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Determination of Alpha Quartz Particle Distribution in Respirable Coal Mine Dust Samples and Reference Standards

By C. W. Huggins, S. N. Johnson, J. M. Segreti, and J. G. Snyder

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The objective of this Bureau of Mines research was to compare the size distribution of respirable quartz collected at coal mines with that of several reference standards used to quantify quartz in coal mine dust samples. Particle size measurements were made on 23 samples and 4 reference standards using a scanning electron microscope in the backscatter electron mode of operation, interfaced with an image analysis system. The Mine Safety and Health Administration provided the 23 respirable coal mine dust samples, which were collected at surface and underground coal mines in 7 States. The accumulated particle size measurements indicate three of the reference standards, minus 5-μm Min-U-Sil, minus 5-μm Supersil, and NBS 1878, would be preferred over the fourth, Silver Bond B, for quantitative quartz determinations in coal mine dusts by X-ray diffraction and infrared spectrometry.

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UNIT OF MEASURE ABBREVIATIONS USED IN THIS REPORT

cm	centimeter	mg/m^3	milligram per cubic meter
h	hour	µm	micrometer
kHz	kilohertz	pct	percent
kV	kilovolt	s	second

DETERMINATION OF ALPHA QUARTZ PARTICLE DISTRIBUTION IN RESPIRABLE COAL MINE DUST SAMPLES AND REFERENCE STANDARDS

By C. W. Huggins,[1] S. N. Johnson,[2] J. M. Segreti,[3] and J. G. Snyder[3]

ABSTRACT

The objective of this Bureau of Mines research was to compare the size distribution of respirable quartz collected at coal mines with that of several reference standards used to quantify quartz in coal mine dust samples. Particle size measurements were made on 23 samples and 4 reference standards using a scanning electron microscope in the backscatter electron mode of operation, interfaced with an image analysis system. The Mine Safety and Health Administration provided the 23 respirable coal mine dust samples, which were collected at surface and underground coal mines in 7 States. The accumulated particle size measurements indicate three of the reference standards, minus 5-μm Min-U-Sil, minus 5-μm Supersil, and NBS 1878, would be preferred over the fourth, Silver Bond B, for quantitative quartz determinations in coal mine dusts by X-ray diffraction and infrared spectrometry.

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INTRODUCTION

The Federal Coal Mine Health and Safety Act of 1969 established a maximum level for the exposure of coal mine workers to respirable dusts and authorized research on development of new or improved methods of reducing the concentration of respirable dust in the mine atmosphere of active coal mine operations. Effective December 30, 1972, this standard was set at 2.0 mg/m^3 total dust for each 8-h shift. When the respirable dust contains more than 5 pct quartz, the respirable dust standard is adjusted to a lower amount dependent on the concentration of quartz present. One mission of the Bureau of Mines is to conduct research on the control and measurement of coal mine dust. Medical responsibility is appropriated to the National Institute of Occupational Safety and Health. Enforcement of coal mine safety regulations since 1978 has been the responsibility of the Mine Safety and Health Administration (MSHA).

Respirable coal mine dust is the portion of airborne dust that penetrates the deepest portion of the lungs and is generally considered to be particles less than 10 μm in size. The respirable quartz particles in these dusts are the cause of "silicosis," the major contributor to "black lung" disease. Compensation cost for "black lung" is approximately $1.9 billion per year (1).[4]

Dust conditions in coal mines have improved owing to new methods of dust control but still need to be monitored. Approximately 40,000 respirable dust samples are collected by inspectors annually. The quartz content in these samples is determined by either infrared spectrophotometry or X-ray diffraction. Both methods require quartz reference standards for quantitative measurement of quartz in the coal mine dusts. The response of both methods is a function of the particle size (2-4, 6). Joint studies by the Bureau and MSHA show that inaccuracy in quantitative quartz values may be as much as 30 pct when the particle size distribution of the quartz standard varies significantly from that of the coal mine dust. It is, therefore, essential that the particle size distribution of both the respirable quartz standards and the coal mine dust be established in order to select the appropriate quartz reference standard to provide an accurate determination.

The objective of this research was to determine the particle size distribution of quartz in respirable quartz standards and in coal mine dust samples collected from surface and underground coal mines. From these data, a better match of standard to coal dust should be achieved. Twenty-three respirable dust samples collected at surface and underground coal mines in seven States were provided by MSHA, Pittsburgh, PA, for this investigation. The quartz reference standards used for this research were minus 5-μm Supersil, minus 5-μm Min-U-Sil, Silver Bond B, and NBS 1878.

Supersil is supplied by the Pennsylvania Glass & Sand Co., Berkeley Springs, WV, as minus 325-mesh material. It was wet-sieved at MSHA, Pittsburgh, PA, to obtain a minus 5-μm material. Minus 5-μm Min-U-Sil, also from Pennsylvania Glass and Sand Co., was used as received. Because minus 5-μm Min-U-Sil is commercially available, and similar to the quartz found in most respirable dust samples, many laboratories use it as their reference standard. The Silver Bond B, obtained from Tammsco Inc., Tamms, IL, was prepared by sedimentation at MSHA, Denver, CO, to contain only particles smaller than 10 μm.

NBS 1878 has been available since late 1983. To prepare this standard, NBS has taken minus 5-μm Min-U-Sil and slightly improved the purity of the quartz. During purification, some of the very fine quartz particles may have been lost. The crystalline purity reported by NBS is 95.5±1 wt pct crystalline alpha quartz. The mass mean spherical diameter is 1.62 μm.

[4]Underlined numbers in parentheses refer to items in the list of references at the end of this report.

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The authors are indebted to Heidi Triantafillou, former research chemist, Avondale Research Center, for experimental work done in support of this publication, and to Samuel A. Goldberg and Thomas F. Tomb of the Pittsburgh Technical Support Center, Mine Safety and Health Administration, Pittsburgh, PA, for supplying the respirable coal mine dust samples.

SAMPLE PREPARATION

The coal mine dust samples were received from MSHA on Gelman[5] DM-450 polyvinyl chloride membrane filters after MSHA had quantitatively determined the quartz content of the dust samples by infrared spectroscopy. These samples, taken directly from coal mines for regulatory purposes, had previously been low-temperature-ashed and redeposited by MSHA from the original air monitoring collection filters. Sample preparation for image analysis was similar to that described by Snyder and Huggins (5). Wedge-shaped pieces, approximately one-eighth of each filter, were cut and low-temperature-ashed to remove the organic-based filter. The remaining ash was subsequently suspended in isopropyl alcohol, ultrasonicated at 80 kHz for 10 min, and deposited on a 0.2-μm Nuclepore filter. Two rectangular pieces, approximately 1 by 1.5 cm, were cut from each Nuclepore filter sample and mounted with carbon paint on scanning electron microscope (SEM) stubs. The samples were carbon-coated in a vacuum evaporator prior to measurement.

IMAGE ANALYSIS

Size distributions were determined using an Amray model 1400 SEM equipped with a LeMont Scientific Model DB-10 image analysis system and a Kevex model 8000 energy dispersion X-ray analysis system (EDS). The SEM was operated at 20 kV. The backscatter electron mode of operation in the SEM was utilized to provide the best contrast between particles and filter substrate and consequently enhanced gray level differences in the video signal of the image analyzer. The contrast "threshold" level in the image analyzer was set just above background to ensure measurement of all particles. Once a particle is detected in the binary image of the image analyzer, it is sized by deflection of the electron beam in a series of horizontal, vertical, and diagonal movements. The off-point density was set at 256 to ensure location of particles 0.20 μm or larger on the 10-cm cathode ray tube screen. The on-point density, used for particle measurement, was set at 1,024, thus achieving a particle measurement precision of plus or minus one "on point" spacing of 0.044 μm. All particles in the 45-μm^2 field of view were measured. Sizes were measured on every fifth field of view at a magnification of 2,000. Magnification calibration was performed with a Ladd Research Institute 15,240-line-per-inch carbon grating using a magnification calibration program provided by LeMont Scientific.

Following each particle sizing, an X-ray spectrum was acquired at the geometric center of the particle until a preset integral of the 750 net X-ray counts was reached or a maximum X-ray acquisition time of 10 s was met. Windows for the detection of elements commonly present in respirable coal mine minerals were set in the EDS multichannel analyzer, thus monitoring the elements Al, Ca, Fe, K, Mg, Na, S, Si, and Ti. A minimum of 30 X-ray counts was required for an element to be considered present. The particles were categorized into two classes by a chemistry definition file, and the information

[5]Reference to specific products does not imply endorsement by the Bureau of Mines.

was stored on diskette. A particle was classified as quartz if 80 pct or more of the total X-ray count was due to silicon. All other particles were classified as miscellaneous. Approximately 400 quartz particles were measured in each sample.

RESULTS

Table 1 shows the results of particle measurements on the 4 reference standards and 9 underground coal mine dust samples taken from mines in Virginia, West Virginia, and Kentucky; table 2 shows data for the 14 surface coal mine dust samples taken from mines in Virginia, West Virginia, Pennsylvania, Ohio, Indiana, and Tennessee. The particle size distributions in these tables are a function of the particle frequency percentage based upon particle lengths in each sample. The particle lengths were taken as the maximum measured particle diameter in micrometers. Particles smaller than 0.3 µm were not measured as most of them were lost in the MSHA sample preparation onto Gelman DM-450 filters, which have a pore size of 0.45 µm.

The surface coal mine dusts contained slightly more particles in the larger size ranges than were found in the underground coal mine dusts. This can be seen in the particle size range of 4.2 to 9.6 µm. The average frequency percent of particles in this size range for the underground coal mine samples is 2.7±1.7 pct, whereas 6.4±3.7 pct was found for the surface mine samples examined in this study. Few of the 400 quartz particles measured in each sample were larger than 9.6 µm. Three of the nine underground mine samples and 4 of the 14 surface mine samples have 1 particle, i.e., 0.25 pct of their total particles, larger than 9.6 µm. The distributions in particle size ranges less than 4.2 µm are very similar for all samples and for the reference standards.

An examination of the four reference standards in the particle size range of 4.2 to 9.6 µm shows that Silver Bond B has approximately 62 pct of its particles in this size range (table 1); approximately 3.5 pct of the Silver Bond B particles are larger than 9.6 µm. In comparison, the minus 5-µm Supersil, the minus 5-µm Min-U-Sil, and the NBS 1878 reference standards exhibit, respectively, 2.2, 2.8, and 4.5 pct of their total particles in the 4.2- to 9.6-µm size range. Supersil has no particles larger than 9.6 µm, minus 5-µm Min-U-Sil has 0.25 pct total particles larger than 9.6 µm, and the NBS 1878 standard has 0.50 pct larger than 9.6 µm.

Tables 1 and 2 also show the mean quartz particle sizes, length and diameter, observed in each of the surface and underground coal mine samples; there are no significant differences between surface and underground particle sizes.

Table 3 compares the average quartz particle lengths and diameters of the reference standards with the means for the surface and underground respirable coal mine dust samples. The overall mean quartz particle length for surface coal mine dusts is 0.3 µm larger than for underground dust samples, and the overall mean diameter for the quartz is 0.24 µm larger in the surface mines.

Based on these quartz particle size distribution comparisons, the minus 5-µm Supersil, the minus 5-µm Min-U-Sil, and the NBS 1878 are all similar to the surface and underground coal mine dust samples. The silver Bond B reference standard has a significantly greater percentage of particles in the larger size ranges than any of the dust samples analyzed and, therefore, would not be a suitable reference standard for quartz in respirable coal mine dusts.

CONCLUSIONS

Surface and underground coal mine dust samples show only slight differences in particle size distribution. Samples collected from surface coal mines show a slightly larger quartz particle size distribution than those collected from underground mines. However, on the basis of particle size, neither can be

TABLE 1. - Quartz particle size distribution, quartz particle frequency (4.2-9.6 μm), and mean quartz particle size for underground coal mine samples and reference standards

	Frequency, pct												
	Underground coal mines									Reference standards			
	U1	U2	U3	U4	U5	U6	U7	U8	U9	R1	R2	R3	R4
Quartz length, μm:													
0.0- 0.3	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
0.3- 0.6	8.25	3.50	7.00	9.25	7.75	8.25	5.90	8.00	3.25	6.25	6.87	1.76	4.71
0.6- 0.9	22.25	13.50	18.00	23.25	22.75	20.75	22.05	24.75	16.00	18.75	28.33	4.62	13.40
0.9- 1.2	17.25	17.00	13.50	20.00	16.00	20.50	22.82	19.25	15.50	25.75	21.24	5.27	16.63
1.2- 1.5	15.50	12.75	12.00	11.00	14.50	19.00	13.33	14.25	14.00	15.00	14.16	5.49	11.66
1.5- 1.8	10.25	12.25	13.25	10.00	11.25	9.50	9.74	5.75	12.75	8.00	9.01	2.86	11.17
1.8- 2.1	7.25	7.50	7.00	4.75	8.50	6.25	6.67	6.25	6.25	7.50	5.36	3.30	10.17
2.1- 2.4	5.75	8.00	8.25	5.50	4.50	5.25	5.64	5.75	8.00	5.00	5.58	1.10	6.95
2.4- 2.7	4.25	4.75	4.50	5.00	5.75	4.00	2.82	5.75	5.25	4.00	2.15	.88	6.45
2.7- 3.0	2.50	3.50	4.00	3.25	2.00	2.75	2.05	2.75	3.50	2.25	1.07	1.32	3.47
3.0- 3.3	2.50	5.50	2.25	2.50	1.25	1.00	3.08	1.75	4.25	1.50	1.07	.44	3.72
3.3- 3.6	1.25	3.75	2.00	1.75	1.75	.25	2.31	1.50	2.00	1.50	1.72	1.98	1.49
3.6- 3.9	.75	2.25	3.50	1.25	.50	.25	1.28	1.25	1.75	.75	1.07	1.32	1.74
3.9- 4.2	1.00	.75	0	1.00	1.25	.50	.77	1.25	2.00	.75	.21	3.74	3.23
4.2- 4.5	.75	1.25	1.00	.50	.25	.25	.51	.50	.50	.25	0	4.18	.99
4.5- 4.8	0	.75	.75	.25	0	0	0	0	1.25	.25	0	8.13	.99
4.8- 5.1	0	1.50	.50	0	.25	.25	.51	.25	.25	.25	.21	6.59	.50
5.1- 5.4	.25	.50	.25	0	.75	0	0	0	1.50	.50	.43	7.03	.25
5.4- 5.7	0	0	.50	0	.25	.50	0	.25	.50	0	0	3.52	.50
5.7- 6.0	0	.25	.75	0	0	.25	.26	.50	.25	.25	.43	5.05	.25
6.0- 6.3	.25	.50	.25	.25	0	0	0	0	.75	0	.86	5.49	0
6.3- 6.6	0	0	.25	0	0	0	0	0	0	0	0	3.30	0
6.6- 6.9	0	0	0	.55	.25	.25	0	0	0	.25	0	3.52	.50
6.9- 7.2	0	0	.25	0	0	0	0	0	0	0	0	3.52	.25
7.2- 7.5	0	.25	0	0	.25	0	0	0	0	.50	0	1.98	0
7.5- 7.8	0	0	0	0	0	0	.26	0	.25	.25	0	1.76	0
7.8- 8.1	0	0	0	0	0	0	0	0	0	0	0	1.98	0
8.1- 8.4	0	0	0	0	0	0	0	0	0	0	0	1.32	0
8.4- 8.7	0	0	0	0	0	0	0	0	0	0	0	1.10	0
8.7- 9.0	0	0	0	0	0	0	0	0	0	.25	0	1.10	0
9.0- 9.3	0	0	.25	0	0	0	0	0	0	0	0	1.32	.25
9.3- 9.6	0	0	0	0	0	0	0	0	0	0	.25	1.32	0
9.6- 9.9	0	0	0	0	0	0	0	0	0	0	0	1.54	0
9.9-10.2	0	0	0	0	.25	0	0	0	0	0	0	.22	0
10.2-10.5	0	0	0	0	0	0	0	0	0	0	0	0	.50
10.5-10.8	0	0	0	0	0	0	0	0	0	0	0	.44	0
10.8-11.1	0	0	0	0	0	0	0	0	.25	0	0	.22	0
11.1-11.4	0	0	0	0	0	0	0	0	0	0	0	0	0
11.4-11.7	0	0	0	0	0	0	0	0	0	0	0	0	0
11.7-12.0	0	0	0	0	0	0	0	0	0	0	0	.22	0
12.0-12.3	0	0	0	0	0	0	0	0	0	0	0	.22	0
12.3-12.6	0	0	0	0	0	0	0	0	0	0	0	0	0
12.6-12.9	0	0	0	0	0	0	0	0	0	0	0	0	0
12.9-13.2	0	0	0	0	0	0	0	0	0	0	0	0	0
13.2-13.5	0	0	0	0	0	0	0	0	0	.25	0	0	0
13.5-13.8	0	0	0	0	0	0	0	0	0	0	0	0	0
13.8-14.1	0	0	0	0	0	0	0	0	0	0	0	.22	0
14.1-14.4	0	0	0	0	0	0	0	0	0	0	0	0	0
14.4-14.7	0	0	0	0	0	0	0	0	0	0	0	.22	0
14.7-15.0	0	0	0	0	0	.25	0	0	0	0	0	0	0
15.0-15.3	0	0	0	0	0	0	0	0	0	0	0	.22	0
Quartz frequency, 4.2-9.6 μm	1.25	5.00	4.75	1.55	2.00	1.50	1.54	1.50	5.25	2.75	2.18	66.21	4.48
Mean quartz length, μm	1.17	1.59	1.47	1.19	1.24	1.13	1.21	1.19	1.59	1.26	1.10	4.54	1.65
Mean quartz diameter[1], μm	0.94	1.31	1.18	0.93	0.98	0.87	0.95	0.91	1.27	0.97	0.87	3.53	1.31

ND Not determined. [1]Average of the 4 diagonals used for each particle measurment.

Underground coal mine identifications:
- U1--Tazco Inc., Laurel Mines #1, Doran VA.
- U2--Tandem Mining Corp. #1, Grundy, VA.
- U3--Ray Coal Co., Hazard, KY.
- U4--McClure River Coal Co., Inc., #1 Mine, Abingdon, VA.
- U5--Little Egypt Coal Co., Inc., #2 Mine, Raven, VA.
- U6--Doublecamp Branch Mine, Robinson Phillips Coal Co., Pineville, WV.
- U7--Eastern Association Coal Corp., Keystone #2 Mine, Herndon, WV.
- U8--Apple Tree Mining Co., Inc., #1 Mine, Whitesburg, KY.
- U9--Price Coal Co., Inc., #1, Hatfield, KY.

Reference standard identifications:
- R1--5-μm Min-U-Sil.
- R2--5-μm Supersil.
- R3--Silver Bond B.
- R4--NBS 1878.

TABLE 2. - Quartz particle size distribution, quartz particle frequency (4.2-9.6 μm), and mean quartz particle size for surface coal mine samples

	Frequency, pct													
	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14
Quartz length, μm:														
0.0- 0.3.....	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
0.3- 0.6.....	3.50	2.50	5.50	7.50	9.00	3.99	6.25	6.50	4.75	3.75	5.50	5.50	5.03	7.25
0.6- 0.9.....	13.50	14.25	15.75	22.50	24.75	18.95	18.50	15.50	18.75	12.00	9.50	11.25	11.56	17.50
0.9- 1.2.....	16.00	11.25	13.75	17.25	21.00	19.70	16.00	15.25	16.75	12.75	7.50	14.50	10.80	13.25
1.2- 1.5.....	12.00	12.00	15.50	15.25	13.00	14.96	12.50	9.50	13.75	10.00	12.00	13.50	9.80	12.25
1.5- 1.8.....	10.75	9.25	10.75	12.50	5.75	11.97	10.00	8.75	8.75	9.50	8.25	12.00	14.57	8.50
1.8- 2.1.....	8.25	10.00	5.75	4.75	7.75	10.72	11.50	7.50	8.00	7.00	6.50	9.25	11.06	8.75
2.1- 2.4.....	7.75	8.25	6.75	5.50	6.25	5.74	6.00	6.25	7.50	8.00	7.50	6.50	8.79	7.25
2.4- 2.7.....	5.25	6.75	5.25	4.00	3.75	3.99	5.25	7.00	6.00	9.00	6.25	5.25	7.04	4.75
2.7- 3.0.....	4.00	5.75	4.50	2.50	1.50	3.74	3.75	5.00	5.75	3.75	4.00	4.00	5.03	3.00
3.0- 3.3.....	4.50	5.00	5.00	1.75	2.00	1.50	4.25	5.75	3.00	6.25	5.50	3.50	4.52	3.00
3.3- 3.6.....	3.00	2.50	1.75	1.00	1.50	2.00	1.00	2.25	2.25	3.75	2.50	1.75	2.51	1.75
3.6- 3.9.....	2.75	1.50	3.00	1.00	1.00	.75	1.00	1.75	.75	2.50	6.25	1.75	1.26	1.25
3.9- 4.2.....	2.00	1.50	2.00	1.25	.25	.75	1.00	1.25	1.50	2.50	4.25	1.25	1.26	2.75
4.2- 4.5.....	1.00	2.25	.50	.75	.25	.25	.75	1.25	.75	1.25	3.25	1.25	1.76	1.75
4.5- 4.8.....	1.50	1.50	1.50	1.25	.25	.50	1.00	1.75	.25	2.00	2.75	.75	1.26	.75
4.8- 5.1.....	.75	1.75	1.25	.25	.25	.50	.25	1.00	.25	1.50	2.00	1.75	1.01	1.00
5.1- 5.4.....	.25	1.00	0	.25	.25	0	.50	.50	.25	1.00	2.75	1.50	.75	1.50
5.4- 5.7.....	.75	.50	.50	0	0	0	.25	1.00	0	.25	1.00	.75	.75	1.00
5.7- 6.0.....	.25	.50	.25	0	.25	0	0	.75	0	.50	1.50	.50	.25	.50
6.0- 6.3.....	.50	.50	.50	.25	.25	0	0	.75	.25	.25	.25	.50	.25	0
6.3- 6.6.....	.25	0	.25	0	.25	0	.25	0	0	.50	.25	.25	0	.75
6.6- 6.9.....	.50	.50	0	0	0	0	0	0	0	1.00	0	1.00	0	.25
6.9- 7.2.....	.25	.25	0	0	0	0	0	0	0	.25	.25	.25	.25	.25
7.2- 7.5.....	.50	0	0	0	.25	0	0	.25	.25	.25	.25	0	0	0
7.5- 7.8.....	0	.25	0	.25	0	0	0	0	0	.25	0	0	0	.50
7.8- 8.1.....	.25	0	0	0	0	0	0	.25	0	0	0	.75	.25	0
8.1- 8.4.....	0	0	0	0	.25	0	0	0	0	0	0	.25	0	0
8.4- 8.7.....	0	.25	0	0	0	0	0	0	.25	0	0	0	0	.25
8.7- 9.0.....	0	.25	0	0	0	0	0	.25	0	0	0	0	0	0
9.0- 9.3.....	0	0	0	.25	.25	0	0	0	0	0	0	0	0	0
9.3- 9.6.....	0	0	0	0	0	0	0	0	0	0	0	.25	0	0
9.6- 9.9.....	0	0	0	0	0	0	0	0	0	0	.25	0	0	0
9.9-10.2.....	0	0	0	0	0	0	0	0	0	0	0	.25	0	0
10.2-10.5.....	0	0	0	0	0	0	0	0	0	0	0	0	0	.25
10.5-10.8.....	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10.8-11.1.....	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11.1-11.4.....	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11.4-11.7.....	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11.7-12.0.....	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12.0-12.3.....	0	0	0	0	0	0	0	0	0	0	0	0	.25	0
Quartz frequency, 4.2-9.6 μm.....	6.75	9.50	4.75	3.25	2.50	1.25	3.00	7.75	2.25	9.00	14.25	9.75	6.53	8.50
Mean quartz length.....μm..	1.70	1.84	1.56	1.24	1.16	1.25	1.36	1.68	1.44	1.93	2.16	1.80	1.73	1.66
Mean quartz diameter[1]....μm..	1.35	1.45	1.20	1.00	0.92	1.00	1.08	1.33	1.15	1.54	1.77	1.36	1.43	1.30

ND Not determined. [1]Average of the 4 diagonals used for each particle measurement.

Surface coal mine identifications:

S1--U.S. Steel Mining Co. Inc. #50 surface, Chesapeake, WV.
S2--Stone Mountain Trucking Co. #1 strip, Appalachia, VA.
S3--Wilder Coal Co. #4 strip, Wise, VA.
S4--Solar Sources Inc. #2 strip, Petersburg, IN.
S5--Solar Sources Inc. #2 strip, Petersburg, IN.
S6--Shade Mining Co. #6 strip, Johnstown, PA.
S7--Sky Haven Coal Inc. Speedway #1 strip, Penfield, PA.
S8--Sidwell Bros. Inc. Sidwell-Muskingum, Zanesville, OH.
S9--Sidwell Bros. Inc. Sidwell-Muskingum, Zanesville, OH.
S10--Spradline Ewell Co. #1 strip, Lafollette, TN.
S11--PBS Coals Inc. #1 strip, Friedens, PA.
S12--Burchfield Mining Co. Inc. Burchfield #1 strip, Wise, VA.
S13--Sharon Coal Co. JR #2 strip, Reedsville, WV.
S14--Sharon Coal Co. JR #2 strip, Reedsville, WV.

significantly differentiated for choice of reference standard for quantitative quartz determination by X-ray diffraction and infrared spectrophotometry. Neither sample type is significantly different from minus 5-μm Supersil, minus 5-μm Min-U-Sil, and NBS 1878, all currently available as reference standards for quartz determination in respirable coal mine dusts. NBS 1878 and minus 5-μm Min-U-Sil would be preferred over minus 5-μm Supersil as they require no sizing preparation before usage. Silver Bond B is unsuitable as a reference standard for quantitative measurement of quartz in dusts collected from coal mines. The particle size distribution in Silver Bond B does not adequately match the size distribution of quartz particles found in the airborne coal mine dusts. Wet sieving of Silver Bond B to <5-μm would be necessary to make it a suitable reference standard for quartz in respirable coal dust samples.

TABLE 3. - Average quartz particle sizes for reference standards and for surface and underground respirable coal mine dust samples, micrometers

Sample	Av length	Av diam
Minus 5-μm Supersil.....	1.10	0.87
Minus 5-μm Min-U-Sil.....	1.26	.97
NBS 1878.....	1.65	1.31
Silver Bond B.....	4.54	3.53
Underground coal mines:		
Mean.....	1.31	1.04
Standard deviation.....	.19	.17
Surface coal mines:		
Mean.....	1.61	1.28
Standard deviation.....	.29	.24

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