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CONTROL OF DIESEL PARTICULATE EMISSIONS IN UNDERGROUND COAL MINES

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ABSTRACT

The Mine Safety and Health Administration has conducted tests to determine the effectiveness of two methods for reducing diesel particulate emissions in underground coal mines. Both methods involved collection of the particulate material before being released into the environment. One method utilized a disposable pleated paper filter attached to the tail pipe; the other utilized a reusable wire mesh screen attached to the tail pipe.

This paper describes the instrumentation and testing used to evaluate both control methods. Results of respirable dust and diesel particulate measurements made underground are presented and analyzed.

INTRODUCTION

Because of concerns related to adverse health effects resulting from long term exposure to diesel particulates, various methods have been developed to reduce the particulate emissions from diesel equipment used in underground mines. Therefore, the Mine Safety and Health Administration's Pittsburgh Safety and Health Technology Center conducted respirable dust and diesel particulate studies at two underground coal mines employing different methods to reduce diesel particulate emissions.

The first study was made at a large eastern coal mine which employed a wire mesh screen after-treatment device. The second study was made at a large western coal mine which employed a disposable pleated paper after-treatment device. The purpose of these studies was to: 1) determine environmental respirable dust and diesel particulate levels throughout the section of the mine involved in the study; 2) determine diesel particulate emission rates; and 3) determine the effectiveness of each after-treatment device.

Both methods were evaluated by measuring particulate concentrations in the mine atmosphere with and without the after-treatment devices in place. On each of the sections studied, two diesel haulage vehicles were operated. Each vehicle had a nominal 75 kW (100 bhp) rating and was equipped with a water scrubber. Both mines utilized diesel equipment in outby areas of the mine; however, after-treatment devices were not installed on any of the outby diesel equipment.

DESCRIPTION OF OPERATIONS

The study at the large eastern mine was conducted on a seven entry development section. During the study, the section had an average production rate of approximately 1,550 tons per shift. Two Jeffrey Model 4110 Diesel Ramcars with Murphy engines were used for face haulage. The nameplate air quantity for each Diesel Ramcar was 4.1 m^3/s (8,700 cfm). There were also two battery haulage vehicles available on-section. Maintenance was performed as needed.

On the first two sampling shifts, the Diesel Ramcars were operated with a reusable wire mesh screen after-treatment device installed in the tail pipe. This device was custom made by the mining company. The wire mesh screens are reusable and were cleaned after each shift. On the last two sampling shifts, the Diesel Ramcars were operated without the wire mesh screen after-treatment devices.

The study at the large western mine was conducted on a three entry longwall development section. This section has an average production rate of 800 tons per shift. Jeffrey 4114 Diesel Ramcars were used for face haulage. This section utilizes two or three Ramcars with each Ramcar operating three shifts per day. Maintenance was performed as needed. The Ramcars were equipped with Caterpillar Model 3306 engines. The nameplate air quantity for each Ramcar was 8.0 m^3/s (17,000 cfm).

On the first three days of the study, the Ramcars were fitted with a paper exhaust filter. The filter was a standard intake air filter normally used on large surface mining equipment. The filter was placed in a canister and retrofitted to the exhaust pipe of the Ramcars. The diesel engines could withstand up to 6.2 kPa (25 inches of water) back pressure, induced by loading of the filter with diesel particulates. Due to this limitation, filters would last for one shift before they were changed. On the last day of the study, the Ramcars were operated without the filters.

SAMPLING PROCEDURES

Three types of sampling devices were employed in the survey. They included: the standard Mine Safety Appliances (MSA) respirable dust sampler, the Sierra-Anderson Model 298 impactor and the MSHA diesel particulate impactor.

The Sierra Model 298 impactor contains eight impaction plates (substrates) and a final filter. The eight impaction plates have effective cut diameters of 0.5, 0.9, 2.0, 2.5, 6.0, 10.0, 15.0 and 21.0 micrometers. These plates allow dust, separated by inertial impaction, to collect on a 34 mm stainless steel impaction plate. Particulate less than 0.5 micrometers in

size is deposited on a 34 mm polyvinylchloride final filter.

The MSHA diesel particulate impactors, mounted in the standard MSA respirable dust breastplate with a 10 mm nylon cyclone preseparator, are an expanded version of the MSA respirable dust cassette. A 9.5-mm (3/8-inch) spacer was inserted between the MSA plastic cassette pieces to support the impaction plate. The MSA cassette's inlet is fitted with a machined brass insert which has a 1.0 mm diameter nozzle (No. 61 drill). Dust passes through this opening and is separated according to its aerodynamic size. Dust particles greater than 1.0 micrometer impact on a greased stainless steel impaction plate located 3.0 mm from the outlet of the nozzle. Dust particles less than 1.0 micrometer bypass the impaction plate and are collected on a 37 mm FWS-B polyvinylchloride filter.

Packages containing two sampling instruments (MSA respirable and MSHA impactor) were placed at the following locations: the intake and the two Diesel Ramcars. In addition, the sampling package containing two total dust samplers, two Sierra 298 impactors, and five MSHA impactors was located in the section return. All of these packages were operated on-section. All of the various impaction sampling devices were operated by an MSA Model G or MSA Flow-Lite sampling pump. A constant flow rate of 2.0 Lpm was maintained through all of the sampling devices.

RESULTS AND DISCUSSION

Table 1 shows the average airflow, respirable dust and diesel particulate levels measured at the intake and return sampling locations for the mine employing the wire mesh filters. The diesel particulate is included as a part of the respirable dust concentration. On the first two sampling shifts, wire mesh filters were installed in the tail pipes of the Diesel Ramcars. The Diesel Ramcars were operated without the wire mesh filters on the last two sampling shifts. With wire mesh filters installed, the average respirable dust levels at the intake and return locations were 0.18 mg/m^3 and 2.97 mg/m^3, respectively. Without wire mesh filters installed, the average respirable dust levels at these locations were 0.16 mg/m^3 and 5.09 mg/m^3, respectively. With wire mesh filters installed, the average diesel particulate levels at these locations were 0.01 mg/m^3 and 1.12 mg/m^3, respectively. Without wire mesh filters installed, the average diesel particulate levels at these locations were 0.08 mg/m^3 and 1.77 mg/m^3, respectively.

Daily results of the personal diesel particulate samples collected on the Ramcar operators are summarized in Table 2. For the two shifts with the wire mesh filters installed, the Ramcar operators' average diesel particulate exposures was 1.20 mg/m^3. For the two shifts without the wire mesh filters installed, the Ramcar operators' average diesel particulate exposures was 2.06 mg/m^3. (Due to the high particulate levels, use of only one diesel haulage vehicle was permitted during normal mining operations.)

The measurements made in the section return were also used to determine the diesel particulate generation rate. The face area diesel particulate generation

rate was estimated by multiplying the return airflow by the difference between the return and intake diesel particulate concentrations.

$$G = (R-I)*Q/35,315$$

where:
G = Diesel particulate generation rate, gm/min,
R = Return diesel particulate concentration, mg/m^3,
I = Intake diesel particulate concentration, mg/m^3, and
Q = Return airflow, cfm.

The daily results of these calculations are also shown in Table 2. The diesel particulate generation rates ranged from 0.53 to 1.59 gm/min. However, the diesel particulate generation rates with the wire mesh filters installed were approximately 53 percent less than the diesel particulate generation rates without the use of the wire mesh filters.

The results from the study conducted on the section employing a wire mesh after-treatment device are as follows:

1. Average intake respirable dust and diesel particulate levels were 0.09 and 0.04 mg/m^3, respectively.

2. The average diesel particulate levels for the Ramcar operators was 1.20 mg/m^3, with wire mesh filters and and 2.06 mg/m^3, without wire mesh filters.

3. The diesel particulate generation rate ranged from 0.53 to 0.87 gm/min with the wire mesh filters installed and from 1.40 to 1.59 gm/min without the wire mesh filters installed.

4. Diesel particulate generation rates were reduced approximately 53 percent with the wire mesh filters installed in the exhaust pipes of the Diesel Ramcars.

5. Ramcar operators' exposures to diesel particulate was reduced approximately 41 percent with the wire mesh filters installed.

Table 3 shows the average intake and return respirable dust and diesel particulate levels for the mine employing pleated paper filters. The Diesel Ramcars were operated without the pleated paper filters on the last sampling shift. With paper filters installed, the average respirable dust levels at the intake and return locations were 0.16 mg/m^3 and 0.80 mg/m^3, respectively. Without paper filters installed, the average respirable dust levels at these locations were 0.16 mg/m^3 and 1.45 mg/m^3, respectively. With paper filters installed, the average diesel particulate levels at these locations were 0.09 mg/m^3 and 0.13 mg/m^3, respectively. Without paper filters installed, the average diesel particulate levels at these locations were 0.06 mg/m^3 and 0.67 mg/m^3, respectively.

Daily results of the personal diesel particulate samples collected on the Ramcar operators are summarized in Table 4. For the three shifts that the paper filters were used, the Ramcar operators' average diesel particulate exposures was 0.24 mg/m^3. For the one shift when the filters were not used, the Ramcar operators' average diesel particulate exposures was 0.89 mg/m^3. This corresponded

to a reduction in diesel particulate of approximately 76 percent, for the Ramcar operators. In order to reduce the diesel particulate exposure levels further, the intake levels of diesel particulate would have to be reduced.

The diesel particulate generation rate for this section was determined as previously shown. The daily results of these calculations are also shown in Table 4. The diesel particulate generation rates ranged from 0.02 to 0.14 gm/min on the three normal shifts when the paper filters were in use. The diesel particulate emission rate when the paper filters were not used was 1.91 gm/min. This indicates that the use of the pleated paper filters reduced the on-section diesel emission rate by approximately 95 percent.

The results from the study conducted on the section employing a disposable pleated paper after-treatment device are as follows:

1. Average respirable dust and diesel particulate levels in the intake were 0.16 and 0.08 mg/m^3, respectively.

2. The average diesel particulate levels for the Ramcar operators was 0.24 mg/m^3, with the paper filters installed and 0.89 mg/m^3, without the paper filters.

3. Diesel particulate generation rate ranged from 0.02 to 0.14 gm/min with the paper filters installed and was 1.91 gm/min without the paper filters.

4. The use of diesel particulate filters reduced exposure to diesel particulates by 69 to 76 percent.

5. Diesel particulate generation rates were reduced approximately 95 percent with the pleated paper filters installed in the exhaust pipes of the Diesel Ramcars.

SUMMARY

Each of the methods tested was effective in reducing both diesel particulate generation and employee exposure to diesel particulate. Reductions in generation and exposure for the disposable pleated paper filter were 97 and 80 percent, respectively. Reductions in generation and exposure for the wire mesh screen were 37 and 45 percent, respectively.

Due to intake diesel contamination and on-section work practices, the reduction in face area diesel particulate generation was not directly correlated to reduction in employee exposure to diesel particulates.

The effect of ventilation to control diesel particulates was also demonstrated in these studies. The return concentrations without the after-treatment devices in place was 1.77 mg/m^3 when the particulate generation rate was 1.50 gm/min and the return airflow was 9.1 m^3/s (19,000 cfm). With a return airflow of 38.8 m^3/s (81,000 cfm) and a diesel particulate generation rate of 1.91 gm/min, the return diesel particulate concentration was 0.67 mg/m^3. An airflow of 16.7 m^3/s (35,315 cfm) will dilute a diesel particulate generation rate of 1.0 gm/min to 1.0 mg/m^3.

TABLE 1. - AIRFLOW, RESPIRABLE DUST, AND DIESEL PARTICULATE MEASUREMENTS FROM AN EASTERN COAL MINE USING WIRE MESH FILTERS

	LOCATION	
	INTAKE	RETURN
SHIFT No. 1		
AIRFLOW (cfm)	14,250	15,450
RESP. DUST (mg/m^3, MRE)	0.02	3.51
DIESEL PART. (mg/m^3)	0.00	1.32
SHIFT No. 2		
AIRFLOW (cfm)	13,300	17,280
RESP. DUST (mg/m^3, MRE)	0.33	2.42
DIESEL PART. (mg/m^3)	0.02	0.91
AVERAGE (WITH FILTERS)		
AIRFLOW (cfm)	13,775	16,365
RESP. DUST (mg/m^3, MRE)	0.18	2.97
DIESEL PART. (mg/m^3)	0.01	1.12
SHIFT No. 3		
AIRFLOW (cfm)	18,100	16,500
RESP. DUST (mg/m^3, MRE)	0.16	5.94
DIESEL PART. (mg/m^3)	0.11	1.38
Shift No. 4		
AIRFLOW (cfm)	19,900	22,230
RESP. DUST (mg/m^3, MRE)	0.16	4.24
DIESEL PART. (mg/m^3)	0.04	2.15
AVERAGE (W/O FILTERS)		
AIRFLOW (cfm)	19,000	19,365
RESP. DUST (mg/m^3, MRE)	0.16	5.09
DIESEL PART. (mg/m^3)	0.08	1.77

TABLE 2. - RAMCAR OPERATORS' DIESEL PARTICULATE EXPOSURES AND SECTION DIESEL PARTICULATE GENERATION RATES FROM AN EASTERN MINE USING WIRE MESH FILTERS

	DIESEL PARTICULATE	DIESEL GENERATION RATE
	mg/m^3	gm/min
SHIFT No. 1		
Ramcar 1	1.50	0.87
Ramcar 2	1.43	
SHIFT No. 2		
Ramcar 1	1.04	0.53
Ramcar 2	0.81	
AVERAGE (WITH FILTERS)	1.20	0.70
SHIFT No. 3		
Ramcar 1	1.70	1.40
Ramcar 2	1.94	
SHIFT No. 4		
Ramcar 1	2.26	1.59
Ramcar 2	2.32	
AVERAGE (W/O FILTERS)	2.06	1.50

TABLE 3. - AIRFLOW, RESPIRABLE DUST, AND DIESEL PARTICULATE MEASUREMENTS FROM A WESTERN MINE USING PLEATED PAPER FILTERS

	LOCATION	
	INTAKE	RETURN
SHIFT No. 1		
AIRFLOW (cfm)	48,000	56,000
RESP. DUST (mg/m^3)	0.14	0.82
DIESEL PART. (mg/m^3)	0.07	0.11
SHIFT No. 2		
AIRFLOW (cfm)	53,000	59,000
RESP. DUST (mg/m^3)	0.20	0.68
DIESEL PART. (mg/m^3)	0.08	0.10
SHIFT No. 3		
AIRFLOW (cfm)	60,000	74,000
RESP. DUST (mg/m^3)	0.15	0.91
DIESEL PART. (mg/m^3)	0.09	0.17
AVERAGE (WITH FILTERS)		
AIRFLOW (cfm)	53,700	63,000
RESP. DUST (mg/m^3)	0.16	0.80
DIESEL PART. (mg/m^3)	0.09	0.13
SHIFT No. 4 (W/O FILTERS)		
AIRFLOW (cfm)	66,000	81,000
RESP. DUST (mg/m^3)	0.16	1.45
DIESEL PART. (mg/m^3)	0.06	0.67

TABLE 4. - RAMCAR OPERATORS' DIESEL PARTICULATE EXPOSURES AND SECTION DIESEL PARTICULATE GENERATION RATES FROM A WESTERN MINE USING PLEATED PAPER FILTERS

	DIESEL PARTICULATE mg/m^3	DIESEL GENERATION RATE gm/min
SHIFT No. 1		
Ramcar 1	0.28	0.13
Ramcar 2	0.33	
SHIFT No. 2		
Ramcar 1	0.18	0.02
Ramcar 2	0.21	
SHIFT No. 3		
Ramcar 1	0.14	0.14
Ramcar 2	0.27	
AVERAGE (WITH FILTERS)	0.24	0.09
SHIFT No. 4		
Ramcar 1	0.91	1.91
Ramcar 2	0.87	
AVERAGE (W/O FILTERS)	0.89	1.91