Comparison of Surface Coal Mine Respirable Dust Concentrations Measured With MRE and Personal Gravimetric Sampling Equipment

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COMPARISON OF SURFACE COAL MINE RESPIRABLE DUST CONCENTRATIONS MEASURED WITH MRE AND PERSONAL GRAVIMETRIC SAMPLING EQUIPMENT

by

J. J. Alvarez,[1] T. F. Tomb,[2] R. R. Gadomski,[3] and J. L. Custer[4]

ABSTRACT

All coal mine respirable dust concentrations measured with approved personal respirable dust sampling instruments are converted to equivalent MRE sampler concentrations by multiplying by the factor 1.38. This conversion factor was determined from comparison measurements made in underground coal mine environments.

This report describes the results of the Mine Safety and Health Administration's (MSHA) sampling of surface mining operations to determine if 1.38 is a valid factor for converting surface coal mine dust samples collected with approved personal samplers to equivalent MRE concentrations.

Comparative measurements were obtained with the MRE and personal gravimetric dust samplers at a variety of surface mining operations and coal preparation plants. Regression analysis was used to derive a relationship between measurements obtained with the MRE and personal respirable dust samplers. The factor derived for surface measurements was within 9 percent of that derived for underground measurements. It was concluded that 1.38 is the most applicable factor to use for converting personal respirable dust measurements to equivalent MRE measurements.

[1]Formerly mining engineering technician, Dust Branch, Technical Support, Pittsburgh, Pa.

[2]Chief, Dust Branch, Technical Support, Pittsburgh, Pa.

[3]Industrial hygienist, Dust Branch, Technical Support, Pittsburgh, Pa.

[4]Director, Occupational Safety and Health, Solar Fuel Division, Gulf and Western Industries, Inc., Somerset, Pa. (formerly an industrial hygienist with the Dust Branch).

INTRODUCTION

The current respirable dust standard for the active workings of coal mine environments is 2.0 milligrams per cubic meter of air. The reference instrument for making a determination with respect to this standard is the MRE[5] instrument. However, the Federal Mine Safety and Health Act of 1977 authorizes the Secretary of Labor to approve other sampling devices. For a device to be considered as an alternate sampling device, it must first be demonstrated that measurements obtained with it yield equivalent concentrations. Currently, nearly all coal mine respirable dust concentration determinations are obtained with personal respirable dust sampling instruments approved under Part 74 of Title 30, Code of Federal Regulations. Concentration determinations obtained with these instruments are converted to equivalent MRE concentrations by multiplying by the constant factor 1.38.[6]

The 1.38 factor was established from simultaneous measurements obtained in underground coal mines with approved personal respirable dust samplers and the MRE. All of the simultaneous measurements were made on continuous or conventional mining sections with the instruments located within 3 feet of the mining or cutting machine operators.

Because various investigators[7] have demonstrated that this factor may vary if there is a significant variation in the particle size distribution of the aerosol sampled, and because the size distribution of dust aerosols generated during surface coal mining operations can be significantly different from those generated during underground operations, a program was conducted to determine the validity of using the 1.38 factor for converting measurements obtained with approved personal respirable dust samplers to equivalent MRE measurements. This report describes the sampling program conducted at surface mining operations and surface installations of underground coal mines to establish the validity of the 1.38 conversion factor.

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[5]Isleworth Model 113A, four-channel, horizontal elutriator gravimetric respirable dust sampling instrument developed at the Mining Research Establishment of the National Coal Board, Isleworth, England.
Reference to specific makes of equipment is made for identification purposes only and does not imply endorsement by the Mine Safety and Health Administration.

[6]Tomb, T. F., et al. Comparison of Respirable Dust Concentrations Measured With MRE and Modified Personal Gravimetric Sampling Equipment. BuMines RI 7772, 1973, 29 pp.

[7]Lynch, J. R. Evaluation of Size-Selective Presamplers: I. Theoretical Cyclone and Elutriator Relationships. Am. Ind. Hyg. Assoc. J., v. 31, 1970, p. 548.
Caplan, K. J., et al. Performance Characteristics of the 10-mm Cyclone Respirable Mass Sampler: Part 1--Monodisperse Studies. Am. Ind. Hyg. Assoc. J., v. 38, 1977, p. 83, and Part 2--Coal Studies. Am. Ind. Hyg. Assoc. J., v. 38, 1977, p. 162.
Moss, O. R., and H. J. Ettinger. Respirable Dust Characteristics of Polydisperse Aerosols. Am. Ind. Hyg. Assoc. J., v. 31, 1970, p. 546.

PROCEDURES

Sampling packages, of the type shown in figure 1, containing one MRE and two personal sampling instruments were located at a variety of surface mining operations. All instruments were calibrated prior to sampling following procedures published in Bureau of Mines Information Circular 8503. The MRE and personal respirable dust sampling instruments were calibrated to sample at 2.5 and 2.0 liters of air per minute, respectively.

The packages were located in work areas suspected of having average full-shift dust concentrations in excess of 1.0 mg/m^3 (MRE equivalent concentration). Generally, this was in the area of drills, shovels, bulldozers, and in preparation plants. Where possible, the packages were positioned on the equipment adjacent to or in front of the operator within 3 feet of his breathing zone. In areas such as preparation plants where men did not customarily work a full shift, the instruments were located to sample the highest dust concentration. All samples were collected during a full production shift. Filter cassettes

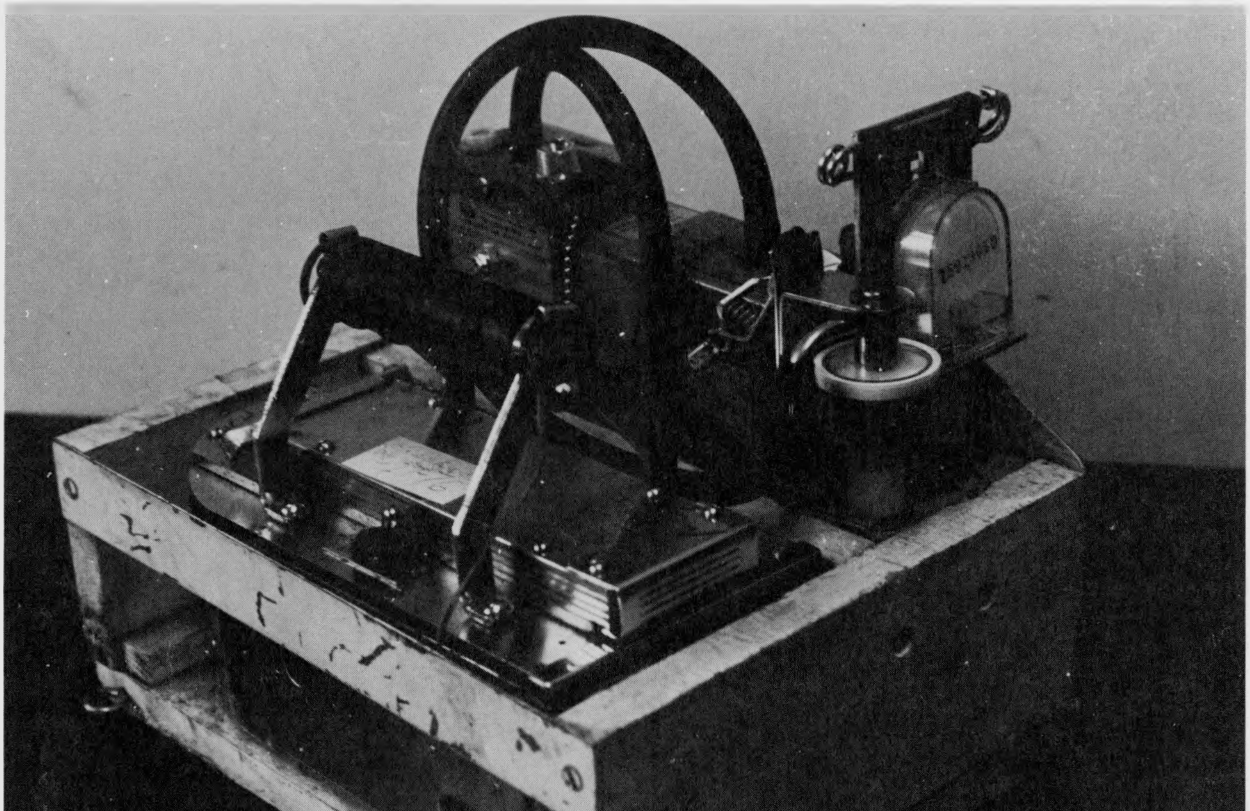

FIGURE 1.- Sampling package containing MRE and two personal sampling instruments.

were pre- and post-weighed to 0.01 mg on a Mettler Model HE20 electronic balance. Environmental concentrations, for the respective measurements, were calculated using the following formula:

$$C = \frac{1,000 W}{F X T},$$

where C = dust concentration, milligrams per cubic meter,

W = net mass of dust on filter, milligrams,

F = appropriate instrument flowrate, liters per minute,

and T = duration over which sample was collected, minutes.

Nineteen total dust samples representing five different operations were particle sized with a Model T Coulter Counter using an analytical technique previously described.[8] A 50-micrometer aperature tube was used on the Coulter Counter to classify particles ranging from 0.79 to 25.4 micrometers in size into 15 particle size intervals.

TREATMENT OF DATA

Tables 1 and 2, respectively, depict the comparative concentration measurements obtained at the various operations. Initially, respirable samples collected at the various operations were subjectively divided into two categories for analysis, coarse and fine. This was done to ascertain if dust clouds generated by different operations would have a significant effect on the factor derived. The coarse category contained samples from operations that typically generate dust clouds with a higher percentage of coarse particles. Coarse particles, in this case, are defined as particles in the 5 to 10 micrometer size range. Operations in this category included high wall drilling, crushing, screening and cleaning, and coal tipples. Comparative measurements in the fine category were, in general, from samples collected on earth and coal moving equipment.

TABLE 1. - Respirable dust concentrations categorized as containing a high percentage of coarse dust particles

Type of operation	Concentration, mg/m^3		
	MRE	Personal No. 1	Personal No. 2
B. E. drill	3.60	2.30	2.60
Do	3.30	1.60	1.90
Rotary breaker	.80	.60	.60
Tail end of belt take up drive--tipple	.90	-	.60
Rail car shake out	.70	.80	.70

[8]Tomb, T. F., and Lewis D. Raymond. Evaluation of the Penetration Characteristics of a Horizontal Plate Elutriator and of a 10-mm Nylon Cyclone Elutriator. BuMines RI 7367, 1970, 9 pp.

TABLE 1. - Respirable dust concentrations categorized as containing a high percentage of coarse dust particles--Continued

Type of operation	Concentration, mg/m^3		
	MRE	Personal No. 1	Personal No. 2
Vibrator room	1.30	1.40	1.30
Air tables	.60	.40	.40
Auger	.26	-	.26
B. E. 40-R diesel operated highwall drill	.44	.23	.16
Screen house raw coal exit	.51	.27	.49
Tripper--top of blending bin	.82	.41	.74
Loading plant--#2 dried coal belt	1.25	1.05	-
Screen building--heat drier shaker	2.13	1.31	1.66
Tipple building--crusher	5.64	3.99	5.56
Tipple--shaker room	.49	.20	.44
Secondary crusher	4.75	3.31	-
Primary crusher	5.97	4.47	-
Do	2.03	1.44	1.77
Secondary crusher	.75	.67	.51
Tipple--shaker room	.56	.59	.50
Bottom--primary crusher	1.25	1.05	-
Top--primary crusher	1.65	1.38	-
Bottom--primary crusher	1.37	.98	1.27
Top--primary crusher	1.35	1.10	-
Chicago pneumatic drill operator controls	.24	.20	.25
Air tables	4.52	2.06	2.35
Refuse belt	4.58	4.30	4.84
Control room--outside about 5 feet	4.26	3.52	3.70
Air tables	3.83	2.92	3.13
Control room--outside about 5 feet	4.00	3.13	-
Type D Roto-clone highwall drill	3.88	3.02	3.75
Davey highwall drill	3.92	2.80	2.80
Do	1.48	1.35	1.48
Auger conveyor--carrying coal	.29	.24	.12
Chicago pneumatic highwall drill	1.62	1.43	1.31
Highwall drill	.28	.24	.12
Refuse and clean coal belt area of prep. plant	2.64	-	2.88
Adjacent to operator's control panel	1.89	-	1.06
Refuse and clean coal belt area of prep. plant	1.44	.60	.96
Adjacent to operator's control panel	2.14	.84	1.57
Air tables	2.84	1.10	1.59
Refuse and clean coal belt area of prep. plant	2.78	1.63	-
Air tables	3.68	1.41	2.24
Refuse and clean coal belt area of prep. plant	1.67	1.36	1.60
Adjacent to operator's control panel	3.17	1.48	2.59
Air tables	3.80	-	1.86
#4 filters and #6 dryers of water treat. plant	.91	.81	.48
Do	.91	.65	.48
Crushing platform--tipple	.64	.28	.31
Screening area near picking table	2.03	1.47	1.53
Filter floor in screening room	.93	.65	.50

TABLE 2. - Respirable dust concentrations categorized as containing a high percentage of fine dust particles

Type of operation	Concentration, mg/m³		
	MRE	Personal No. 1	Personal No. 2
Set at prep. plant operator loader panel[1].........	0.50	0.40	0.20
Set on electrical panel (control room)[1]...........	.40	.30	.30
Cab--D-9 caterpillar dozer........................	1.80	1.60	-
Cab--caterpillar 992 front-end loader.............	.80	-	.60
Cab--caterpillar D-9G dozer.......................	1.50	-	1.20
Cab--caterpillar D-9G dozer (track)...............	.20	.10	-
Cleaning plant control panel......................	.81	.57	.59
Caterpillar 637 pan...............................	3.30	2.80	1.96
Do..	3.88	2.92	2.91
Bucyrus Erie shovel (track) loading earth.........	.49	.48	.48
Caterpillar 621 B-series carry-all (wheel base) loading earth..................................	.47	.18	.35
Cab--caterpillar D-9G dozer (track) moving earth..	.37	.40	.33
Tipple control panel room[1]......................	.12	.12	-
B. E. 195-B shovel[1].............................	.10	-	.08
Dart 600 loader[1]................................	.69	.65	-
B. E. 195-B shovel[1].............................	.14	.10	.14
191 Marion shovel (pit area)[1]...................	.20	.08	.09
Cab--dragline[1]..................................	.25	-	.18
Cab--caterpillar D-9G dozer--moving earth.........	.70	.53	.78
Cab--caterpillar 6B1-B pan--moving earth[1].........	.34	.30	.35
Cab--caterpillar D-9G dozer--moving earth[1].......	.34	.33	.36
Cab--613-B caterpillar pan--moving earth[1].........	.13	.10	.18
Do.[1]..	.12	.09	.08
Cab--613-B caterpillar pan--moving earth..........	.26	.13	.15
Open cab--D-9G caterpillar dozer (track)..........	.53	.22	.36
Cab--980-B front-end loader--wheel base loading coal..	1.15	.48	.86
Cab--922-B caterpillar wheel loader--moving earth.	.20	.25	.25
Cab--caterpillar D-9G track dozer--moving overburden...	1.51	.47	-
Cab--mountaineer P. T. bulldozer--moving overburden...	.78	.49	-
Cab--caterpillar 992 front-end loader (wheel base)	.49	.48	.24
Bulldozer 7117 moving overburden..................	.52	.43	.33
Caterpillar D-9G track dozer[1]...................	.00	-	.00
B. E. 195-B shovel[1].............................	.10	.10	.10
Cab--caterpillar 922-B wheel loader--moving earth[1]	.00	.00	-
Cab--613-B caterpillar pan--moving earth[1].........	.20	.10	.10
Cab--dragline[1]..................................	.80	.60	.48

[1]Denotes samples collected in enclosed cabs.

The empirical relationship between personal respirable dust samples and MRE measurements was derived using the method of least squares, the same statistical treatment of data employed to derive the 1.38 factor.[9] The standard error of estimate, $S_{y/x}$, and the correlation coefficient, r, were also calculated and used to assess the degree of variability about the regression line and the degree of linearity between the variables, respectively.

DISCUSSION OF RESULTS

The parameters characterizing the linear relationships derived for the coarse and fine categories are shown on table 3. A comparison of these relationships shows that the intercepts and slopes derived for the coarse and fine categories are different. Because respirable coal mine dust samples are normally weighed to an accuracy of 0.1 mg/m^3, enough zero pairs of data were added to force the intercept, a, of the regression line derived for the coarse category to be 0.1. This raised the respective slope for the coarse category regression line from 1.16 to 1.25. The regression equation for the fine category was not normalized because its intercept was less than 0.1.

TABLE 3. - Statistical relationships derived from data to compare surface respirable dust concentrations measured with MRE and personal gravimetric sampling equipment

Category	Relationships	Parameters
Coarse	Equiv. MRE = 0.31 + 1.16 Pers.	n = 89 r = 0.93 $S_{y/x}$ = 0.57
Fine	Equiv. MRE = 0.02 + 1.30 Pers.	n = 62 r = 0.97 $S_{y/x}$ = 0.20
Coarse, normalized	Equiv. MRE = 0.10 + 1.25 Pers.	n = 164 r = 0.96 $S_{y/x}$ = 0.44
Fine, closed cab	Equiv. MRE = 0.01 + 1.18 Pers.	n = 28 r = 0.93 $S_{y/x}$ = 0.08
Fine, all other	Equiv. MRE = 0.05 + 1.29 Pers.	n = 34 r = 0.97 $S_{y/x}$ = 0.26
Combined coarse plus fine, all other.	Equiv. MRE = 0.22 + 1.20 Pers.	n = 123 r = 0.94 $S_{y/x}$ = 0.51
Combined coarse plus fine, all other normalized.	Equiv. MRE = 0.10 + 1.25 Pers.	n = 184 r = 0.96 $S_{y/x}$ = 0.43

[9] Work cited in footnote 6.

Because the slope derived for the fine category of dust was significantly greater than that derived for the coarse category (theoretically, it would be expected to be less), the data for the fine category were further analyzed by dividing them into the following two categories for statistical treatment:

1. Comparative measurements obtained in enclosed cabs; and

2. All other comparative measurements.

The relationships derived for these categories are also depicted on table 3. As would be expected, the slope (1.18) of the regression line derived for comparative measurements obtained in enclosed cabs was significantly lower than the one (1.29) derived from "all other measurements" in the fine category. This indicates that the mass distributions of the dust clouds in enclosed cabs are different than those found in unenclosed cabs. In addition, a comparison of respirable dust concentrations measured with the MRE in the two previously mentioned categories shows that the average respirable dust concentration in enclosed cabs is approximately 25 percent of the average concentration for "all other measurements" in the fine category. The data used to calculate the average concentration for respective categories are shown on table 2. The significantly lower average concentration found in enclosed cabs was statistically confirmed using the "Student-t"[10] test for independent populations with different standard deviations. Therefore, data collected in enclosed cabs were not used in establishing the relationships for the fine category.

Because the slope of the regression line derived for the fine category was similar to the slope derived for the normalized (intercept forced to be 0.1) coarse category regression line, all measurements except those obtained in enclosed cabs were used to establish the relationship for surface coal mine measurements. This relationship, along with its correlation coefficient and standard error of estimate is shown on table 3. The normalized relationship, obtained after the intercept was forced to be 0.1, is also shown on this table.

The validity of this relationship was confirmed by comparing it to a theoretical relationship derived using mass distribution data representative of surface coal mine environments and the respective sampling characteristics of the MRE and personal respirable dust samplers. The curves on figure 2 show the mass distribution representative of the total dust aerosol found in surface mine environments and the fraction of that distribution that would penetrate the first stage collectors of the MRE (curve designated "a") and personal (curve designated "b") respirable dust samplers. In constructing the mass distribution for surface mines a particulate density of 2.6 grams per cubic centimeter was assumed. This assumption was based on the fact that dust generated during surface mining operations was more likely to contain rock rather than coal dust particles. The theoretical relationship was obtained by comparing the areas under curves "a" and "b." The theoretically derived relationship of 1.23 agrees with the empirically derived relationship 1.25 (the slope of the normalized regression line).

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[10]Crow, Edwin L., et al. Statistics Manual. Dover Publications, Inc., New York.

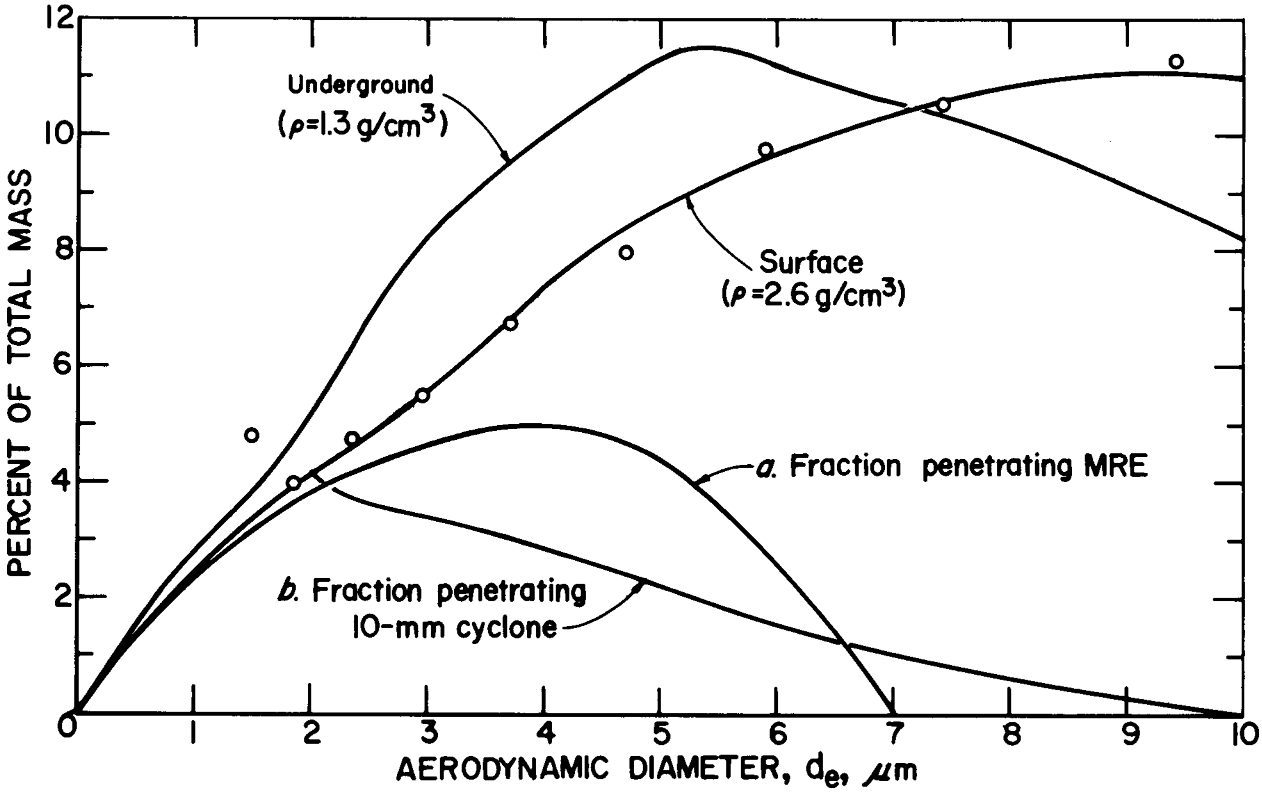

FIGURE 2. - Theoretical comparison of respirable mass penetration curves.

Also depicted on figure 2 is an average mass distribution derived from measurements obtained in underground coal mines. A comparison of the distributions shows that the percentage of fines (<7 micrometers in size) in the underground distribution is greater than in the surface distribution. However, it must be realized that the magnitude of this difference is dependent on the density of the aerosol. If a density of 1.32 grams per cubic centimeter had been assumed, there would be very little difference depicted between the underground and surface mass distributions. It should be noted that the mass distributions were derived for particles up to 25.4 micrometers; however, only data up to 10 micrometers were plotted and used in deriving the theoretical factor. Data beyond 10 micrometers have no impact on the relationships derived because no particles greater than 10 micrometers penetrate the first stage collectors of the MRE or personal respirable dust samplers.

The "Student-t" test was used to test the significance of the difference between the factors derived for surface and underground measurements. The regression coefficients (slopes of the derived regression lines) for both the unnormalized and normalized relationships were tested. The statistical tests showed that at a significance level of 5 percent there was no significant difference in the regression coefficients of 1.20 (surface) and 1.17 (underground) for the unnormalized relationships. A significant difference was found for the regression coefficients (1.25 for surface and 1.38 for underground) of the normalized relationships. However, it is believed that the significance of this difference is artificial because it would be affected by the number of zero pairs that were required to be added. The underground data required a much larger number of zero pairs to be added in order to force the intercept of the regression equation to be 0.1 mg.

SUMMARY AND CONCLUSIONS

This study was conducted to determine if the constant factor (1.38) derived from underground measurements is the most appropriate factor to use when converting measurements obtained with personal respirable dust sampler units to equivalent dust concentrations as measured with an MRE instrument.

Environmental measurements representing a variety of surface coal mine operations were obtained simultaneously with the MRE and personal respirable dust sampling instruments. An empirical relationship derived from statistical treatment of the data was compared to a factor theoretically derived by comparing the calculated mass penetration for the respective sampling instruments using an average mass distribution derived from samples collected in a number of surface mine environments.

The results of the study showed that the factor derived from comparing surface measurements obtained with an MRE and a personal respirable dust sampler is 1.25. This factor is approximately 9 percent lower than the 1.38 factor derived for underground measurements. The data also showed that the relationship derived for measurements obtained in enclosed cabs would yield MRE concentrations 10 percent less than those derived using the factor 1.25. Although this limited study indicates that 1.18 or 1.25 may be more appropriate factors to use for measurements obtained in enclosed cabs and other surface measurements, respectively, it is concluded that the 1.38 factor should continue to be used for surface measurements because:

1. The difference in underground and surface aerosol mass distributions cannot be accurately quantitated due to the wide variation in the density of surface mine dust clouds;

2. The quantity of data used to derive the 1.25 factor is much more limited than that used to establish the 1.38 factor; and

3. Use of the 1.38 factor provides maximum health protection.

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