Quartz Exposure Levels in the Underground and Surface Coal Mining Industry

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ABSTRACT

Occupational quartz exposure data gathered from the MSHA's respirable dust enforcement program and a program to monitor quartz were compiled and analyzed to assess the status of quartz exposures in the coal mining industry. The analysis showed that, in underground mines, a substantial number of samples contained greater than five percent quartz. Occupations which showed a high frequency of excessive quartz exposure included the roof bolter, continuous miner operator and continuous miner operator helper. In surface coal mines, the highwall drill operator and helper, bulldozer operator, scraper operator and truck drivers were frequently exposed to high quartz concentrations.

INTRODUCTION

The allowable respirable coal mine dust standard is 2 milligrams per cubic meter (mg/m^3) of air (MRE equivalent concentration*) when the quartz content of the respirable dust is five percent or less. However, when the quartz content exceeds five percent, the dust standard is lowered and is determined by dividing the percentage of quartz into the number 10.[1] Adjusting the standard using this equation maintains the concentration of quartz present in the mine environment at or below 100 micrograms per cubic meter ($\mu g/m^3$) of air**.

As discussed elsewhere,[2] the process of adjusting the respirable dust standard is initiated based on the quartz content of samples collected by Mine Safety and Health Administration (MSHA)

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* Parts 70, 71 and 90 of Title 30 of the Code of Federal Regulations define respirable dust concentrations as being made with an instrument developed by the Mining Research Establishment (MRE) of the National Coal Board, England or its equivalent. All concentrations given in this paper are MRE equivalent concentrations.

** Due to truncation and rounding, the concentration may not be exactly 100 micrograms per cubic meter.

inspectors. For underground coal mining operations, samples typically analyzed for quartz are collected on the designated occupation (DO) and on the roof-bolting occupation(s).

The DO is the occupation that has been determined to have the highest respirable dust concentration on a mechanized mining unit (MMU) and is the occupation sampled for determining compliance with the respirable dust standard. The quartz percentage of the DO sample is typically used to establish the standard for other occupations on the MMU. Because the quartz content of roof-bolter samples frequently exceeds that found in DO samples, the roof bolter is often established as a designated area (DA) requiring mine operator bimonthly sampling. When a roof bolter becomes a DA, it may be placed on a different standard than the DO. For surface coal mining operations or surface work areas of underground mines, samples collected on any occupation specifically designated by MSHA as a designated work position (DWP) or other occupations suspected of being exposed to excessive levels of quartz are analyzed for quartz content. DWPs are those occupations which are exposed to dust concentrations exceeding 1 mg/m^3 or exceed the applicable standard if less than 1 mg/m^3. Occupations designated as DO's, DAs and DWPs are required[3] to be sampled bimonthly by the mine operator.

If the quartz content of any sample collected by a coal mine inspector is greater than five percent, the mine operator may collect a sample for analysis on the same mine entity/occupation that the inspector originally sampled. When the mine operator submits a sample, the percentage of quartz determined in that sample is compared to that of the original inspector sample. If the percentage of quartz in the operator sample is not within two percent of the inspector sample (e.g., inspector sample seven percent, operator sample five to nine percent), the operator is notified and has the option to collect a second sample. The respirable dust standard for mining operations found to have in excess of five percent quartz can, therefore, be adjusted based on the average of as many as three samples.

The agency has a program in place for reviewing adjusted standards every six months. Samples collected by mine operators to fulfill the requirements for dust compliance as stated in 30 CFR 70, 71, and 90 are selected, based on sampling location and sample weight, to be analyzed for quartz content. If the quartz percentage of the selected operator's sample is not within two percent of the quartz percentage used to adjust the standard, the operator has the option to submit a sample. The quartz percentages determined from the six-month and operator optional sample are averaged with the quartz percentage used to establish the standard in place to adjust the dust standard.

In 1988, the agency initiated a program to analyze samples collected by inspectors on occupations other than the DO, roof bolter and DWP for quartz content. These additional samples represented nondesignated occupations (NDO) in underground mining and nondesignated work positions (NDWP) in surface mining. The results from the analysis of these samples were used for informational purposes and not as part of the program to adjust an entity's respirable dust standard.

In July of 1991, the agency implemented a special inspection program in underground mines that included the quartz content analysis of most of the respirable dust samples that were collected. At least five occupations were sampled (which included the DO and the DA, where applicable) plus an intake air sample. All samples were collected on the same day, and only samples with sufficient weight gain (equal to or greater than 0.3 mg) were analyzed for quartz content (intake air samples typically did not have enough mass for quartz analysis). Since the beginning of the special inspection program, approximately 12,000 samples from underground mining MMUs have been analyzed for quartz content.

All quartz exposure data obtained between 1988 and 1992 have been compiled and analyzed to:

1) Assess the status of occupational exposures to quartz in the surface and underground coal mining industry;

2) compare the quartz percentages of all samples collected on a MMU; and

3) determine the degree to which the mining industry is participating in the dust standard-setting process.

DATA ANALYSIS

Occupational quartz exposure data were compiled for all samples analyzed for quartz content during the period 1988 through 1992. The data were separated by date and by type of mining (surface or underground). The data compiled on underground mining operations were further classified according to the method of mining (conventional, continuous or longwall).

The data representative of underground mining operations were further classified into two time periods, January, 1988 through June, 1991 and July, 1991 through December, 1992. July, 1991, was chosen as the point to separate the data because this was when the agency began analyzing all enforcement samples with sufficient mass for quartz content. Also, determinations after

that date provide an up-to-date assessment of occupational exposures based on relatively recent data. Because the distributions of quartz percentage and concentration for occupations with a substantial number of samples for underground mines were similar for the two time periods, the analysis performed in this report is only on data compiled for the period July, 1991, through December, 1992.

Since the number of occupational exposure determinations compiled for surface mining operations (7,500) was considerably less than the number made at underground mining operations (27,000), the data for surface operations were not separated into two time periods. However, the data were further classified by whether they were samples collected on a DWP or an NDWP. For both surface and underground operations, data for occupations that had fewer than 20 samples analyzed within the respective time periods were not compiled for analysis.

Occupational exposures were evaluated to assess the degree to which samples were found to contain greater than five percent quartz and to determine the frequency with which occupational exposures were exceeding 100 $\mu g/m^3$. In addition, samples collected on underground occupations working on the same MMU, on the same day, were compared to determine if the quartz percentage of the DO was less than that obtained for any other occupation.

The data were also analyzed to establish the frequency with which mine operators were participating, by submitting optional samples for quartz analysis, in the establishment of the dust standard. MSHA's program of reassessing an adjusted respirable dust standard at six-month intervals also was reviewed.

DISCUSSION

The comparison of quartz percentages of samples collected on underground occupations working on the same MMU on the same day for the period July, 1991, through December, 1992, is depicted on Table I. Shown by underground mining method is the percentage of times that at least one sample collected on an occupation other than the DO had a quartz content greater than that of the DO sample collected simultaneously. The percentage was calculated two ways: the first was using all the occupation samples collected on the MMU; and using all occupations excluding the samples representative of the roof-bolting occupation(s). Also shown is the percent of time that at least one roof-bolter sample had a quartz percentage greater than that obtained on the DO sample.

The data on Table I show that on conventional and longwall mining operations approximately 50 percent of the MMUs had an occupation (excluding samples collected on the roof-bolting occupation) whose sample had a higher quartz percentage than that determined on the DO sample. On continuous mining operations the quartz percentage of the DO sample was higher than, or the same as, that determined from samples for all other occupations (excluding the roof bolter) approximately 70 percent of the time. This indicates that, particularly on conventional and longwall mining operations, occupations other than the DO should be investigated to determine their potential for being designated for regular sampling for compliance purposes. The percentages established for these comparisons are similar to those reported by Tomb, et al.[4] The data also show that on approximately 60 percent of the occasions on which samples were collected, a roof-bolting operation sample had a higher quartz percentage than the sample collected on the DO. This also confirms the results of Tomb, et al., who concluded that adjustment of the dust standard based on the quartz percentage of the DO will not necessarily provide protection to personnel performing roof-bolting duties.

A more detailed comparison of quartz determinations obtained for samples collected at the same time on the different occupations sampled and the DO is shown on Figure 1. As depicted, samples collected on roof-bolting occupations have a higher quartz percentage than the DO samples more than 50 percent of the time. However, it is also evident from the data that samples representative of nearly all occupations were found to have quartz percentages that were higher than their respective DO sample. Again, this indicates that when a respirable dust standard is adjusted based on the quartz percentage of the DO sample, the standard may not be applicable to the environments to which other occupations may be exposed.

The compilation of quartz data for underground mining operations for the two time periods previously discussed is shown on Table II. As previously noted, discussion of the data is limited to July, 1991, through December, 1992, time period. Figures 2 and 3, respectively, show selected percentiles for the distribution of samples on which the percentage and concentration of quartz were determined. This percentile range was selected to keep the quantity of data manageable and to eliminate the influence of extreme outliers. As an example, the RB Single Head occupation in conventional mining has a median (50th percentile) quartz percentage of four percent, with the 80th percentile at seven percent, the 90th percentile at 10 percent and the 95th percentile at 13 percent.

The percentage of samples with greater than five percent quartz was greater on roof-bolting than for other occupations on both continuous and conventional mining operations. The data on Table II for conventional mining operations, except for the roof bolter, show that 85 percent or more of the samples had quartz contents equal to or less than five percent. For continuous mining operations, the percentage of samples with greater than five percent quartz is generally two to four times that obtained for occupations in conventional operations. Approximately 40 percent of continuous miner and continuous miner helper samples exceeded five percent quartz. The percentage of samples (excluding roof bolter) with greater than five percent quartz was approximately 25 percent for the other occupations.

Approximately 15 percent of the longwall mining occupation samples contained more than five percent quartz. As shown on Figure 2, overall quartz percentages were generally lower in the longwall operations in that the quartz percentage for more than 95 percent of the samples collected on all occupations was less than 10 percent quartz. It is also worth noting on Figure 2 that 10 percent or more of the samples collected from the roof bolter, continuous miner and continuous miner helper occupations contained more than 10 percent quartz.

In general, the data on Table II also show that those occupations having a significant percentage of samples with greater than five percent quartz had a significant percentage of samples that represented respirable quartz exposures greater than 100 $\mu g/m^3$. For the roof-bolting occupation on conventional mining, the percentage of samples (38 percent) with more than five percent quartz was approximately the same as the percentage (32 percent) of samples that exceeded 100 $\mu g/m^3$. For continuous mining operations the percentage (35 percent) of roof-bolter samples (excluding mounted roof bolters) that exceeded 100 $\mu g/m^3$ was approximately 60 percent of those (58 percent) that contained greater than five percent quartz. For other occupations in these operations, the number of samples that represented exposures greater than 100 $\mu g/m^3$ was generally 50 to 80 percent of those containing greater than five percent quartz. As shown in Figure 3, quartz exposures were found to exceed 200 $\mu g/m^3$ (twice the level the adjusted standard is intended to maintain) at least 10 percent of the time on the roof-bolter occupation, in both continuous and conventional mining operations, and for the continuous-miner operator occupation. For longwall operations, the percentage of samples representing exposures greater than 100 $\mu g/m^3$ was approximately the same (l5 percent) as the percentage that contained greater than five percent quartz. For these operations quartz exposures on the longwall operator

(tailgate side) and return side face worker exceeded 200 µg/m^3 at least five percent of the time.

These data indicate that, based on samples collected on occupations that are typically the DO (cutting machine operator, continuous miner operator, longwall operator [tailgate side]), a significant number (greater than 35 percent) of underground mining operations would be expected to be on a reduced respirable dust standard. At the time the operations represented by these data were sampled for compliance with the respirable dust standard, approximately 20 percent of the miners were exposed to quartz concentrations greater than 100 µg/m^3.

Table III shows the compilation of quartz data for surface coal mines and surface facilities of underground mines. The percentage of samples that contain more than five percent quartz for certain surface occupations is significantly higher than for most underground occupations. For the DWP occupations--highwall drill operator and helper, bulldozer operator, scraper operator, and all truck drivers--approximately 70 percent of the samples contained greater than five percent quartz. Of the samples collected on these occupations, approximately 50 percent represented occupations whose exposures were greater than 100 µg/m^3. NDWP samples collected for these occupations, as well as for the blaster/shooter/shotfirer occupation, had percentages of samples with greater than five percent quartz and more than 100 µg/m^3, similar to those obtained for the DWP occupations.

For surface operations, controlling the dust exposure of one occupation may have little or no influence on the dust exposure of other employees working in the same occupation in different locations or on different occupations working in the same general location. Examples would be truck drivers and bulldozer operators, and highwall drill operators and helpers. Therefore, personnel assigned as highwall drill operator, highwall drill operator helper, bulldozer operator, scraper operator, coal truck driver and refuse/backfill truck driver should be sampled frequently to assess their designation for operator sampling.

The data compiled to compare the percentage of quartz determined from MSHA selected mine operator samples submitted in accordance with the regulatory requirements, to the percentage of quartz that was used to establish the adjusted respirable dust standard for entities on a reduced dust standard, are shown on Table IV. The data show that approximately 43 percent of the time the percentage of quartz found in the "six-month" sample is within ±2 percent of that used to set the adjusted standard. The percentage of quartz found in the six-month sample is more than two percent different from the quartz percentage used to set the

previous standard of 57 percent of the time, thus requiring the process of reestablishing a standard to be initiated. For the data analyzed it is interesting to note that almost half of the samples are more than two percent lower than the value used to establish the adjusted standard and less than one-tenth are more than two percent higher.

The degree to which mine operators participate in the standard setting process is shown in Table V. When a mine operator is given the first option to submit a sample for quartz analysis, approximately 65 percent of the time a sample is submitted. This percentage is 72 percent if the option is given to submit a second sample. However, when the operator is offered the opportunity to submit an optional sample following the analysis of a six-month sample, the participation rate is only 28 percent. Regardless, overall participation by operators is considerably higher than the 35 percent reported in 1986[3], shortly after MSHA instituted a revised quartz analysis program permitting mine operator samples to be used in the dust standard setting process.

SUMMARY

Occupational quartz exposure data gathered by MSHA during the period 1988 through 1992 were compiled. Selected data from this compilation were analyzed to assess occupational exposures to quartz in underground coal mining operations and at surface coal mines and surface facilities of underground coal mines to compare the quartz percentage of all samples collected on an MMU. The analysis also assessed the continued suitability of standards that have been adjusted, and evaluated the extent to which mine operators are participating in the program to provide data for adjusting the respirable dust standard.

Analysis of the quartz data showed that:

1. In underground coal mines, regardless of mining type (continuous, conventional, or longwall), there was a substantial percentage of occupational samples that contained greater than five percent quartz. Approximately 60 and 40 percent of the samples collected on the roof-bolting occupation in continuous and conventional mining operations, respectively, were found to contained greater than five percent quartz. Approximately 35 percent of the samples represent quartz exposures that exceeded 100 $\mu g/m^3$. Forty percent of the samples collected on the continuous-miner operator and continuous-miner operator helper occupations in continuous-mining operations were found to contain greater than five percent quartz while approximately

30 percent of the samples for these occupations represent quartz exposures exceeding 100 µg/m^3.

2. Approximately 30 percent of the time, samples collected on occupations (other than the roof bolter) had a quartz percentage greater than that used to adjust the respirable dust standard on an MMU.

3. In surface coal mines, approximately 70 percent of the DWP and NDWP samples representative of the highwall drill operator and helper, bulldozer operator, scraper operator and truck drivers contained greater than five percent quartz. Approximately 50 percent of these samples represented exposures that exceeded 100 µg/m^3. These data indicated that these occupations should be sampled frequently to establish their status for operator sampling.

4. Mine operators are participating in the standard-setting process at a rate of approximately 65 percent.

5. MSHA's program of using operator samples, at six-month intervals to monitor the status of mines on an adjusted dust standard showed that 57 percent of the time the percent quartz in the six-month sample minus the percent used to set the adjusted standard was more than ±2 percent. Approximately 80 percent of the six-month samples that differed by more than two percent are lower than the percentage previously used to adjust the standard.

REFERENCES

1. "Mineral Resources," *Code of Regulations* Title 30, Pts. 70.206, 71.206, 90.206, 1992, pp. 465, 479-480, 703.

2. Tomb, T.F., P.S. Parobeck and A.J. Gero: MSHA's Revised Quartz Enforcement Program. In *Respirable Dust in the Mineral Industries*. R.L. Franz and R.V. Ramani, eds. University Park, PA: The Pennsylvania State University, 1986. pp. 9-14.

3. "Mineral Resources," *Code of Regulations* Title 30, Pts. 70.208, 71.208, 1992, pp. 466-467, 480.

4. Tomb, T.F., R.G. Peluso and P.S. Parobeck: Quartz in United States Coal Mines. In International Conference on the Health of Miners, R.W. Wheeler, ed. Cincinnati, OH:

American Conference Government Industrial Hygienists, 1986. pp. 513-519.

Table I. Quartz Exposure Comparison for Occupations Sampled on the Same Shift (July 1991-1992)

Mining Method	Occasions Sampled	Percent with a Quartz Percentage Of at Least 1 Occupation > DO Including RB	Excluding RB	Of at Least 1 RB > DO[A]
Conventional	191	81	51	69
Continuous	1,658	67	28	58
Longwall	224	-	51[B]	-

[A] DO = designated occupation; RB = roof bolter
[B] no roof bolter occupation in longwall mining

Table II. Quartz Exposure in Underground Coal Mining Occupations

Occupation[A]	1988 Through 1991 Number of Samples	1988 Through 1991 Percentage of Samples >5%	1988 Through 1991 Percentage of Samples >100 $\mu g/m^3$	July 1991 Through 1992 Number of Samples	July 1991 Through 1992 Percentage of Samples >5%	July 1991 Through 1992 Percentage of Samples >100 $\mu g/m^3$
Conventional						
Roof bolter single head	284	39	34	140	37	32
Roof bolter DA	83	34	19	40	42	33
Coal drill operator	127	18	16	116	12	8
Scoop car operator	64	14	8	151	11	9
Cutting machine operator	456	9	12	187	10	12
Shutte car operator std.	36	8	4	20	12	4
Loading machine operator	27	7	12	39	9	7
Continuous						
Roof bolter single head	1,082	63	45	546	61	30
Roof bolter DA	1,827	50	34	1,067	61	39
Roof bolter twin intake	403	49	33	361	52	30
Roof bolter twin return	684	48	32	366	48	33
Roof bolter helper single	64	45	34	60	68	40
Continuous miner operator	4,839	39	32	2,245	42	30
Continuous miner helper	583	35	26	561	41	25
Scoop car operator	103	33	16	224	31	19
Shuttle car operator	730	29	17	1,431	25	11
Roof bolter mounted return	97	19	17	44	11	9
Utility man	24	17	21	136	21	14
Roof bolter mounted intake	73	14	13	42	12	7
Mobile bridge operator	<20	-	-	164	28	13
Section foreman	<20	-	-	132	19	9
Electrician	<20	-	-	37	19	8
Tractor operator/motorman	<20	-	-	51	24	6
Mechanic	<20	-	-	31	23	13
Longwall						
Tailgate operator	25	32	44	<20	-	-
Longwall operator tailgate	386	22	26	261	20	20
Jack setter	322	21	22	384	19	16
Return side face worker	21	19	43	20	25	35
Longwall operator headgate	36	14	23	146	14	19
Headgate operator	28	7	0	154	6	3
Section foreman	<20	-	-	46	4	4
Mechanic	<20	-	-	58	5	2

[A] DA = designated area

Table III. Quartz Exposure in Surface Coal Mining Occupations (1988-1992)

Occupation[A]	Number of Samples	Percentage of Samples >5%	Percentage of Samples >100 $\mu g/m^3$
Surface-DWP			
Highwall drill helper	21	91	76
Highwall drill operator	574	82	63
Bulldozer operator	391	71	45
Scraper operator	28	68	19
Refuse/backfill truck driver	244	46	22
Coal truck driver	28	43	22
Highlift operator	108	23	11
Oiler/greaser	23	22	9
Coal sampler	26	12	8
Cleanup man	87	7	10
Washer operator	32	7	7
Scalper-screen operator	60	7	3
Mechanic	77	5	4
Laborer/blacksmith	135	4	6
Electrician	25	4	0
Fine coal plant operator	155	4	3
Tipple operator	116	2	2
Cleaning plant operator	96	0	0
Dryer cell operator	25	0	0
Froth cell operator	35	0	0
Surface--NDWP			
Highwall drill helper	21	100	45
Highwall drill operator	656	84	62
Blaster/shooter/shotfirer	37	76	35
Scraper operator	74	73	39
Bulldozer operator	1,136	59	31
Refuse/backfill truck driver	538	45	13
Road grader operator	35	37	9
Coal truck driver	64	36	16
Highlift operator	699	26	6
Crusher attendant	24	21	4
Oiler/greaser	46	17	4
Mechanic	77	13	0
Auger operator	27	11	11
Laborer/blacksmith	125	11	3
Coal sampler	30	7	7
Washer operator	36	6	0
Scalper-screen operator	39	5	3
Welder (Shop)	24	4	7
Auger helper	23	4	0
Tipple operator	159	3	0
Utility man	37	3	0
Cleaning plant operator	99	3	2
Cleanup man	39	3	3
Electrician	36	3	3
Fine coal plant operator	59	0	0

[A] DWP = designated work position; NDWP = nondesignated work position

Table IV. Comparison of Quartz Percentage of Six-Month Sample and Quartz Percentage Used to Set Previous Dust Standard (July 1991-1992)

Six-Month Value Versus Previous Value	Number of Samples	Percentage of Samples
within 2%	177	43
>2% less	186	45
>2% more	47	12

Table V. Operator Participation of MSHA's Quartz Enforcement Program (September 1991-1992)

Triggering Sample	Number of Options	Number Submitted	Percent
Inspector			
1st operator optional	1,528	995	65
2nd operator optional	361	260	72
Six-month	111	31	28

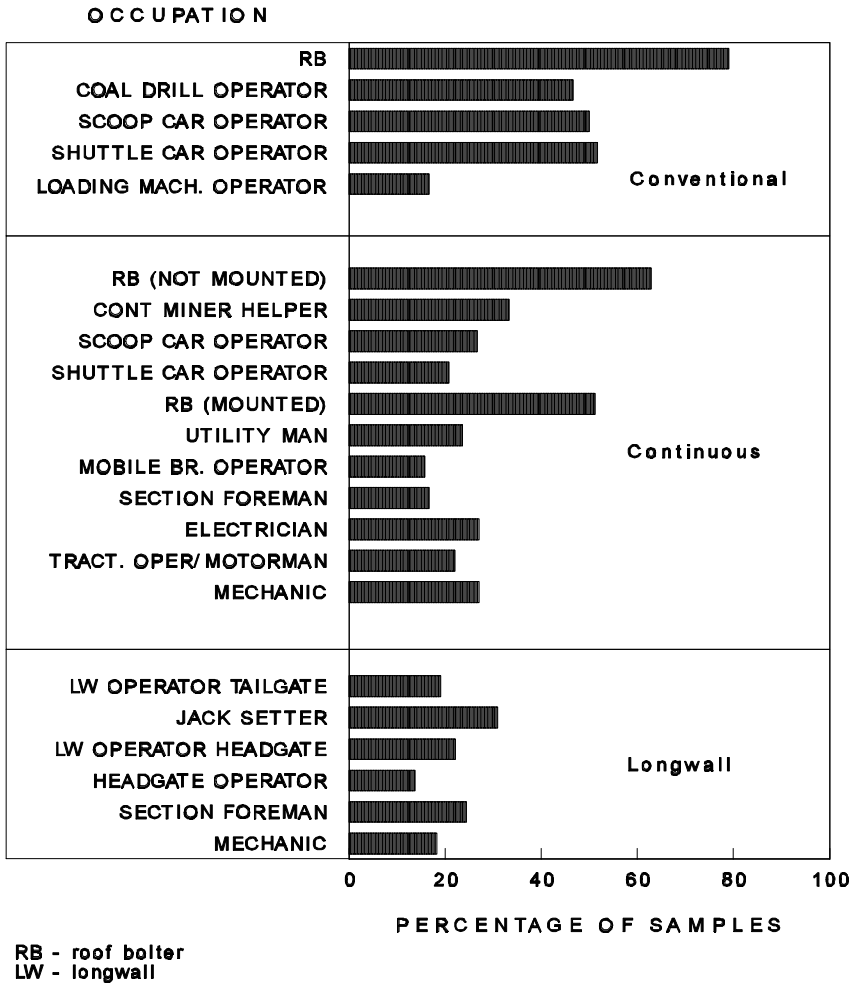

Figure 1. - Occupational samples whose quartz percentage was greater than the DO's

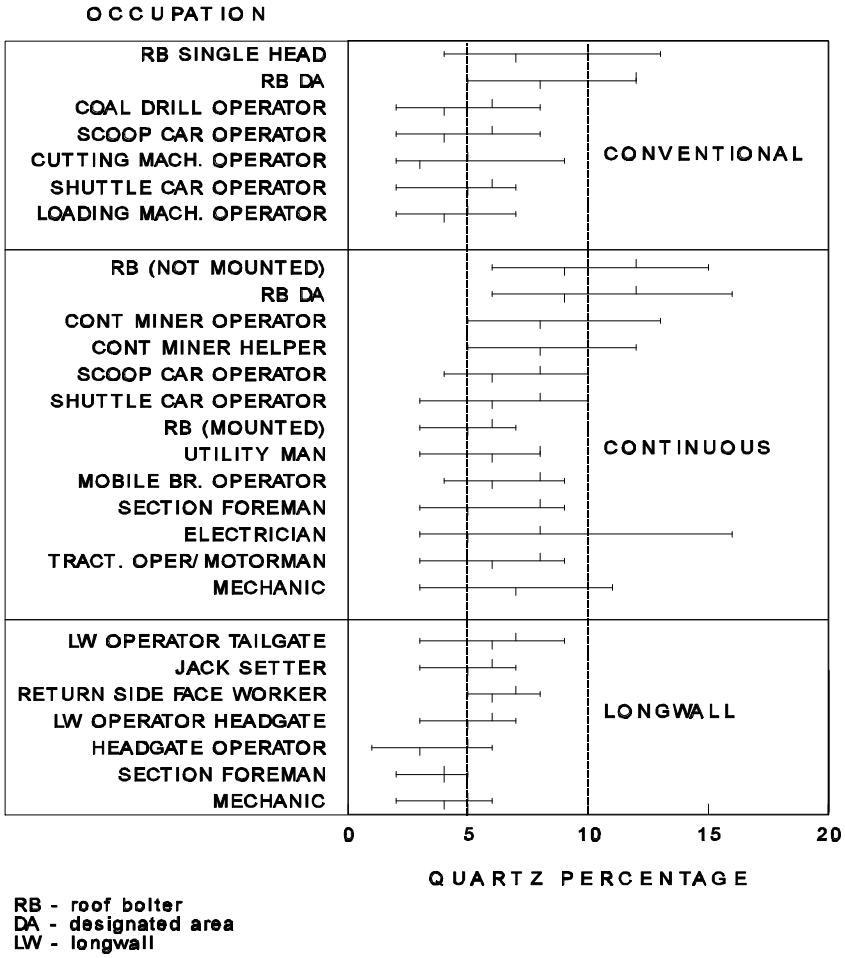

Figure 2. - Distribution of quartz percentages for underground coal mining occupations (50th, 80th, 90th, and 95th percentiles)

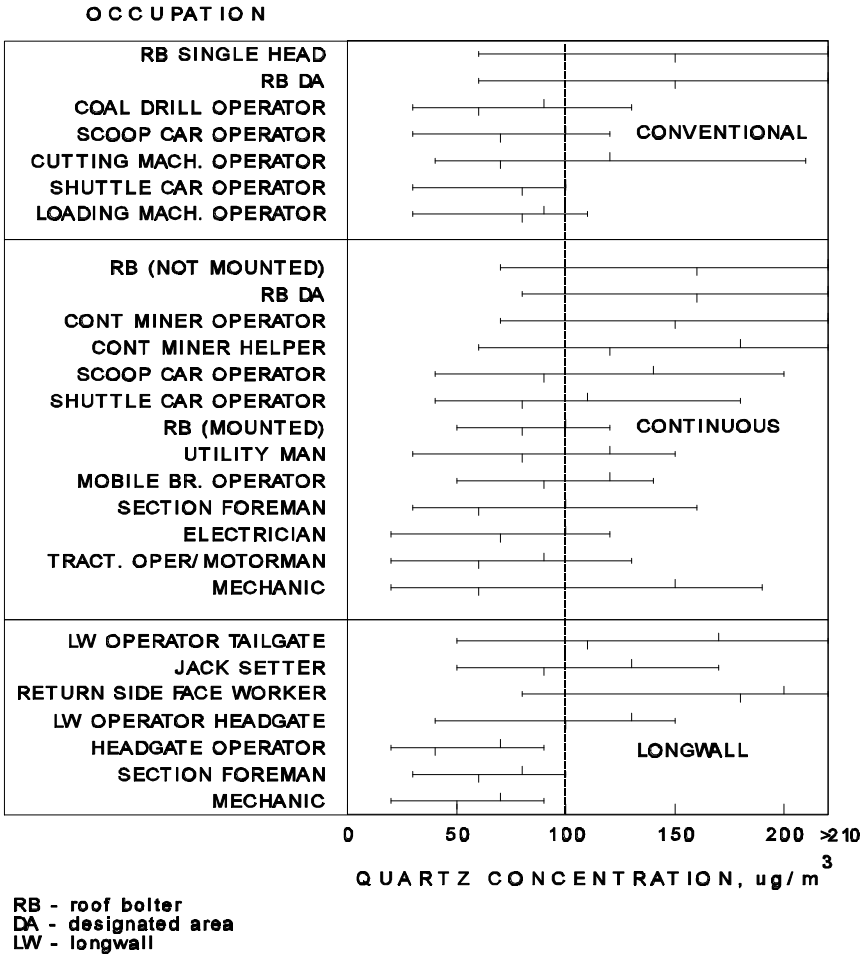

Figure 3. - Distribution of quartz concentrations for underground coal mining occupations (50th, 80th, 90th, and 95th percentiles)