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UNIT OF MEASURE ABBREVIATIONS USED IN THIS REPORT

A	ampere	mg/cm^2	milligram per square centimeter
cm	centimeter	mg/L	milligram per liter
cm^2/mg	square centimeter per milligram	min	minute
cm^3/L	cubic centimeter per liter	mm	millimeter
ft	foot, feet	nm	nanometer
kg	kilogram	s	second
m	meter	V ac	volt, alternating current
m^2	square meter	V dc	volt, direct current
m^3	cubic meter	wt-pct	weight percent
m/cm	meter per centimeter	µm	micrometer
m/s	meter per second	%	percent
mA	milliampere		

FULL-SCALE TESTING OF THE FLOAT DUST DEPOSITION METER

By Robert A. Cortese[1] and Henry E. Perlee[2]

ABSTRACT

Coal dust and float coal dust, produced during normal mining operations, in underground coal mines, are carried from the point of origin downstream by the ventilating air, where it deposits on the surfaces of the mine entry. In an explosion, this dust is lifted from the surfaces by the aerodynamic disturbances and, if of sufficient quantity, can continue to propagate the explosion. To prevent the surface coal dust from contributing, it must be inerted, typically by spreading pulverized limestone, i.e., rock dust, over the coal dust surface. To facilitate the dusting operation, the National Institute for Occupational Safety and Health (NIOSH), Pittsburgh Research Laboratory (PRL), developed an automated system that continuously monitors the accumulation of coal dust. This system could activate a rock-dusting machine that disperses rock dust into the ventilation air when dangerous deposits accumulate and deactivate the machine when sufficient inert has been deposited on top of the coal dust.

The system consists of a microprocessor-controlled optical float dust deposition meter. This device measures the light intensity reflected from a deposited layer of dust. A standard cap lamp is used as a fixed-position light source. From the reflected light signal, the microprocessor determines the hazard level of the deposited layer and performs the appropriate action.

Full-scale studies conducted in the Experimental Mine at PRL's Lake Lynn Laboratory, using alternating thin layers of rock dust and coal dust, successfully demonstrated the operation of the device. Based on the statistical data from these studies, a mathematical model was developed to predict long-term error in total rock dust content using this inerting procedure. Downwind dust dispersion was also examined to provide optimum placement of the dust sensors and to determine the need for better rock dust dispersion techniques.

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INTRODUCTION

Coal dust generated in underground coal mines at the cutting face and points of coal transfer is floated downwind by the ventilating air. The floating coal dust settles on the mine surfaces over extended distances and, if not rendered inert, represents an explosion hazard. Using the minimum estimate for the lower explosive limit [Weiss et al. 1989], 50 mg/L, surface layers as thin as 0.05 mm can form a flammable air/dust mixture. For an operating mine, coal dust layers of this thickness can develop in hours.

Usually a visual inspection by a mine foreman determines when and where to spread a layer of rock dust. The rock dust is usually applied in one of three ways: sprayed from a hose attached to a dust pump and hopper; sprayed from a piping manifold of nozzles connected to a vehicle containing the dust pump and rock dust and directed at the floor, roof, and ribs; or dispersed from a stationary pumping station and carried downwind by the ventilating air. The third procedure is referred to as "trickle dusting." Because of the uncertainty associated with visual inspection, the National Institute for Occupational Safety and Health (NIOSH), Pittsburgh Research Laboratory (PRL), designed and built a float dust deposition meter (FDDM). The FDDM is located several meters downwind of a trickle duster to automatically measure the loading densities of dusts. The trickle duster is turned on when the coal dust loading density approaches dangerous proportions and turned off when a sufficient amount of rock dust has been deposited.

Due to the current limitations of the FDDM, the meter will be restricted to use in return airways. Federal law requires 80 wt-pct incombustible content in the dust deposited in return airways in the absence of methane.

BACKGROUND

THEORY

The operation of the FDDM is based on the difference in optical reflectivity of coal and rock dust. Rock dust is optically light and highly reflective; coal dust is dark with a significantly lower optical reflectivity. The mathematical expression for the normalized intensity (Φ) from a given layer is given by Sapko et al. [1988]:

$$\Phi = \frac{I_s - I_c}{I_r - I_c} , \tag{1}$$

where I_c and I_r correspond to the intensity of light reflected from a semi-infinite thick layer of pure coal dust and rock dust, respectively. I_s represents the intensity of light reflected from a thin layer of either dust deposited on a semi-infinite layer of the other dust.

Because the reflected light intensity is measured with a silicon photodiode, whose photoelectric current is a linear function of the light intensity, equation 1 can be written as:

$$\Phi = \frac{V_s - V_c}{V_r - V_c} , \tag{2}$$

where V is the voltage output from a high-impedance transconductance amplifier connected to the photodiode.

The behavior of the resultant curve traces for the two deposition processes (rock dust on coal dust and vice versa) follow a common exponential relationship and are given by the following equations:

$$\Phi_c = e^{-(\alpha_c \cdot \sigma_c)} \tag{3}$$

and

$$\Phi_r = 1 - e^{-(\alpha_r \cdot \sigma_r)} , \tag{4}$$

where Φ_c corresponds to the theoretical expression for coal dust deposited on an optically thick layer of rock dust. Complementarily, Φ_r corresponds to rock dust deposited on an optically thick layer of coal dust. The loading density of coal dust and rock dust in the given equation is expressed in milligrams per square centimeter and is represented by σ_c and σ_r, respectively. Also associated with each dust is a coefficient of attenuation, α_c and α_r, respectively.

The attenuation coefficient is a function of the optical characteristics of the individual particles and the particle size distribution. Figure 1 shows the particle size distribution of both the coal and rock dust used in these studies. For this graph and the remainder of this report, the volumetric median diameter is reported as representative of the dust size. Because the function of the FDDM is to correlate reflectance with the mass of a deposited layer, the volumetric median diameter was chosen to best represent the mass of a dust particle.

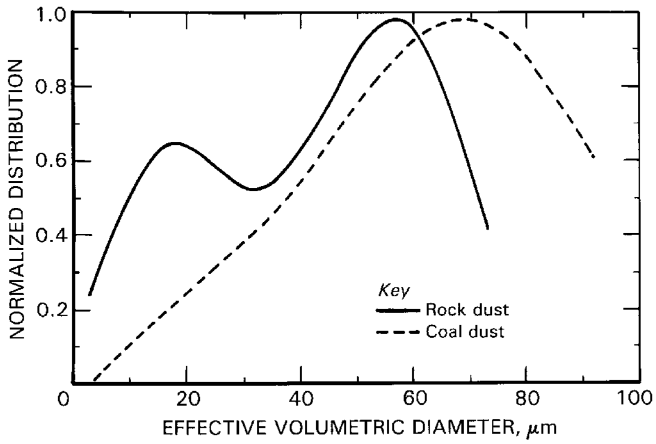

Figure 1.—Normalized particle size distribution of both coal and rock dust.

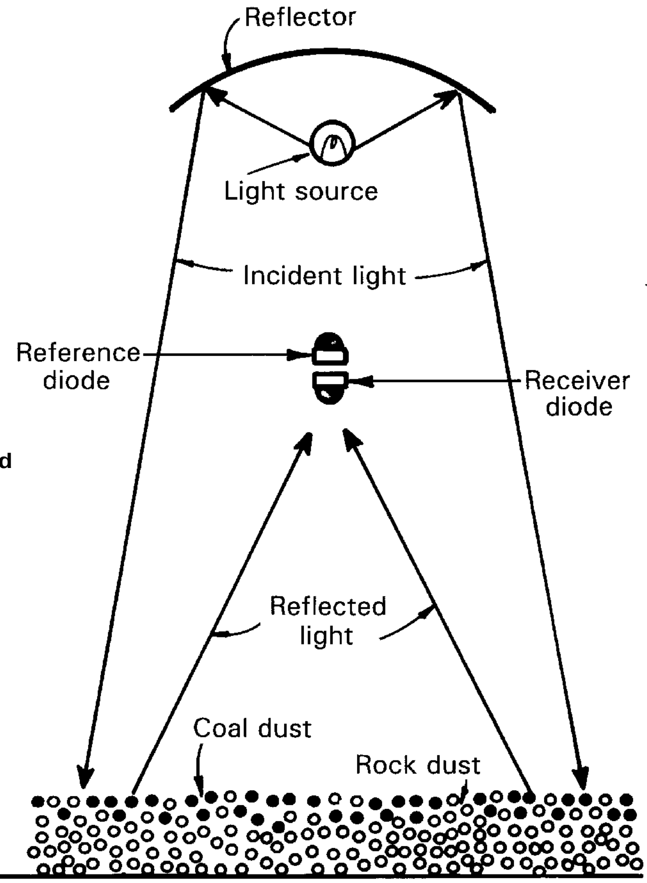

Figure 2.—Principle of operation of float dust deposition meter.

BENCH STUDIES

A principle of operation drawing of the FDDM, used in the bench-scale research [Cortese et al. 1992] to verify the above theoretical expressions, is shown in figure 2. The α's in equations 3 and 4, obtained by regressing the two equations using measured Φ values determined with the FDDM for both Pittsburgh pulverized coal and commercial limestone dust, are $\alpha_c = 1.0 \pm 0.05$ and $\alpha_r = 0.3 \pm 0.02$, respectively.

The effects of both ambient light and distance between the dust layer surface and the source light were also examined. Although both factors affected the absolute light intensity at the receiver diode, they did not affect the values of α. It was also found that deposits of dusts on substrates with optical reflectivities slightly different from those of pure coal and rock dust had no measurable effect on the values of α. This is an important observation because for its intended use the substrate will rarely be pure coal or pure rock dust. It was also discovered that the α's were dependent on the porosity, i.e., compaction, of the substrate, although no attempt was made to quantify this observation because it is not likely to be a factor in the instrument's intended use.

EXPERIMENTAL PROCEDURE

Following the successful demonstration of the feasibility of the reflectance technique to measure the loading density of coal dust deposited on rock dust and vice versa, it remained to conduct full-scale experiments at the Experimental Mine at PRL's Lake Lynn Laboratory near Fairchance, Fayette County, PA (figure 3). The facility and supporting research have been fully documented by Triebsch and Sapko [1990].

The first full-scale experiments conducted were designed to measure the accuracy of the FDDM by comparing the loading densities measured by the FDDM with values obtained by collecting and weighing dust in petri dishes positioned down the entry. These tests were conducted in D-drift of the mine, approximately 6 m wide by 2 m high by 500 m long, using a commercially available trickle duster located 30 m outby the bulkhead and equipped with a 4-cm outside-diameter flexible hose and nozzle to disperse the dust. The nozzle was positioned in the center of the entry, 2 m above the floor, and directed so as to dispense the dust in the same direction as the ventilating air. The air exited the nozzle at approximately 3 m/s. This point source arrangement produced a conical dust deposit on the floor for the first 10-15 m from the nozzle beyond which the deposit reached the ribs. Air from the ventilation shaft in E-drift was controlled by the speed of a mine ventilation fan and the extent of closure of the bulkhead door. In the initial studies, using three of the bench-model FDDMs and a ventilation velocity of 0.9 m/s, the FDDMs were positioned at 30, 60, and 90 m downwind of the nozzle (figure 3). The three FDDMs were connected by electrical cable to a microcomputer located upstream of the trickle duster. The microcomputer controlled the operation of the

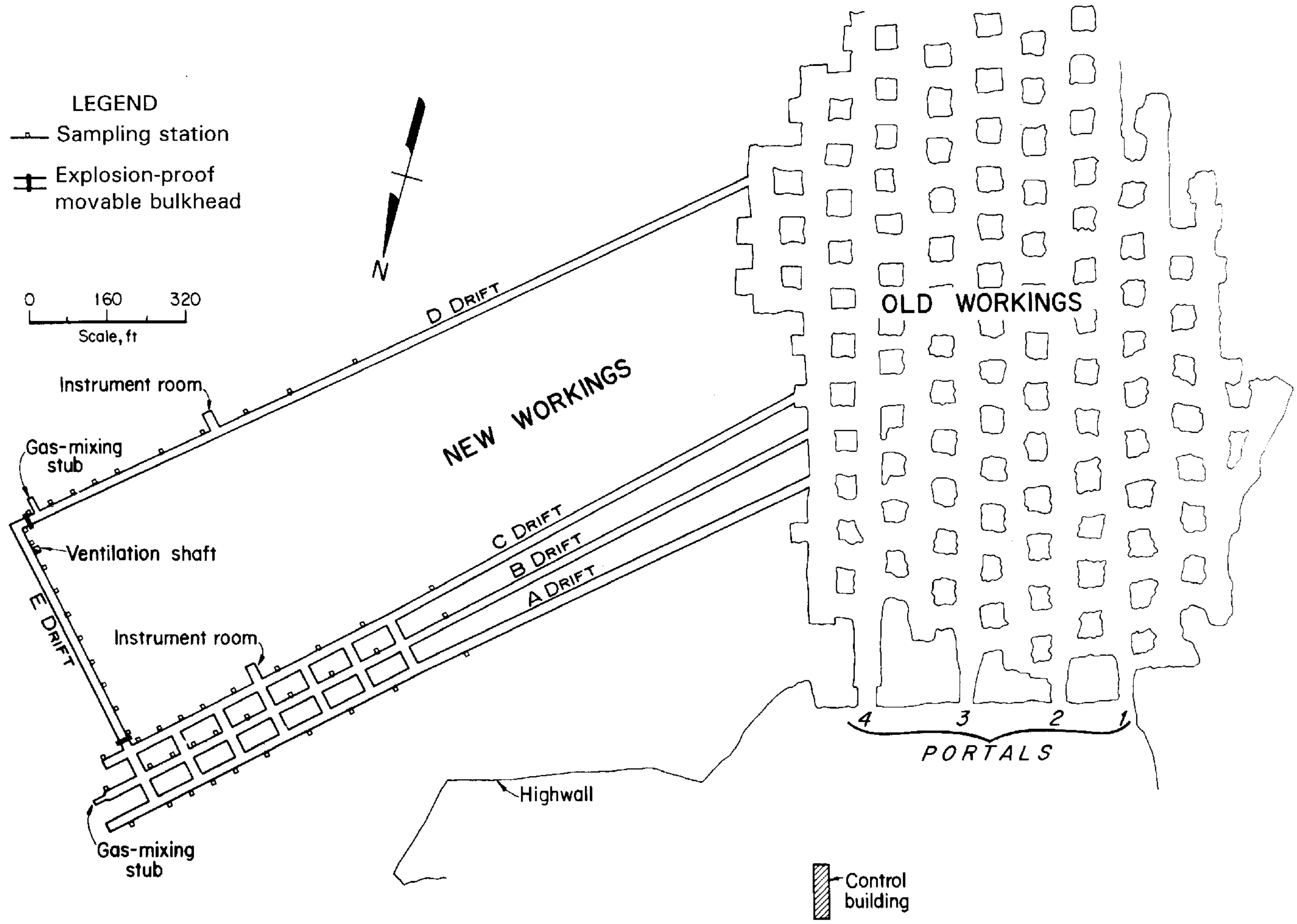

Figure 3.—Experimental Mine at Lake Lynn Laboratory near Fairchance, PA.

FDDMs and acquired, digitized, and stored the FDDM analog sensor signals. To achieve a reliable estimate for the loading density, three dust-collection petri dishes (with a 6.9-cm radius and 1.3 cm deep) were placed 0.5 m upwind of each of the three FDDMs in the center of the entry. An electronic balance located upwind of the trickle duster nozzle was used to weigh the dishes of dust to determine the mass of dust deposited. Preliminary dust dispersal studies were conducted in D-drift without the FDDMs to determine the deposition durations per cycle required to achieve the desired loading densities. The desired coal dust loading density was calculated based on the following equation:

$$LD = \frac{0.25 \cdot ME \cdot V}{SA \cdot L \cdot CF}, \quad (5)$$

where (0.25 · ME) represents restricting the maximum coal dust accumulation between rock-dusting procedures to 25% of the minimum estimate for the lower explosive limit (mentioned earlier as 50 mg/L). V represents the volume contained in a 1-m-long entry (12 m^3 for these studies). SA represents the total surface area of the ribs, floor, and roof in a 1-m-long entry (16 m^2 for the Lake Lynn Experimental Mine entry). CF is the conversion factor to obtain the loading density (LD) in the proper units (for this case, CF is 1,000 $cm^3/L \cdot 0.01$ m/cm). The resulting coal dust loading density for these studies is 0.9 mg/cm^2. Because the FDDM will initially be located only in returns, the rock dust loading density was chosen to achieve the 80 wt-pct regulation, namely, 3.8 mg/cm^2.

Because the intent of this report is to simply demonstrate the feasibility of the FDDM, these calculations have been simplified with a few assumptions. First, it was assumed that the dust will deposit equally on all mine surfaces; in practice, most of the float coal dust and rock dust will accumulate on the floor. Secondly, these calculations assume that rock dust is the only incombustible present, i.e., there is no water or ash. From these preliminary dust dispersal studies, it was determined that 30 kg of rock dust dispersed in 24 min and 10 kg of coal dust deposited in 6 min will produce the desired loading densities. To a obtain a value for the two α's by regression for these experiments, the half-cycle deposition of each dust was divided into three equal-time intervals, i.e., three 2-min coal dust minideposits and three 8-min rock dust minideposits. Before beginning the experiment, 35 kg of rock dust was dispersed in the entry to provide an optically thick substrate for the initial coal dust deposit.

To conduct an experiment, the trickle duster, loaded with coal dust, was started and the coal dust was dispersed for 2 min. The duster was then stopped, and time was allowed for the remaining entrained dust to settle. The petri dishes were collected, weighed, and replaced, and the reflectivity of the dust surface was recorded with the FDDM. The duster was restarted and the process was repeated two more times, after which the same sequence was followed using rock dust deposited on the recently deposited coal dust layer. A total of four cycles were included in each experiment. It was discovered during these experiments that suitable data could not be obtained from all three stations simultaneously. In order to collect a measurable quantity of dust at the 60- and 90-m stations to accurately analyze the data, the 30-m station optically saturates, preventing further measurements of the layer loading density at this location. As a result, the experimental setup for subsequent testing was altered to locate the three FDDMs at one location and measure the variance between the meters.

These initial studies also demonstrated that the bench-model FDDM was unsuitable for in-mine use primarily because the entrained dust deposited on the internal surfaces of the instrument caused extraneous reflections. This problem was solved with the design shown in figure 4. The optics are enclosed in a housing (18 cm wide by 18 cm long by 76 cm high), equipped with a surface (square 15 cm on side) that can be extended outside the housing to collect the depositing dust, and retracted inside the housing to measure the reflectivity of the deposit. In the bench model, an oblique optical system was used to allow the dust to properly deposit on the collection surface. With the retractable collection surface, the oblique optical system is no longer necessary, resulting in increased intensity of the reflected light reaching the optical receiver. A 20-cm-wide flow divider was attached to the leading edge of the housing to minimize the generation of turbulent eddies over the extended surface as the air flows around the housing. The lamp battery, relays, and photodiode electronics were contained in the top compartment.

The microprocessor-based controller (figure 5), requiring 5 V dc at 250 mA, performs the following functions when requested: (1) powers the screw drive motor, drawing 30 mA at 120 V ac (forward and reverse) for the retractable surface, (2) powers the lamp (4.5 V dc at 1.2 A) and electronics (± 15 V dc at 50 mA and 5 V dc at 50 mA), (3) records the photosensors' outputs, and (4) processes the sensor data. The controller consists of (1) an 8086-compatible microprocessor chip running a C language program, (2) a 128K RAM, (3) a 128K EPROM, and (4) a 0- to 5-V dc, 10-bit, analog-to-digital converter.

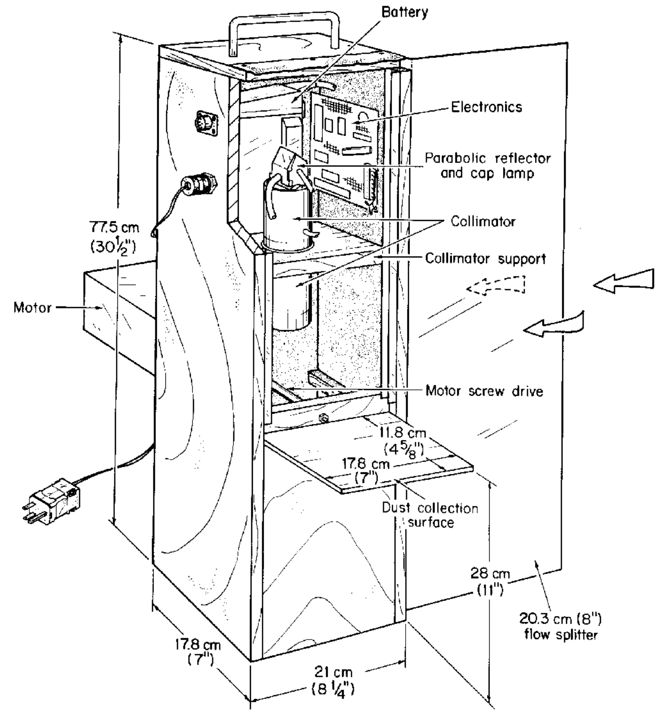

Figure 4.—Float dust deposition meter used during full-scale studies at the Lake Lynn Experimental Mine.

After the controller is energized, the program enters a continuous loop, where it waits for a sample request from the researcher. After the request is received, the optic electronics are powered and the retractable tray is retracted. At this point, the software enters a 3-cycle loop where the following sequence of events occurs: (1) the lamp is turned on, (2) all 6 sensors (2 for each unit, 1 for the receiver, and 1 for the reference) are read 10 times over a 3-s period and averaged, (3) the averaged receiver-to-reference ratio is calculated, (4) the receiver, reference, and resultant quotient averaged values are stored, and (5) the lamp is turned off. After executing the three cycles of this loop, the collection surface is returned to the extended position, the optic electronics are powered down, and the system waits for the next sample request. The program is terminated when power is removed from the controller.

The next series of experiments was designed to measure the reproducibility of the FDDMs. Three different air velocities were used in these studies: 0.9, 1.2, and 2.0 m/s. In these tests, the three FDDMs were placed across the entry 30 m downwind of the trickle duster nozzle, with one unit placed in the center of the entry and a unit 0.7 m on both sides of the center unit. The controller was placed along the rib also at 30 m. A sample-request switch was located 2 m upwind of the trickle duster nozzle. The collection dishes were positioned adjacent to the FDDMs on a raised platform 30 cm above the floor (the same height as the retractable dust collection

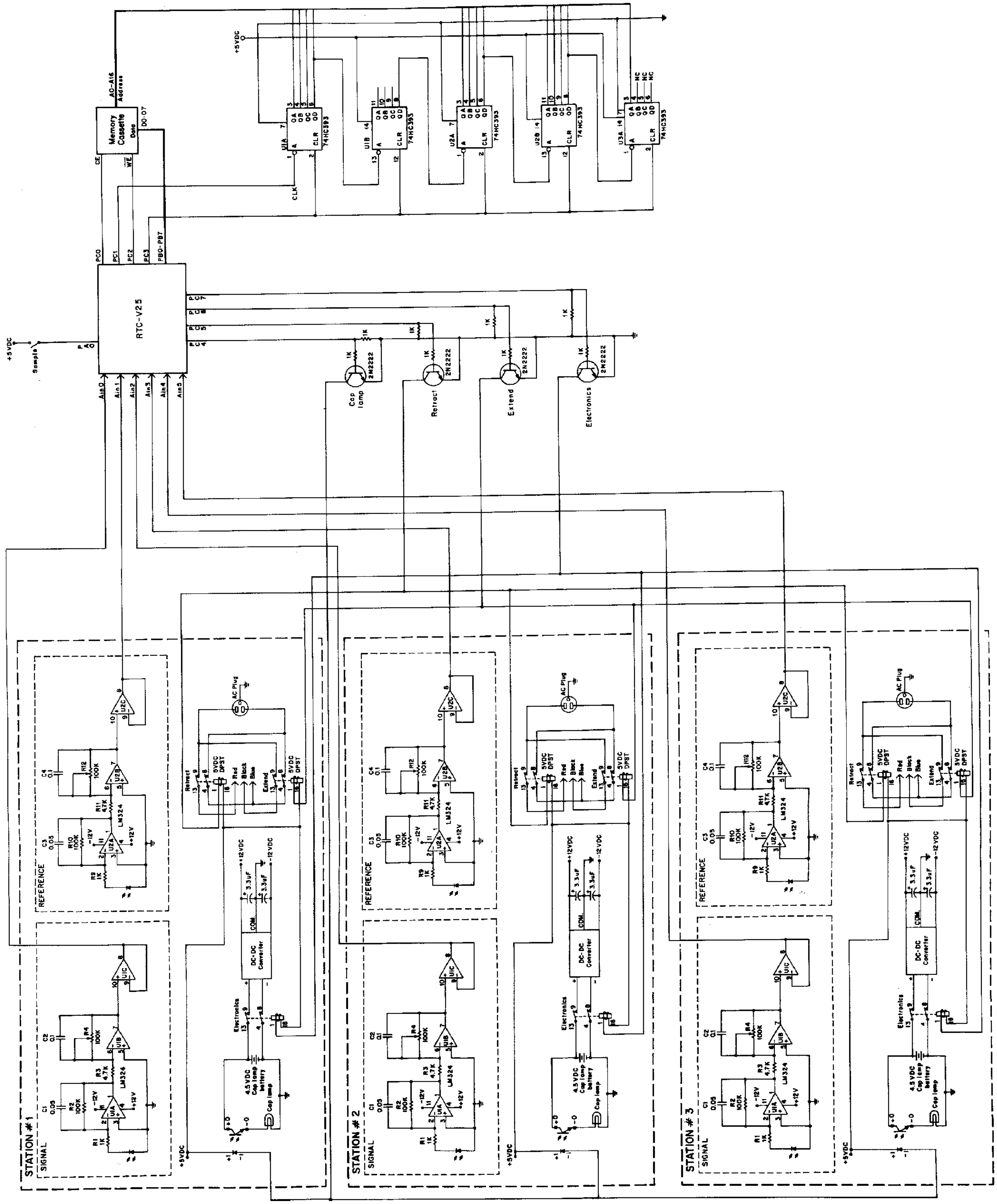

Figure 5.—Electronic circuitry.

surfaces). These dishes were collected and weighed after each minideposition. Additional dishes were placed on the floor in the center of the entry at 15, 30, 46, 61, 91, 122, and 152 m downwind of the duster. The dishes at the first four locations were collected and weighed after each minideposition; the last three were collected and weighed after completion of the experiment. The particle size distribution for the pure dust samples collected during the first cycle were measured using a Coulter Counter. A similar coal size analysis was performed on the dust collected at the three farthest locations (91, 122, and 152 m) after the rock dust was removed by acid leaching. The acid-leaching process also determined the coal dust to rock dust mass ratio. Because acid leaching dissolves the rock dust, only the coal dust particle size distribution can be obtained at these locations. Additionally, a 633-nm helium neon laser was installed at the 30-m station and directed across the entry (4 m) to a photodiode to measure the beam attenuation due to the intervening dust. Knowing the attenuation and the particulate mass flux (determined from the mass deposited in the dishes), the mean particle size of the airborne dust can be determined. This was necessary because the Coulter Counter measures the unagglomerated particle size distribution after collection, and the bulk of the airborne coal and rock dust particles most likely contain significant quantities of agglomerates [Fink 1975]. These results, along with a detailed explanation of the theory, will be reported in a future publication.

RESULTS AND DISCUSSIONS

DUST DISPERSION

The volumetric median particle diameters and dust deposition rates were obtained from the petri dishes, as indicated above. The median diameters were measured because the coefficient of attenuation is theoretically dependent upon this factor and therefore could influence the results of the FDDM. The dust deposition rates were measured to assist in determining an optimum location of the FDDM in a mine relative to the rock dust source.

Figure 6 shows the unagglomerated (Coulter Counter, with an aperture setting of 200 μm) volumetric mean particle diameters [Woods et al. 1988] of the coal and rock dust collected in the dishes as a function of the downwind distance from the trickle duster for the three ventilation velocities. As previously noted, the rock dust size data are not available at the three farthest distances. As expected, the median particle size for both dusts decreases with distance from the source because the larger particles are the first to settle. Figure 6 also shows, unexpectedly, that there is no statistically significant difference in the median particle diameters at any location for the three ventilation velocities for either dust. It was anticipated that the results would show larger diameter particles farther downwind for the higher ventilation velocities.

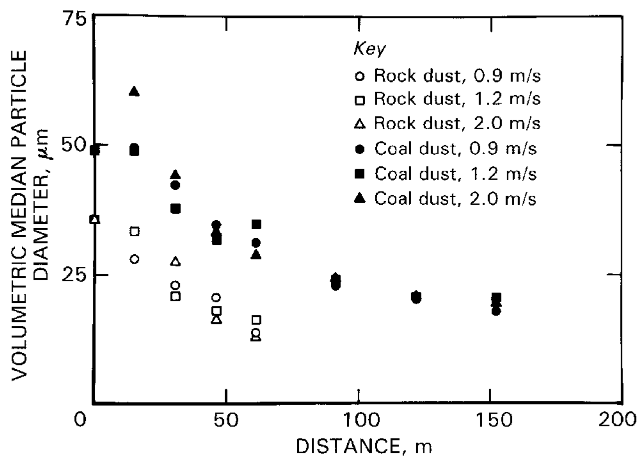

Figure 6.—Unagglomerated volumetric median particle diameters of coal and rock dust deposits as a function of distance downwind of the dust source.

Figure 7 illustrates the mass loading density for coal and rock dust, determined from the petri dishes, as a function of distance from the source. The figure shows that more of the rock dust, being of smaller median particle diameter, is carried downwind than coal dust. This would result in higher rock dust to coal dust loading density ratios, i.e., mass per unit area ratios, downwind of the measuring station. This would also ensure that if the deposit is nonflammable at the point of measurement, it is also nonflammable downwind, assuming that at the measurement station the deposition processes have stabilized. Figure 8 shows the percentage of rock dust in the total sample of coal and rock dust that was deposited in the dishes at the conclusion of the experiment. Data are shown as a function of location for the three ventilation velocities. It is apparent from the figure that the rock dust concentrations in the samples increase with increasing distance, asymptotically approaching 90 wt-pct. The dashed line in figure 8 represents the average 80 wt-pct of rock dust dispersed in the experiment. The figure shows that coal dust has a lower concentration farther downwind; this is expected because the coal dust has a larger median particle size and therefore a larger mass sedimentation flux than the rock dust.

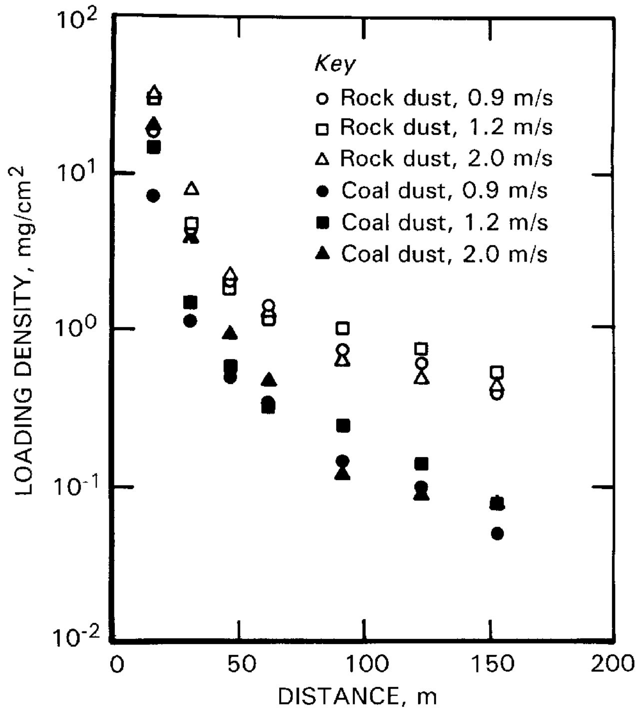

Figure 7.—Loadings of coal and rock dust deposited at various distances downwind of the dust source for three ventilation velocities.

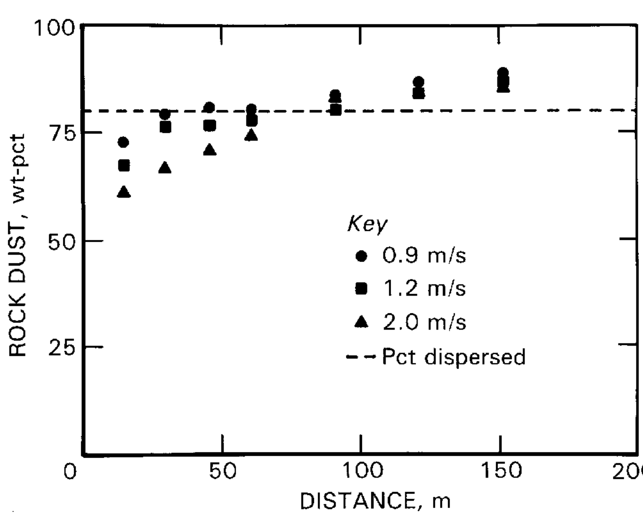

Figure 8.—Wt-pct of rock dust deposited as a function of distance from the dust source for three ventilation velocities.

Figures 9*A* through 9*C* show data from the FDDM. Each is a plot of Φ, calculated using equation 2, as a function of the dust loading density, as measured from the petri dish samples over the four cycles. As expected, because the same mass of each dust was used in each cycle, the value of Φ oscillates between an upper and lower bound, with Φ = 1 and Φ = 0 corresponding to an infinite layer of rock dust and coal dust, respectively. This is intended to simulate the starting and stopping of the trickle duster using upper and lower Φ limits.

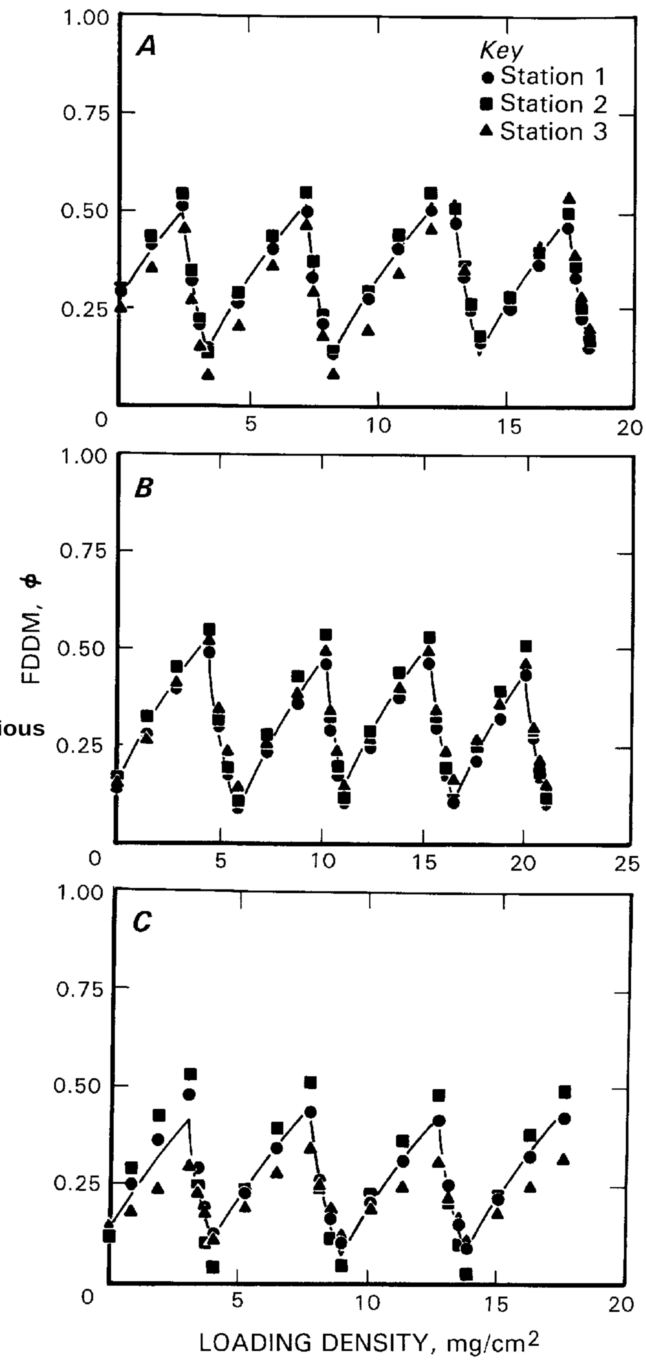

Figure 9.—Float dust deposition meter (Φ) versus loading density, as measured from the petri dishes, with fitted theory for (A) 0.9 m/s (α_c = 1.38 and α_r = 0.15 cm²/mg), (B) 1.2 m/s (α_c = 1.27 and α_r = 0.13 cm²/mg), and (C), 2.0 m/s (α_c = 1.40 and α_r = 0.13 cm²/mg).

This is similar to the means in which the meter will be used under actual mining conditions, i.e., rock dust is dispersed until Φ = 0.5, then coal accumulates during mining operations until alarming at Φ = 0.15, etc. To compare the values of α

Table 1.—Best-fit α's with a 95% confidence interval

Station	0.9 m/s		1.2 m/s		2.0 m/s	
	Rock dust	Coal dust	Rock dust	Coal dust	Rock dust	Coal dust
Station 1	0.14±0.04	1.35±0.31	0.12±0.01	1.31±0.40	0.13±0.04	1.29±0.26
Station 2	0.16±0.04	1.35±0.26	0.15±0.02	1.42±0.40	0.19±0.03	2.08±0.58
Station 3	0.14±0.02	1.45±0.63	0.12±0.01	1.07±0.32	0.07±0.02	0.82±0.14
Composite . .	0.15±0.01	1.38±0.13	0.13±0.01	1.27±0.15	0.13±0.03	1.40±0.44

determined in the bench studies with those of the full-scale studies, the results shown in figures 9*A* through 9*C* were least-squares fit to equations 3 and 4. Equation 2 was substituted for Φ, and a regression using four fit parameters in the equations, namely V_r, V_c, α_r, and α_c, was performed. Ideally, all four parameters should be statistically determined using the fit; however, this technique results in a set of eight highly nonlinear equations. The process was simplified by forcing the fitted expressions through the first point at the start of each cycle, which in effect eliminated V_r and V_c. The remaining data, in each half-cycle, were then fit to equation 3 or 4 to obtain an estimate and variance for α_r and α_c. The α's for the four half-cycle estimates were averaged and the variances pooled to obtain the best estimate for the α's and their respective tolerance limits, as shown in table 1. The results show that, at a 95% confidence interval, there is no statistical difference in the α's as measured by the three FDDMs at the same air velocity. We conclude from these results that the theory, as expressed in equations 1 through 4, is sufficiently accurate for our purposes and the three FDDMs provide the same results for a given layer. However, it is to be noted that the α values, as measured in the bench experiments (α_r = 0.3 and α_c = 1.0), are statistically different from those obtained in the full-scale experiments. Although it remains to be investigated, it is believed that this difference is due to the difference in the particle size distributions of both the coal and rock dusts between the two experiments. Although the same starting coal and rock dust were used for the experiments, the median particle diameters of the collected large-scale samples were smaller due to the distance from source size classification effects. The median particle diameters for both dusts collected in the bench studies were identical to those of the starting materials, because for those tests the dust was confined to a stove pipe and settled horizontally. The median diameters for coal and rock dust in the bench studies were 49 µm and 36 µm, respectively, whereas the corresponding median diameters at 30 m from the source were 42 µm and 24 µm (average of all three air velocities), respectively. A significant difference with various air velocities is not evident. This is not surprising because the mean diameters of both rock and coal dust do not differ statistically with air velocity at the 30-m location, as shown in figure 6. Some inconsistencies were evident in the 2.0 m/s test; this was caused by low batteries (this was the last of the three tests conducted).

The small variations in the α's are most likely attributed to the measurement errors in calculating the loading density. Significant variations in the loading densities were observed between the three trays placed 20 cm apart used to determine the minideposit loading density. These variations are most likely caused by a nonuniform cross-sectional deposition of the dust due to a nonuniform distribution of turbulence.

MATHEMATICAL SIMULATION

Using the mean values of the α's, respective tolerances, and equations 1 through 4, a Monte Carlo simulation of the FDDM was undertaken. The simulation estimated the error in the total mass fraction of rock dust in the stratified deposits for a cyclic deposition of coal dust and rock dust. The simulation assumed that the α's are normally distributed with means and confidence intervals equal to the measured values, i.e., rock dust 0.14 ± 0.02 and coal dust 1.35 ± 0.24. For the simulation, the value of Φ required to turn on the trickle duster was set at 0.05 and the value to turn off the duster was 0.55, which should result in an 80 wt-pct rock dust mixture. Figure 10 shows the results of the simulation. The shaded area brackets the solution shown as the solid line and indicates the total mass fraction of rock dust in the stratified mixture. This is plotted as a function of the combined loading density of coal dust and rock dust as the cyclic deposition progressed. The simulation was run 20 times for 10 cycles; the error in total mass fraction of rock dust after the 10th cycle was found to be ±3%. The plot shows that, even taking into consideration the variability of the α's, the meter performs within acceptable limits.

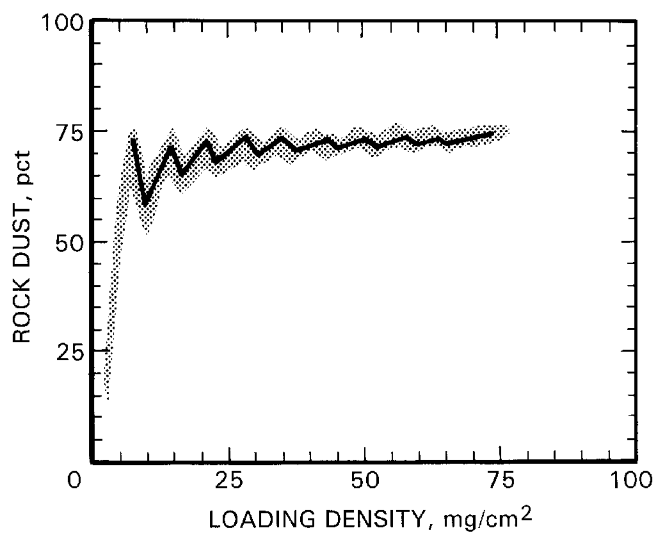

Figure 10.—95% confidence band of total mass fraction as a function of the combined rock dust/coal dust loading density over a simulated 10 cycles.

CONCLUSIONS

An FDDM designed to monitor the mass of float coal dust depositing in underground coal mine passageways and to automatically control a rock-dusting machine has been successfully tested under full-scale conditions. The test demonstrated that the unit is reproducible and capable of maintaining the total rock dust concentration in the deposited dust downwind of the source well within acceptable limits.

Still to be resolved is the technique to determine the correct α's for installing the meter. Currently, the determination of the constants requires making parallel measurements of loading density and surface reflectance under actual operating conditions, i.e., rock dust dispersal techniques and float coal dust generation during typical mining operation, at the desired meter location. Further studies are being discussed that will focus on determination of α's relative to given dust properties, such as median diameter, density, and reflectance of pure material.

ACKNOWLEDGMENTS

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REFERENCES

Cortese RM, Sapko MJ, Perlee H [1992]. Automated rock dusting controllers. In: Proceedings of the IEEE-Industrial Applications Society Annual Meeting, pp. 2034-2040.

Fink ZJ [1975]. Agglomeration of particles flowing down a vertical duct. Powder Technology *12*:287-289.

Sapko MJ, Pinkerton JE, Bubash JR [1988]. Optical dust deposition meter. IEEE Transactions on Industry Applications *24*(3):508-513.

Triebsch GF, Sapko MJ [1990]. Lake Lynn Laboratory: a state-of-the-art mining research laboratory. In: Proceedings of the International Symposium on Unique Underground Structures. Chapter 75, pp. 75-1 to 75-21.

Weiss ES, Greninger NB, Sapko MJ [1989]. Recent results of dust explosion studies at the Lake Lynn experimental mine. In: Proceedings of the 23rd International Conference of Safety in Mines Research Institutes. Washington, DC: pp. 843-854.

Woods T, Sapko MJ, Perlee H [1988]. Analog optical rock dust meters. In: Proceedings of the IEEE-Industrial Applications Society Annual Meeting, pp. 1272-1276.

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