INFLUENCE OF AIRFLOW AND PRODUCTION ON LONGWALL DUST CONTROL

Robert A. Haney, Robert S. Ondrey, and Kenneth G. Fields

Mine Safety and Health Administration
Pittsburgh, PA

ABSTRACT

As part of an MSHA program to assess the effectiveness of dust control parameters for longwall mining operations, respirable dust studies were conducted on six longwall sections. The purpose of these studies was to evaluate the influence of airflow and production on longwall dust control. The sections were sampled for 3 to 35 shifts. In addition to dust, ventilation and production measurements, other dust control and operational parameters were measured. The water spray system at each operation conformed with generally recommended practices. Therefore, improvements to the dust control system would be most appropriately achieved through improvements to ventilation along the face. Two methods of assessing the influence of ventilation and production were used.

For two of the six mines where extensive sampling (22 and 35 shifts) was conducted, multiple linear regressions were used to relate the dust concentration versus airflow and production data. For these two mines, statistically significant correlations existed between concentration and both production and airflow. The multiple regressions fit to the data indicated that for every 0.47 m^3/s (1,000 cfm) increase in airflow, there would be approximately 0.04 to 0.07 mg/m^3 reduction in dust concentration; and, for every 1,000 ton increase in production, there would be approximately 0.15 to 0.50 mg/m^3 increase in dust concentration.

For the four mines with limited data (3 to 10 shifts), as well as for the two mines with extensive sampling, an average ratio of airflow per ton of coal mined was calculated by proportioning the airflow to production and the designated occupation personal respirable dust exposure to a 2.0 mg/m^3 concentration. The airflow-to-tons ratio required to maintain a 2.0 mg/m^3 dust concentration ranged from 0.0038 0.0071 m^3/s per ton (8 to 15 cfm/ton). Both of these data treatments were used to calculate airflow requirements based on normal production rates. For the two mines where both the regression and airflow-to-tons ratio were calculated, results from the two methods agreed within 25 percent.

INTRODUCTION

During the last 10 years the number of longwall sections has remained relatively constant. Typically, 80 to 100 longwall sections operate in any given year. While the number of longwalls has been relatively constant, the production from longwalls has steadily increased. In 1980 a typical longwall produced from 1,000 to 1,500 tons per shift. MSHA inspector data for 1991 showed that average longwall production was 2,900 tons ± 1,400 tons per shift. Longwall capacity generally exceeds 5,000 tons per shift, with some longwall sections reporting production in excess of 10,000 tons per shift.

Much of the increased capacity has been attributed to wider faces, increased panel lengths, higher capacity shearers and higher capacity face haulage systems. Face widths up to 300 meters (1,000 ft) with panel lengths of 4600 meters (15,000 ft) have been mined. Face conveyor systems can move 1,500 tons per hour.

During the 1980's the U. S. Bureau of Mines conducted extensive research to develop and evaluate various longwall dust control techniques. Many of these techniques have been successfully implemented by the industry and have contributed to longwall sections meeting the 2.0 mg/m^3 standard even as production increased. MSHA data shows that the average designated occupation respirable dust concentration on longwall sections during 1991 was 1.9 mg/m^3.

Additional improvements in controlling dust on higher production longwall sections should come from industry initiatives or application of proven dust control technology. One of the most basic technologies for controlling any airborne contaminant is dilution by airflow. The purpose of this study is to evaluate the influence of airflow and production on longwall dust control.

DESCRIPTION OF OPERATIONS

Respirable dust studies were conducted on six longwall mining operations. Although specific details vary, all six longwall sections had similarities. All of the sections utilized a double drum ranging arm shearer operated by radio remote control. All shearers employed wet cutting drums and an external spray system which approximated the shearer clearer system developed by the U.S. Bureau of Mines. The longwall faces were all ventilated from headgate to tailgate.

Typical dust control measures in the headgate included having the crusher completely enclosed with metal plates and attaching conveyor belting to the inby end of the crusher to prevent the escape of dust from within the crusher. Water sprays were located inside the crusher, however, no provisions were made to directly observe whether or not these sprays were functioning. Additional water sprays were located at the stage loader-to-section belt transfer point.

SAMPLING PROCEDURE

For each operation studied, gravimetric respirable dust samples were collected on the two or three production shifts each day. These samples were collected to determine personal exposures and dust generating sources. During these studies, full-shift respirable dust measurements were obtained and details of the mining operation and procedures in place to control dust were documented. The number of shifts sampled ranged from 3 to 35.

All respirable dust samples were collected using approved MSA personal respirable coal mine dust samplers calibrated and operated at a flow rate of 2.0 liters per minute. All filter cassettes were pre- and post-weighed on an analytical balance to a hundredth of a milligram. The dust concentration was determined by dividing the mass of dust collected by the volume of air sampled. All personal and fixed-point respirable dust concentrations were converted to MRE equivalent concentrations by multiplying by the constant factor 1.38.

Personal samples were collected on face occupations including both shearer operators, headgate men, and the shield setters. Fixed-point samples were collected in the intake and belt entries; and at the headgate and tailgate along the longwall face. The personal samples were collected from portal-to-portal. Fixed-point samples collected at the intake, belt, headgate and tailgate, were operated only on section. The fixed-point samples were used to identify dust sources. In addition to respirable dust measurements, ventilation data, production data and operational parameter information were also collected.

RESULTS AND DISCUSSION

Results of Dust Samples and Dust Control Parameters

Table 1 shows a compilation of selected data extracted from the information gathered during the mine visits. The data extracted and compiled in Table 1 for each mine include: number of shifts sampled, average occupation exposures, average concentration of dust at the intake, belt, headgate and tailgate, average air quantities and velocities, average external and drum spray water pressures and average production.

In all cases the designated occupation was the tail drum operator who, typically had the highest average exposure. However, at some time, each of the occupations sampled, had the highest respirable dust exposure for a shift. The variation in location of the occupation sample with the highest exposure was attributed to work practices. The work practice that had the greatest impact on dust exposure was the amount of time that a worker spent downwind of the shearer. The occupation with the greatest number of maximum exposures was the shield setter.

The average fixed-point sampling results are also shown in Table 1. Average results of the fixed point samples collected at the headgate (shield 10), ranged from 0.6 to 1.7 mg/m^3. Average increases in dust concentration along the longwall face ranged from 1.8 to 11.3 mg/m^3. These values measured along the face indicate that position of workers, relative to dust being generated, was critical to controlling worker exposure.

The water spray system at each operation generally conformed with normally recommended practice. Recommended practices for longwall dust suppression water spray systems include: one drum spray per bit, with a 480 - 690 kPa (70 - 100 psi) water pressure; an external spray system with a minimum of 860 kPa (125 psi) spray pressure; and an enclosed crusher/stageloader with 9 sprays operating at 480 kPa (70 psi) water pressure.

Most of the dust control technologies developed by the Bureau of Mines had been incorporated into the companies' respirable dust control plan. Dust control technology that had not been generally implemented includes reverse drum rotation and reduced drum rotational cutting speed. As a result, improvements to the dust control system would be most appropriately achieved through improvements to ventilation along the face.

Influence of Face Airflow and Production on Dust Levels

To examine the influence of face airflow and production on face worker exposure, a multiple regression analysis was preformed on the data from the two mines where extensive sampling was conducted.

Figure 1 shows the designated occupation (DO) respirable dust concentration for each shift at mine B, plotted against the average headgate face airflow for that shift. This data indicates that as the airflow increases, the designated occupation dust concentration decreases. The variability in designated occupation dust concentration for a given airflow was attributed to variations in work practices, production and water spray pressures.

Figure 2 shows the designated occupation respirable dust concentration for each shift, plotted against the tonnage mined on that shift from Mine B. This data indicates that as production increases, designated occupation dust exposures also increase.

For Mines A and B, a multiple linear regression was fit to the designated occupation concentration versus airflow, and production data. For Mine A the resulting equation was:

$$C = -0.039 \times (Q/1000) + 0.15 \times (T/1000) + 2.35 \quad \text{(Equation 1)}$$

and for Mine B the resulting equation was:

$$C = -0.074 \times (Q/1000) + 0.52 \times (T/1000) + 3.22 \quad \text{(Equation 2)}$$

Where:
C = Designated Occupation Dust Concentration, mg/m^3,
Q = Face Headgate Airflow, cfm, and
T = Production, tons.

These equations indicate that for every 0.47 m^3/s (1,000 cfm) increase in airflow, there would be approximately 0.04 to 0.07 mg/m^3 reduction in dust concentration; and for every 1000 ton increase in production, there would be approximately 0.15 to 0.5 mg/m^3 increase in dust concentration.

These relationships have a Standard Error for the concentration estimate of 0.36 and 0.72, with correlation coefficients of 0.67 and 0.60, respectively. Statistics indicate that individual correlations exist between concentration production and airflow.

A two dimensional plot of equation 2 is shown in Figure 3. Figure 3 shows a plot of concentration versus airflow for various production levels. For each production rate an increase in airflow results in a decrease in dust concentration. Additionally, an increase in production requires an increase in airflow to maintain the specific dust level.

Solving equations 1 and 2 for the air quantity (Q) at a 2.0 mg/m^3 gives:

$$Q = (3.8 \times T) + 9{,}000 \quad \text{for Mine A} \quad \text{(Equation 3)}$$

and

$$Q = (7.0 \times T) + 16{,}500 \quad \text{for Mine B} \quad \text{(Equation 4)}$$

Statistically significant multiple regressions could not be determined for the concentration versus airflow and production data from Mines C, D, E, and F. This was due to the limited amount of data collected at each mine, and the narrow range of operational parameters under which this data was collected.

For each of these four mines, as well as Mines A and B an average ratio of airflow per ton of coal mined was calculated by proportioning the designated occupation's personal respirable dust exposure, face airflow and shift production to 2.0 mg/m^3 by the formula:

$$R = \frac{C \times Q}{2 \times T} \quad \text{(Equation 5)}$$

Where:

R = Airflow to Tons Ratio, m^3/s per ton (cfm/ton),
C = Designated Occupation Dust Concentration, mg/m^3,
Q = Face Airflow, m^3/s (cfm), and,
T = Production, tons.

The average ratio for each mine was calculated using only those shifts which produced at least 60 percent of normal production. Results of this calculation for each mine are given in Table 2. The average airflow-to-tons ratio for the six mines, based on airflow at the headgate ranged from 0.0016 to 0.010 m^3/s per ton (3.3 to 22.1 cfm/ton). The average airflow-to-tons ratio for the six mines, based on airflow at the tailgate ranged from 0.0015 to 0.0073 m^3/s per ton (3.1 to 15.4 cfm/ton). Typical variation in the individual mine airflow-to-tons ratio as indicated by the coefficient of variation was approximately 25 percent.

Table 2 gives the required airflow to maintain a 2.0 mg/m^3 designated occupation concentration, based on average section production and the multiple regression for Mines A and B. Figure 4 shows a comparison of the calculated airflow requirements at the headgate for Mine B, using the regression (Equation 4) and the calculated average airflow-to-ton ratios. The production levels ranged from 2,000 to 5,000 tons per shift. For productions within 25 percent of those observed during the study, either method gives similar results. For productions 25 percent above those observed during the study, the airflow estimate from the regression is less than the airflow estimate from the air-to-tons ratio.

MSHA Spot Inspection Program Data

Between September 1, 1991 and November 1, 1991, MSHA conducted a Spot Inspection Program (SIP) to determine dust levels and dust control parameters in place for various mining operations. During the SIP, 80 longwall sections were sampled. For productions greater than 1,000 tons, the average airflow-to-tons ratio to maintain dust concentrations at 2.0 mg/m^3 was 0.0056 m^3/s per ton (11.8 cfm/ton) with a standard deviation of 0.0031 m^3/s per ton (6.6 cfm/ton).

Figure 5 shows a plot of the airflow-to-tons ratios to achieve 2.0 mg/m^3 for each operation versus production. The figure shows a decreasing airflow-to-tons ratio with increasing production. However, because the airflow-to-tons ratio for a section does not vary with airflow or production, this change in airflow-to-tons requirement should not be attributed to increased production, but rather to a either a less dusty coalbed or an increased level of other dust controls. Other dust control parameters could include better water management systems or the use of automated controls on the mining operation.

The airflow-to-tons ratio gives a basis for calculating the required airflow on a longwall face, and can provide indication of the dustiness of the coal and the effectiveness of other dust controls parameters. Typically the airflow-to-tons ratio will range from 0.005 to 0.010 m^3/s per ton (10 to 20 cfm/ton). However, in situations where the airflow-to-tons ratio exceeds 0.010 m^3/s per ton (20 cfm/ton), consideration should be given to improving dust suppression through an improved shearer water system, and/or improving the headgate controls, etc. If the airflow-to-tons ratio is less than 0.005 m^3/s per ton (10 cfm/ton) consideration should be given to increasing the face airflow to account for increased production.

Proportionally increasing airflow to account for increased production rates provides a practical method of assessing control requirements for reducing dust exposure. While airflow and water application (quantity, pressure, and type and location of nozzle) are the major quantifiable dust control parameters, mining conditions and work procedures also can significantly effect employee dust exposure on longwalls. Therefore the quantities calculated in this paper are only for these operations with their unique set of mining conditions and work procedures. In order to make similar calculations for another mining operation with a different set of mining conditions and work procedures, respirable dust exposures measured on that operation would have to be utilized in the calculations.

SUMMARY

MSHA has conducted a series of tests to evaluate the influence of airflow and production on longwall dust control. Data were obtained from multiple shift respirable dust studies on six longwall mining sections, and from single shift studies on 80 sections.

Statistical analysis of the data from the multiple shift studies, indicate that individual correlations exist between concentration and both production and airflow. The correlations show that as the airflow increases, the dust concentration decreases; and that as production increases, dust exposures also increase.

For the six mines where multishift sampling was performed, an average ratio of airflow-to-tons mined was calculated using only those shifts with production greater than 60 percent of normal. The average airflow-to-tons ratio for the six mines, based on airflow at the headgate ranged from 0.0016 to 0.010 m^3/s per ton (3.3 to 22.1 cfm/ton). The average airflow-to-tons ratio for the six mines, based on airflow at the tailgate ranged from 0.0015 to 0.0073 m^3/s per ton (3.1 to 15.4 cfm/ton).

Results from the 80 single shift studies, indicated that for mines with productions greater than 1,000 tons, the average airflow-to-tons ratio was 0.0056 m^3/s per ton (11.8 cfm/ton).

These studied demonstrated that proportionally increasing airflow to account for increased production rates provides a practical method of assessing control requirements for reducing dust exposure. Because airflow, water application, mining conditions and work procedures also can significantly effect employee dust exposure on longwall sections, consideration needs to be given to these parameters when optimizing a longwall respirable dust control system.

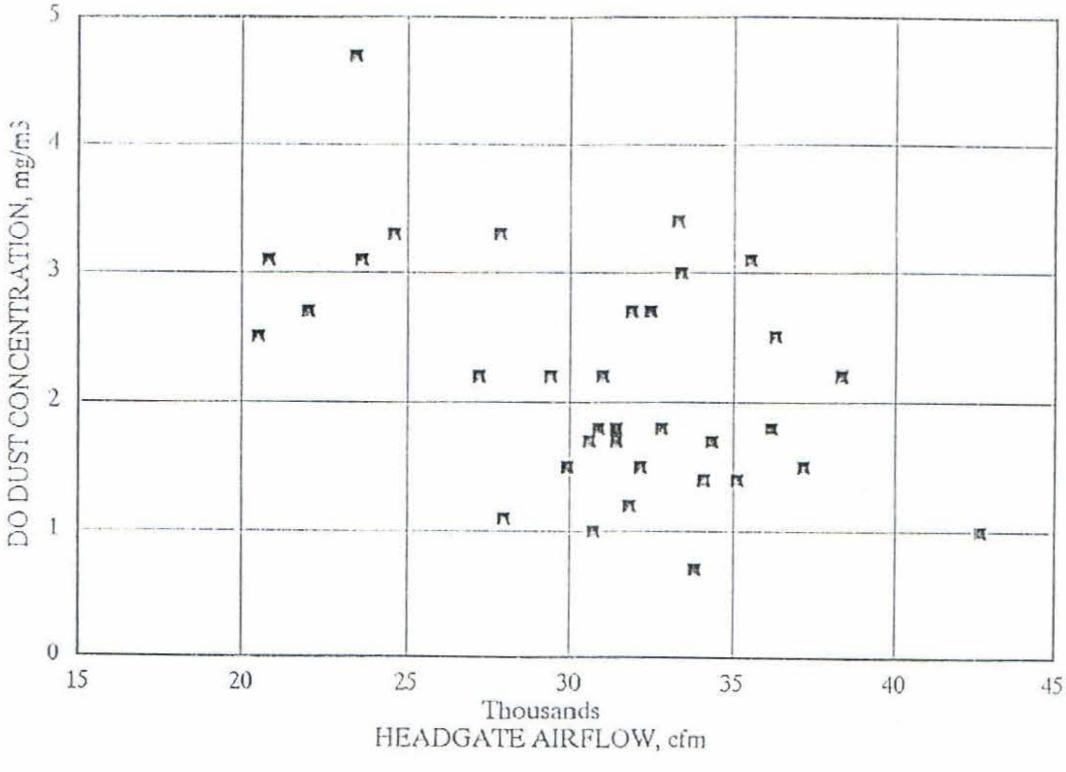

Figure 1. - Designated Occupation Respirable Dust Exposure vs. Headgate Airflow.

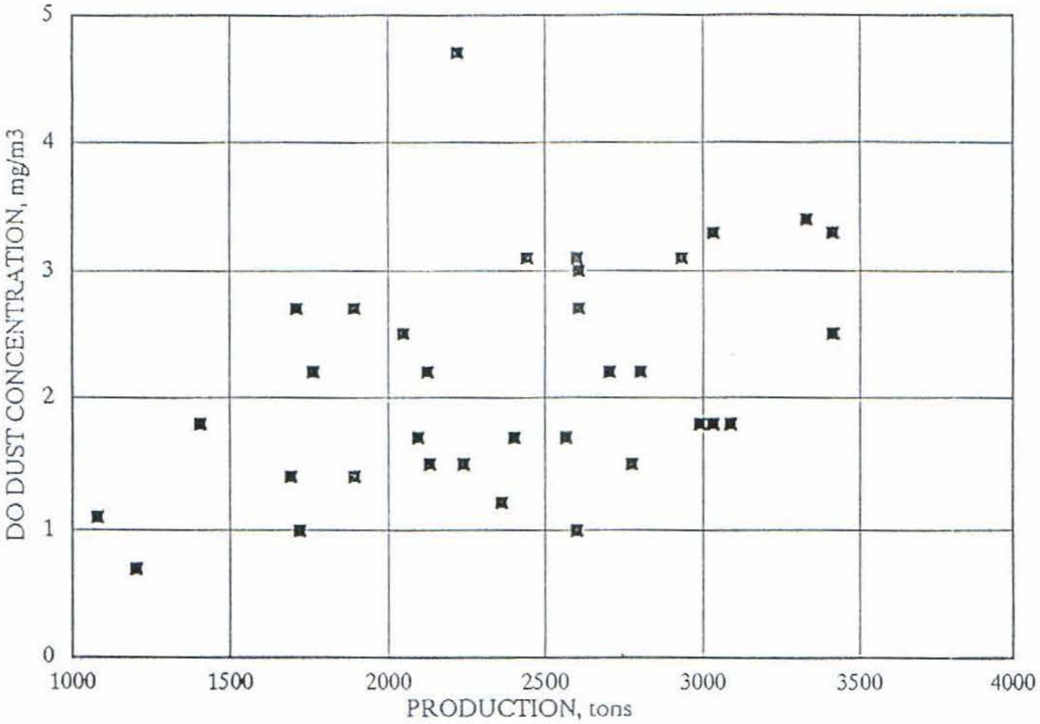

Figure 2. - Designated Occupation Respirable Dust Exposure vs. Production.

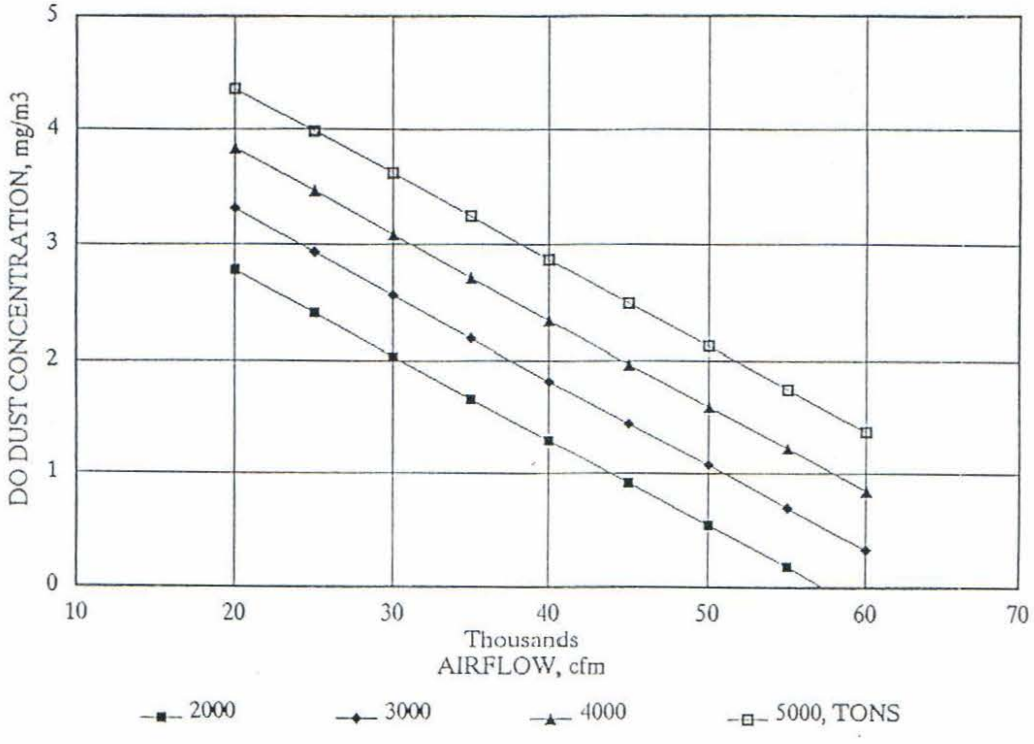

Figure 3. - Regression Analysis of Designated Occupation Respirable Dust Exposure vs. Headgate Airflow for Various Production Rates.

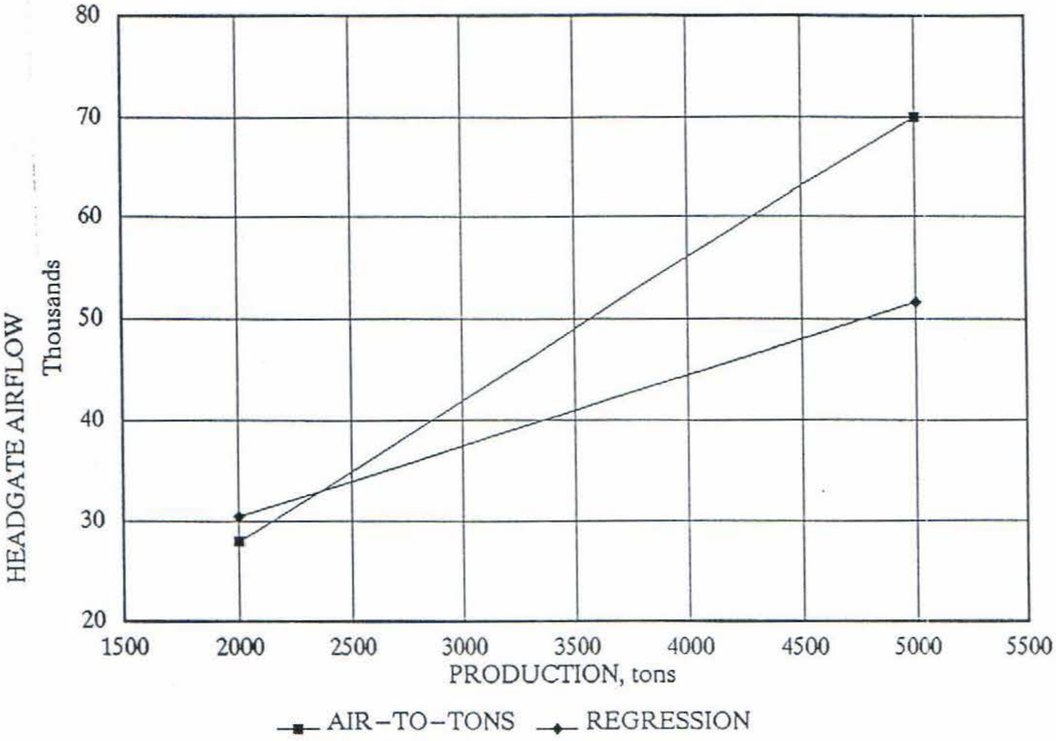

Figure 4. - Comparison of Airflow-to-Tons Ratio and Regression Analysis for Headgate Airflow versus Production for a 2.0 mg/m^3 Dust Exposure.

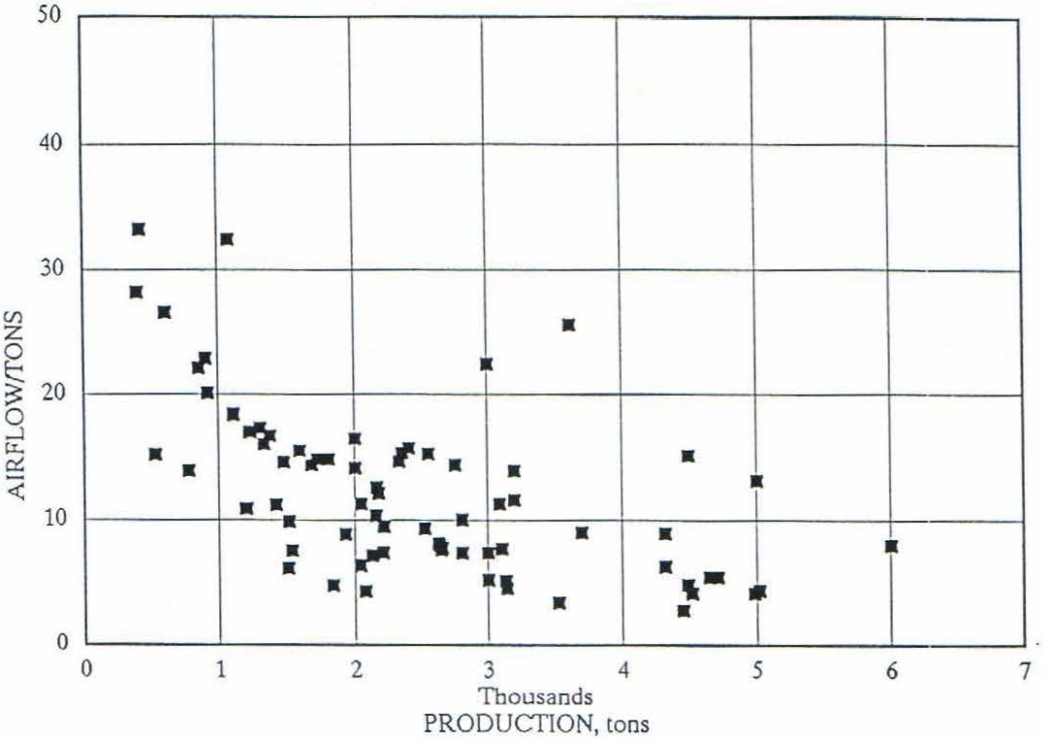

Figure 5. - Plot of Airflow-to-Tons Ratio to Achieve 2.0 mg/m^3 vs. Production for Longwall from MSHA Spot Inspection Program.

TABLE 1. - SUMMARY OF RESPIRABLE DUST SAMPLING, DUST CONTROL PARAMETERS, AND PRODUCTION MEASUREMENTS FOR SIX LONGWALL MINING SECTIONS.

MEASUREMENT	UNITS	Mine A	Mine B	Mine C	Mine D	Mine E	Mine F
SHIFTS SAMPLED		22	35	10	3	10	9
RESPIRABLE DUST							
TAIL DRUM	mg/m^3	1.6	2.2	1.9	1.1	2.4	1.2
HEAD DRUM	mg/m^3	1.7	1.5	1.6	1.5	1.4	---
HEADGATE MAN	mg/m^3	0.9	1.2	0.9	1.1	---	0.3
SHIELD SETTER	mg/m^3	1.6	1.7	1.9	1.5	2.2	1.2
SHIELD SETTER	mg/m^3	1.8	1.7	1.9	1.2	2.0	---
AVERAGE	mg/m^3	1.5	1.7	1.6	1.3	2.0	0.9
INTAKE	mg/m^3	0.3	0.1	0.2	0.4	0.4	0.2
BELT	mg/m^3	0.6	---	0.8	1.2	0.5	0.4
HEADGATE	mg/m^3	1.0	0.6	1.4	1.0	1.7	1.0
TAILGATE	mg/m^3	3.1	11.9	3.6	4.4	3.5	2.9
VENTILATION							
INTAKE	cfm	19300	37100	28500	38800	31600	44400
BELT	cfm	15500	NA	13000	3000	4300	53600
HEADGATE	cfm	31500	30900	41500	32300	34800	83800
TAILGATE	cfm	25100	16400	35700	30000	32900	57800
HEADGATE	fpm	394	475	587	340	498	1132
TAILGATE	fpm	319	252	507	320	470	852
WATER							
EXT. SPRAY	psi	275	175	180	175	115	118
BIT SPRAY	psi	150	67	88	120	110	114
PRODUCTION							
ACTUAL	tons	3129	2347	3844	5000	4503	2218
NORMAL	tons	3500	3784	4471	8200	4500	3860

TABLE 2. - CALCULATED AIRFLOW-TO-TONS RATIOS, COEFFICIENT OF VARIATION AND AIRFLOW REQUIREMENTS FOR SIX LONGWALL SECTIONS.

VALUE	UNITS	Mine A	Mine B	Mine C	Mine D	Mine E	Mine F
AIRFLOW-TO-TONS RATIO TO MAINTAIN A 2.0 mg/m^3 DUST LEVEL							
HEADGATE	RATIO	7.4	14.0	10.6	3.3	8.8	22.1
COEF. OF VAR.	%	26.9	35.4	23.1	22.4	12.6	22.0
TAILGATE	RATIO	6.1	7.4	9.1	3.1	8.9	15.4
COEF. OF VAR.	%	22.7	41.8	23.6	27.0	16.5	35.2
REQUIRED HEADGATE AIRFLOW AT NORMAL PRODUCTION TO MAINTAIN A 2.0 mg/m^3 DUST LEVEL							
BY REGRESSION	cfm	22300	42988	---	---	---	---
BY RATIO	cfm	25760	52976	47393	27060	39600	85306