations during individual time periods (e.g. time in cut). Figures 3a and 3b show the samplers used for the dust surveys.

Figure 3a. Gravimetric/pDR samplers


Figure 3b. Personal Dust Monitor

Dust Survey Data

Dust measurements from each of the mines were analyzed at the machine operator and in the immediate return to determine dust levels of each spray system at each location. Ultimately, the miner operator location is the where the protection is most important. However, dust levels at this location can be affected by many variables therefore, measurements in the return were necessary to determine whether one system was more effective than the other. All of the intake air and dust generated during mining must go into the return and therefore the return measurements were used to compare the two spray systems over all the mines surveyed. The other variable that directly affects dust generation is production. For all of the surveys, the dust levels were normalized for production.

Table 1 shows the specific parameters for each machine at operation A through E. Although mining heights were fairly consistent between operations, rock thicknesses varied from negligible to nearly 1 m. NIOSH researchers noted little variation in scrubber capacities between studies.

Table 1. Operating parameters for study mines.

Mine designation		A	B	C	D	E
Average mining ht. (m)		1.8	2.0	2.1	1.7	1.8
Average rock thickness cut (m)		0.4	<1.0[1]	0	0.2	0.3
Scrubber capacity (m^3/s)		3.1	3.4	3.2	3.2	[2]See note
Wet head operation	No. of wet head sprays	63	73	73	73	76
	Ave. wet head pressure (kPa)	621	550	620	660	620
	Ave. tonnage (t)	610	620	1590	1347	930
Standard spray operation	No. of boom sprays	25	27	36	36	15
	Ave. boom spray pressure (kPa)	1030	1160	620	690	760
	Ave. tonnage (t)	680	500	1400	1239	930

Notes:
[1]Rock thickness ranged from .1 to nearly1 m during sampling
[2]Continuous miner at Mine E did not use scrubber; but used 15 directional sprayfan sprays on cutting boom.

Thirty two shifts were sampled over the course of the study accounting for a total of 156 production cuts. The individual cuts were compared within each mine to determine consistency of collected data. The many confounding variables within a single mine setting are difficult to limit and therefore comparing individual cuts from mine to mine was not deemed significant and will not be presented. Dust concentrations measured during standard boom spray system operation were compared to those obtained during wet head spray operation at the miner operator and return airway sampling locations.

Table 2 shows the combined shifts for all mines surveyed. The table is segregated by mine designation and shows the shifts surveyed at each according to the type of spray system and the operator and return locations. The table shows the range of dust levels measured at each location for each spray system. Within-mine concentrations are consistent for both spray systems at each location. However, Mine E shows much higher return concentrations due to the lack of a scrubber on the continuous miner. Mines A through D utilized scrubbers. As seen in the table, on most of the shifts, there are reduced concentrations on both operator and return locations using the wet head. However, most improvements are small and some shifts show the wet head concentrations higher. Mine C shows poor performance at the operator location when using the wet head system. This super section operation used a standard spray miner on one side and a wet head miner on the other. Blowing ventilation was used on both sides of the section. However, the miner operator on the wet head machine maintained a large curtain setback distance claiming that dust conditions were improved by this action. This practice kept him out of the mouth of the curtain and, as can be seen by the dust concentrations, exposed to higher levels of dust than the operator on the standard spray section.

Table 2. Gravimetric and PDM dust concentrations from all mines participating in the study.

		Operator		Return	
	Shifts	Standard	Wet head	Standard	Wet head
Mine A Scrubber, blowing vent., super section	1	0.79	0.31	2.89	1.69
	2	n/s	n/s	4.66	1.14
	3	0.79	0.39	3.96	2.22
	4	0.65	0.89	2.88	2.37
Mine B Scrubber, exhausting vent., same continuous miner	1	3.17	2.03	2.47	6.86
	2	2.68	1.76	4.84	1.57
	3	2.21	1.47	2.40	1.89
	4	3.12	2.31	3.96	3.66
	5	2.72	5.92	2.90	4.28
Mine C Scrubber, blowing vent., super section	1	0.33	1.31	1.00	1.02
	2	0.74	2.42	1.80	1.37
	3	0.39	1.83	1.04	1.20
Mine D Scrubber, blowing vent., continuous miner	1	1.24	0.45	1.92	1.32
	2	1.40	0.91	1.06	0.95
Mine E No scrubber, exhausting vent, same continuous miner	1	0.95	0.83	12.62	7.22
	2	1.55	1.51	11.74	10.53

Note: n/s = not sampled

To further illustrate the results, dust concentrations were averaged from each shift for each of the mines surveyed. Figure 4 shows the dust levels of each spray system in the return. The chart shows that of the five mines sampled, Mines A and E show reductions of 33% and 27%, respectively in the return when the wet head sprays are used but little or no improvement at the other mines.

Figure 5 shows the dust levels at the operator

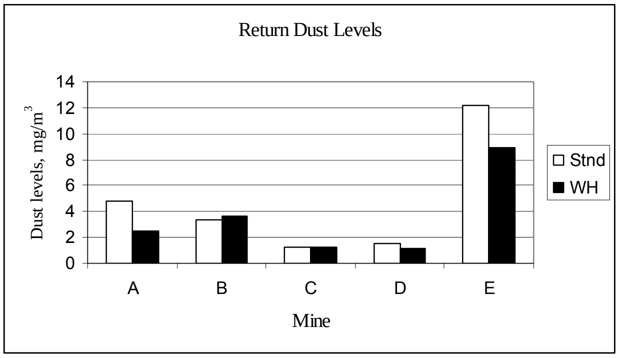

Figure 4. Dust measurements in the return for all mines surveyed.

location. It is obvious that Mine C shows elevated dust levels at the operator but as noted, this was due to the curtain setback during sampling. Mine D showed an improvement of 48% at the operator when the wet head was used.

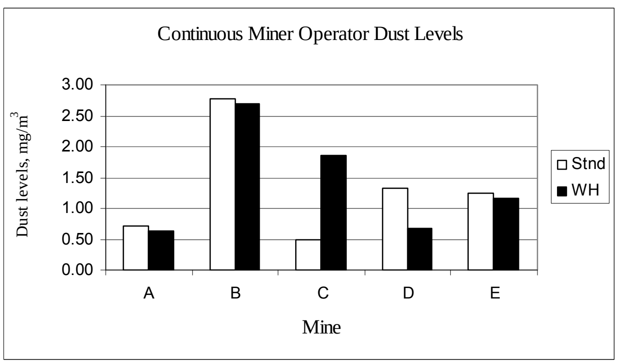

Figure 5. Dust measurements at the CM operator for all mines surveyed.

Respirable silica levels, in the form of quartz dust, varied between the wet head and standard spray machines at Mine A (Table 3). On the wet head, measurable levels were not detected on the operator sample and only low quartz levels were present on the return samples. With the standard spray system, quarts levels were higher at the operator and return sampling locations. At Mine B, much higher quartz levels were present in the operator and return samples. This was likely due to the significant amount of rock being cut during operation of the wet head and standard sprays. Again, higher respirable quartz levels were measured on the standard spray machine. This trend continued to be seen, to a lesser degree, in Mines C and D. At Mine E, the higher quartz measurement occurred on the wet head sprays.

Table 3. Average respirable quartz levels, $\mu g/m^3$

Mine ID	Wet head sprays operating		Standard sprays operating	
	Operator	Return	Operator	Return
A	ND	27	70	143
B	311	359	356	413
C	n/s	0	n/s	29
D	35	21	34	29
E	n/s	742	n/s	694

Notes:
ND = not detected
n/s = not sampled

Summary

There are mixed results from the study as to the effectiveness of the wet head spray system to reduce respirable dust. The dust data reveals that some mines show improvements, some do not. Respirable silica levels were less on the wet head miners in all but Mine E.

Over the course of surveying the mine, some observations were made that may have affected the results. At the onset of the study, super sections were preferred because both spray systems could be monitored during the same shift in the same section with the assumption that variables such as production and air quantities would be similar between each CM unit on the section. These assumptions were correct for these operations. However, it became apparent that other factors influenced dust measurements between the two sections. For example, the CM's scrubber flow and efficiency were not the same, the mine conditions from one side to the other were different, and the CM operators mining habits were different, as was evident by the curtain setbacks at Mine C. The data can be normalized for some but not all variables. In addition, the scrubbers are very efficient dust eliminators and could influence the dust concentration in the return. Four of the five mines (A, B, C, and, D) used scrubbers. In addition, three of these mines used blowing ventilation. On a properly maintained blowing ventilation system, an argument can be made that the operator should be in fresh air all the time and therefore would not be subjected to dust exposure no matter what control technology is being used for dust control.

Mine E did not use a scrubber, was not a super section, and used exhausting ventilation. The same CM unit was used for each spray system. Other than Mine A, this was the only mine the showed reduction of respirable dust in the return entry. However, silica levels were higher.

From visual observations and interviews with mine personnel, there were very favorable responses to the wet head use at the face. All operators found that the wet head system greatly increased visibility while mining. Also, the dust cloud created at the miner's boom while loading shuttle cars was eliminated when the wet head system was used. This cloud often infiltrated the cab area of the shuttle car operators during loading. The increased visibility may be attributed to the close proximity of the sprays to the face, thus decreasing misting or the wet head sprays may be eliminating some of the non-respirable dust fraction.

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