Longwall Respirable Dust Simulator

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A systematic approach for correlating dust generated on a longwall face to personal employee exposure has been developed. The correlation is made through the use of a mathematical model that takes into consideration the magnitude of dust generation sources, exposure time to the source and the relative position of the worker with respect to the source. The correlation is facilitated through the use of an interactive computer program. The use and application of the program is demonstrated from several field studies conducted on longwall mining sections. The effect of various longwall dust control techniques such as dilution with airflow, internal and external spray systems on the shearer and remote control on the shearer are presented.

Introduction

While longwall mining methods offer many safety and production advantages over room and pillar mining systems, development of methods to control employee exposure to respirable dust generated during longwall mining has posed a critical health related problem for the mining industry. Much research has been done in the United States and in foreign countries on methods to reduce the dust generated during longwall mining, and thus reduce the exposure of workers along the longwall face. While no cure-all methods for longwall dust control have been developed, researchers have been able to define various dust generation sources along the face and delineate various control measures which are applicable to a specific dust generating source.

Specific sources of respirable dust include the section intake, the headgate area, face activities and the longwall machine. Dust can be generated in the intake by work activities in outby areas. Dust generating sources in the headgate area include the crusher, stageloader and belt transfer points. Sources of dust along the face include conveying of coal, roof support movement and spalling of coal from the face. Additionally the longwall machine generates dust as coal is mined from the face.

Research has delineated five general engineering methods for dust control. These five methods include suppression, capture, diversion, dilution and avoidance. Suppression utilizes water or mechanical means to reduce the amount of dust from the airstream. Capture utilizes hoods and duct work to remove dust from an area. Diversion involves directing dust ladden airstream away from workers through the use of water sprays or passive barriers. Dilution of the dust concentration can be achieved by increasing the volume of airflow. Finally, a dust cloud can be avoided by removing the miners from the work area.

The effectiveness of these dust control techniques has been evaluated primarily through the use of instantaneous dust measurements. These instantaneous dust measurements give a relative indication of whether dust control and employee exposure improve or deteriorate. Because the instantaneous measurements are a relative indication of concentration and do not reflect either exposure time or work practices it has been difficult to use them to predict employee exposure or the effect that system modifications have on employee exposure. Employee exposures are determined through full shift sampling and are expressed in Mining Research Establishment Instrument (MRE) equivalence.

Code of Federal Regulations, Title 30,[1] requires that in underground coal mines, the operator maintain the average concentration of respirable dust to which each miner is exposed at or below a 2.0 mg/m^3 standard. Additionally, when the dust contains more than 5 percent quartz, the standard shall be determined by dividing the percent of quartz into the number 10.

The purpose of this paper was to present an engineering method to judge the adequacy of existing longwall dust controls and to estimate the potential effectiveness of the implementation of additional controls on the shearer operators' personal exposures.

Data Collection

In order to evaluate a longwall respirable dust problem, a sampling strategy had to be developed that not only identified workers' individual exposures, but also identified and quantified the magnitude of the individual dust generating sources. This differs from the strategy used to determine compliance in that for compliance, only personal exposures not the dust sources are measured.

Since individual exposure is based on an eight-hour gravimetric sample, the decision was made to also utilize gravimetric sampling for source determinations. Additionally the dust concentrations determined through gravimetric sampling represent an average concentration obtained during the sampling period. The primary disadvantage of gravimetric sampling is that extreme high or low readings that may occur for a short period of time are not delineated. These extreme highs and lows can be determined from instantaneous measurements which may be taken as a supplement to the gravimetric measurements.

Gravimetric samples are collected using approved coal mine dust samplers operated at a flow rate of 2.0 lpm. The sampling assembly consists of a 10 mm nylon cyclone and a filter cassette. Sampling instruments are calibrated prior to a study and sample filters are pre- and post-weighed to 0.01 mg. Weighing filters to 0.01 mg gives a more reliable measurement of dust concentration when sample weights are low due to either short sampling times or low dust concentrations. Sample weight gains are converted to dust concentrations and then converted to MRE equivalent concentrations by multiplying by the factor 1.38. Concentra-

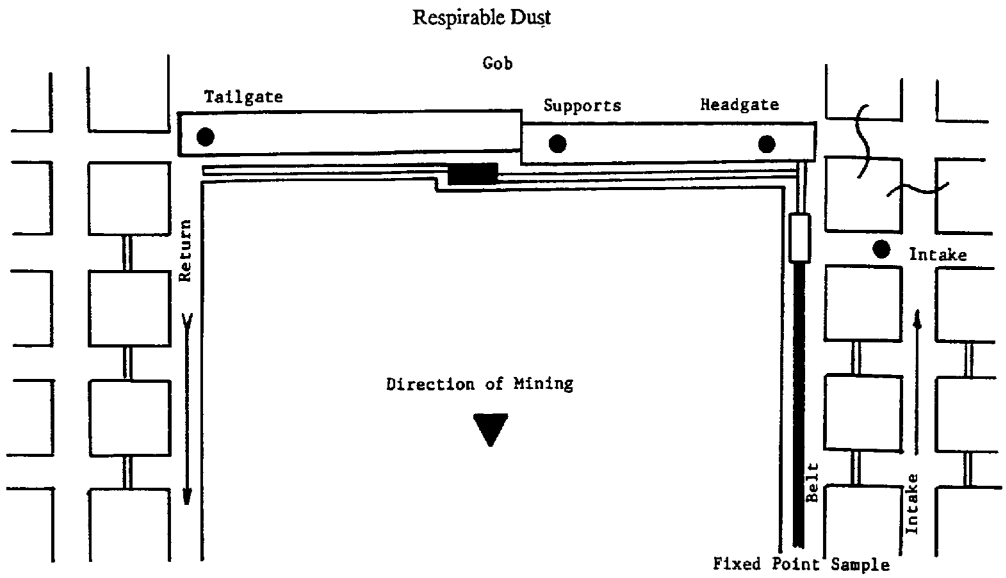

FIGURE 1. Longwall schematic and fixed point sample locations.

tions are expressed in MRE equivalence so that all concentrations are expressed in the same terms as the standard for respirable coal mine dust.

Both fixed point and personal samples are collected to evaluate a longwall dust control system. Personal samples are collected portal-to-portal on five of the face occupations. These occupations normally include head and tail drum shearer operators and jacksetters. Personal samples are used to determine the exposure of the shearer operator, determine the high risk occupation and verify compliance status of the section with respect to the respirable coal mine dust standard. Fixed point samples are collected for three to five hours during the shift. Fixed point sampling locations include the section intake, the headgate area (Shield No. 10), and the tailgate area. An additional on-section sample is collected by an individual that remains 15-20 feet upwind of the shearer. Typical fixed point sampling locations are shown in Figure 1.

In addition to dust measurements, other operational parameters such as water pressure, water quantity, number of sprays and spray direction, air quantity and velocity, drum rotational speed and production are noted. A time study is also made to determine the time to which the shearer operator is exposed to each dust generating source.

Mathematical Relationships

The dust concentration to which an individual is exposed is a function of the magnitude of the individual dust sources, the exposure time to the individual dust sources and the position of the employee relative to the dust sources. For the shearer operators on a longwall section, this mathematical relationship can be expressed as follows:

$$CO = \frac{1}{480} \sum_{i=1}^{n} C_i \times T_i \times P_i \qquad 1$$

where:

CO = Respirable dust concentration of shearer operator, mg/m^3,

Ci = Respirable dust concentration attributed to a specific dust generating source, mg/m^3,

Ti = Exposure time to a dust generating source, minutes,

Pi = Percentage of that source that actually reaches the shearer operator's position, decimal,

n = number of dust generating sources.

On a longwall face, the dust generating sources have been divided into four major areas. These areas include the section intake, the headgate area, the longwall face and the longwall machine. While each of these general areas of dust generation could be further broken down into sources such as the crusher, transfer points and cutting out in the headgate or support movement and spalling of coal along the face, for the analysis presented in this paper that break down was not made.

The longwall shearer operator works downwind of all dust generation sources except the longwall machine. As a result the operator is exposed to 100 percent of all upwind sources plus a portion of the machine dust generated by the longwall. Using this information Equation 1 can be rewritten as follows:

$$CO = \frac{C_I \times T_I}{480} + \frac{C_H \times T_H}{480} + \frac{C_S \times T_S}{480} + \frac{C_M \times T_M \times P_M}{480} \qquad 2$$

where:

CO = Respirable dust concentration of shearer operator, mg/m^3,
C_I = Intake dust concentration, mg/m^3,
C_H = HeaFIGURE 2. Flow diagram for computer program. dgate dust concentration, mg/m^3,
C_S = Support dust concentration, mg/m^3,
C_M = Machine dust concentration, mg/m^3,
T_I = Exposure time to intake dust, min.,
T_H = Exposure time to headgate dust, min.,
T_S = Exposure time to support dust, min.,
T_M = Exposure time to machine dust, min.,
P_M = Position factor for machine operator, decimal.

In the above formula, all variables except PM can be estimated from either gravimetric dust sampling or a time study of face operation. The dust source concentrations C_I, C_H, C_S, and C_M can be determined by taking the difference between gravimetric dust samples collected upwind and downwind of the dust generating source. CO would be the eight-hour full shift exposure of the longwall machine operator. The exposure time represents the actual time during the shift to which an individual was exposed to the dust source.

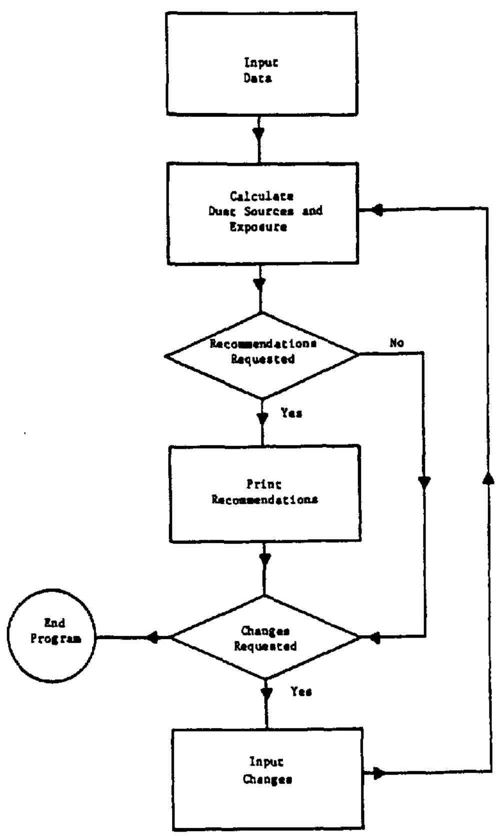

FIGURE 2. Flow diagram for computer program.

TABLE I

Input Data and Concentration Analysis

Enter data for respirable dust concentration (C)-mg/m^3 and exposure time to dust source (T)-Min.

Worker dust concentration exposure
C = ? 2.5

Intake concentration and time
C = ? .1
T = ? 480

Headgate concentration and time
C = ? 1.1
T = ? 360

Support concentration and time
C = ? 1.5
T = ? 360

Machine concentration and time
C = ? 2.5
T = ? 360

	Concentration Contrib mg/m^3	Percent Contrib
Intake	1	4
Headgate	75	30
Supports	3	11
Machine	1.35	54
TOTAL	2.5	100
Position factor	1.8	

Once the time and concentration data is determined, the equation can be rearranged to solve for P_M. It is important to note that while P_M represents the portion of the dust generated by the machine to which the operator is exposed, this value can also be changed through modifications to work practices, machine control locations, etc.

Computer Program

To facilitate the analysis of the data a computer program was developed. The program was written in BASIC and was designed to operate interactively on a personal computer. A flow diagram for the program is shown in Figure 2. The shearer operator's dust exposure concentration as well as fixed point dust concentrations and exposure times are entered into the computer as requested. Additionally other section and operational parameters are entered into the computer. Table I shows a listing of the data inputed into the computer program.

TABLE II

Recommendations for Intake Controls

Increase intake air quantity
Modify outby ventilation system
Change outby work activities

Following the input of the data the computer calculates and lists the contribution of each dust source on the employee exposure. As seen on Table I this contribution is given both in terms of concentration and percentage of total exposure. The final output for this portion of the program is the employee position factor with respect to the mining machine.

TABLE III

Recommendations for Headgate Controls

Increase face air quantity
Install gob and cut out curtains
Increase headgate water pressure
Increase headgate water quantity
Improve headgate enclosure
Add form at headgate
Modify headgate equipment
Install homotropal ventilation system

Also contained in the program is a list of recommendations for improving dust control and reducing employee exposure. These recommendations are based either on accepted engineering practice or the results of U.S. Bureau of Mines research.(2) The list of recommendations has been subdivided into recommendations for intake improvements, headgate improvements, support improvements, machine improvements and position improvements. Tables II through VI contains a complete list of the recommendations contained in the program. The computer, however, will only generate recommendations when a specific source contributes more than 0.7 mg/m^3 to the employee exposure and operation parameter data such as air velocity, water quantity or water pressure, or drum speed requirements have not been met. The face air velocity should be greater than 400 feet per minute. The water quantity through the drums of the longwall machine should be greater than 40 gallons per minute. The water pressure at the spray nozzles should be greater than 100 psi and the rotational speed of the cutting drum should be less than 45 revolutions per minute. Recommendation for position factor improvements are made when the position factor exceeds 1.0. A position factor greater than 1.0 indicates that the operator is being exposed to higher dust levels than are being generated by the source.

TABLE IV

Recommendations for Support Controls

Increase face air quantity
Install gob curtain
Line back of supports with belting
Institute support wash down program
Mofify work practices
Modify cut sequence
Install support remote controls
Water infuse panel

TABLE V

Recommendations for Position Changes

Install machine remote control
Improve directional spray orientation
Install passive barrier on machine
Improve work practices
Modify cut sequence

TABLE VI

Recommendations for Machine Controls

Increase face air quantity
Install GOB curtain
Increase machine water pressure
Increase No. internal sprays
Increase No. external sprays
Improve spray positions
Install water proportioning system
Add surfactant to water
Install passive barrier on machine
Add foam through machine sprays
Water infuse panel
Modify machine cutting parameters
Reduce cutting drum speed
Reverse cutting drum rotation

TABLE VII

Reduction Factors and Resulting Concentration Calculations

Enter reduction factors (R)- % Decimal
And new exposure time (T)-minutes

Intake reduction factor and time
R = ? 1.0
T = ? 480

Headgate reduction and time
R = ? .8
T = ? 360

Support reduction factor and time
R = ? .8
T = ? 360

Machine reduction factor and time
R = ? .8
T = ? 360

Position reduction factor
R = ? .5

	Concentration Contrib mg/m³	Percent Contrib
Intake	0.1	6
Headgate	0.6	40
Supports	0.24	16
Machine	0.54	36
Total	1.48	100
Position factor	0.9	

Measurements indicate compliance

In the final portion of the program the user has the opportunity to make changes to the existing system by reducing dust sources, reducing the percent of machine dust that reaches the operator or reducing the exposure time to a dust generated source. Reductions are entered into the program as percent reduction from the original measured value. A 20 percent reduction would be entered as 0.8 for a reduction factor.

While in most cases the exact reduction which can be attributed to a change has not been quantified, nevertheless, the user has the opportunity to determine, by trial and error, the magnitude of the reduction that may be desired and to evaluate those recommendations which may be best suited to the problem. For example, if a machine dust generation needs to be reduced by 80 percent, it would be inappropriate to expect that this could be achieved by only increasing the water pressure on the machine.

Table VII shows the inputed reduction factors and shows the resulting dust concentration changes when applied to the data presented in Table I. As seen in Table I the primary contributors to employee exposure were the headgate area and the longwall machine. Based on the recommendations, it was decided to improve dust control practices by increasing the face air quantity and installing remote controls on the machine. A face air quantity change affects the concentration generated due to each of the dust sources. A 20 percent increase in air volume would give an 0.8 reduction factor for each source except the section intake. Additionally, it was felt that a 50 percent reduction in exposure due to the position of the worker could be achieved by utilizing remote controls; therefore, a 0.5 reduction factor was entered for PM. The exposure times remained the same for the various dust generating sources. The resulting calculations indicate that if the above reductions were achieved the shearer operator's exposure would be below the 2.0 mg/m³ standard.

Summary

While the results of the program calculation need to be evaluated through additional underground sampling, this computerized approach to reducing longwall dust problems does provide an engineering basis for decision making regarding the potential of various modifications to the dust control system. The approach delineates and focuses on control of those dust sources which are the major contributor to the employee exposure. While this particular application is for control of respirable dust exposure for the longwall shearer operator, similar models and sampling strategies can be developed for plow operations or for other longwall face occupations.

References

1. Code of Federal Regulations, Title 30, Mineral Resources, Part 70, revised July 1, 1985, Office of Federal Register, National Archives and Records Service, General Services Administration, Washington, D.C.

2. *Dust Control Handbook for Longwall Mining Operations*, 223 pp. BCR National Laboratories, U.S. Bureau of Mines Contract J0348000 (1985).