# RESPIRABLE DUST EXPOSURES IN UNDERGROUND U.S. COAL MINES

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## INTRODUCTION

The Federal Coal Mine Health and Safety Act of 1969[1] (amended in 1977[2]) established mandatory dust standards for United States underground and surface coal mines. Effective June 30, 1970, the average concentration of respirable dust in the active workings of underground coal mines was to be maintained at or below 3.0 mg/m$^3$. On December 30, 1972, the 3.0 mg/m$^3$ mandated dust standard was reduced to 2.0 mg/m$^3$. On June 26, 1972, the 2.0 mg/m$^3$ standard also became effective for surface work areas of underground coal mines and for surface coal mines. The Act further stipulated that the 2.0 mg/m$^3$ mandated standard was to be reduced whenever the quartz content in the respirable dust was greater than five percent. The adjusted standard is determined by dividing the percentage of quartz in the respirable dust into the number 10, which results in a maximum exposure to quartz of 100 µg/m$^3$.

The reference dust sampling instrument for measuring respirable dust concentrations with respect to the mandated standard is the Isleworth Type 113A (MRE) gravimetric dust sampler. However, respirable dust measurements in U.S. coal mines are made using a personal sampling device that uses a 10 mm nylon cyclone to separate the dust sampled into two fractions; a respirable fraction and a nonrespirable fraction. Because the size fraction of the particles penetrating the 10 mm nylon cyclone is different from the size fraction penetrating the four-channel horizontal elutriator used on the MRE sampler, measurements obtained with the personal sampling device are multiplied by a constant factor[3] (1.38) to obtain an equivalent MRE concentration.

On July 15, 1991, the Assistant Secretary of Labor directed that a special inspection program be conducted in a representative number of the country's mining operations. One of the main objectives of that program was to obtain information with respect to occupational exposures to respirable dust in the nation's underground mining operations. The program resulted in occupational exposure measurements being obtained in approximately 720 mechanized mining units (coal getting operations).

This paper presents a review of the occupational respirable dust and quartz exposure data that were obtained during the Assistant Secretary's special inspection program.

## DATA COMPILATION AND ANALYSIS

### Occupational Exposure Data

At each working section where a special inspection was conducted, full-shift respirable dust samples were collected on five occupations. Of the five occupations sampled, one was to be the "designated occupation" (DO) and one the roof bolter (if a roof bolting operation was part of the mining operation). For regulatory purposes, "designated occupation" is defined as that occupation on a working section which previous sampling has shown to have the highest respirable dust exposure. A sample was also collected of the intake air being used to ventilate the working section. During the special inspection program approximately 4,000 samples representative of 52 occupations were obtained.

All of the samples collected were analyzed gravimetrically and the equivalent MRE respirable mass concentration determined. Samples with sufficient weight gain were also quantitatively analyzed for quartz content using infrared spectroscopy[4]. Figures 1 and 2 show, respectively, the cumulative frequency distribution of the respirable mass concentration determinations for the occupational measurements and the cumulative frequency distribution of the quartz determinations (as a percentage of the respirable mass concentration) obtained from analysis of the occupational samples. The data on Figure 1 show that approximately 11 percent of the occupational measurements were above 2.0 mg/m$^3$; and, on Figure 2, that approximately 30 percent of the samples collected contained greater than five percent quartz. As previously discussed, mining operations that have greater than five percent quartz in their respirable dust are required to have their respirable dust standard lowered.

A compilation of the respirable dust exposure data by mining type is shown on Tables 1, 2, 3 and 4. Schematics illustrating typical longwall and continuous type mining operations are shown on Figures 3, 4, 5 and 6. Shown on the respective tables are the number of samples collected on each of the respective occupations sampled, the average concentration representative of the exposure for that occupation and the percentage of measurements that exceeded 2.0 mg/m$^3$. Tables 5, 6 and 7 show a similar type of compilation for the quartz data.

The data on Table 1 for longwall mining operations show that approximately 25 percent of the measurements obtained on the DO were greater than 2.0 mg/m$^3$. The data on Table 1 also show that the number of times (24) the exposure of the jack setter occupation (shield setter) exceeded 2.0 mg/m$^3$ was greater than the number of times (21) the DO exceeded 2.0 mg/m$^3$. Analysis of the individual occupational longwall exposure data showed that approximately



50 percent of the time an occupation other than the DO was exposed to the highest concentration of respirable dust.

Data obtained on continuous mining operations (room and pillar) were divided into two categories: data from operations that limit mining advance to 6.1 meters (20 feet) before taking measures to support the roof (Table 2), and data from operations that have been granted permission to mine to depths greater than 6.1 meters (referred to as deep cut mining) before supporting the roof (Table 3). A schematic illustrating the deep cut method of mining is shown on Figure 6. Operations that mine to depths greater than 6.1 meters before supporting the roof typically employ inertial dust collectors (scrubbers) on the mining machine and use remote control to operate the machine. The remote control enables the continuous miner operator, the DO, to be positioned in clean air that is being used to ventilate the working place, and the scrubber reduces the amount of dust exiting the working place. Therefore, the designated occupation's exposure on these operations would be expected to be less than the designated occupation's exposure on operations limiting mining advance to 6.1 meters. Comparison of the data on Tables 2 and 3 confirms this expectation. The percentage of occupational exposures exceeding 2.0 mg/m$^3$ was seven percent greater on operations limiting mining advance to 6.1 meters. This seven percent difference is significant because there are approximately 1.8 times more continuous mining operations that limit their advance to 6.1 meters, before installing roof supports, than operations advancing to depths greater than 6.1 meters.

The data obtained for occupational exposures on conventional mining operations (Table 4) show that approximately 27 percent of the exposures measured on the cutting machine operator, the designated occupation, were greater than 2.0 mg/m$^3$. The data obtained on conventional mining operations also show that, in general, the percentage of occupational exposures that exceeded 2.0 mg/m$^3$ was greater than for either the longwall or continuous methods of mining.

As previously stated, Tables 5, 6 and 7 respectively show the compilation of quartz exposure data of the different mining methods. The compilation shows the percentage of measurements, by occupation for each method of mining, that had quartz percentages that respectively exceeded 5, 10 and 15 percent quartz. The data show that: for longwall mining operations (Table 5), approximately 16 percent of the measurements obtained on the longwall operators and jack setters had a quartz percentage greater than 5 percent; for continuous mining operations (Table 6), approximately 40 percent of the samples obtained on the continuous miner and

his helper and more than 55 percent of the samples for those occupations involved in the roof bolting operation contained greater than five percent quartz; and, that for operations employing conventional mining methods (Table 7), approximately 10 percent of the samples collected on all occupations except the roof bolter had a quartz content greater than five percent. For the roof bolter occupation 37 percent of the samples had quartz contents greater than five percent.

## SUMMARY

Between July 15 and October 30, 1991, a special investigation was conducted in U.S. underground coal mines to assess occupational exposures to coal mine dust. The study showed that while approximately 89 percent of the occupational exposures to respirable coal mines dust were less than 2.0 $mg/m^3$, approximately 18 percent of the face occupations associated with the shearing and jack setting processes on longwall mining operations, 21 percent of the continuous miner operators, helpers and roof bolters on continuous mining operations employing an exhausting face ventilation system and 26 percent of the loading and cutting machine operators on conventional mining operations had exposures greater than 2.0 $mg/m^3$. It also showed that a high percentage of the samples collected on the continuous miner operator and roof bolter occupations contained greater than five percent quartz.

## REFERENCES

1. U.S. Congress, Federal Coal Mine Health and Safety Act of 1969, Public Law 91-173, December 30, 1969.
2. U.S. Congress, Federal Mine Safety and Health Act of 1977, Public Law 91-173, as amended by Public Law 95-164.
3. Tomb, T.F., N.N. Treaftis, R.L. Mundell and P.S. Parobeck, 1973, "Comparison of Respirable Dust Concentrations Measured with MRE and Modified Personal Gravimetric Sampling Equipment", U.S. BuMines RI 7772, 29 pp.
4. Ainsworth, S.M., Parobeck, P.S. and Tomb, T.F., 1989, "Determining the Quartz Content of Respirable Dust by FTIR", MSHA IR 1169.



TABLE 1. – OCCUPATIONAL EXPOSURES OBTAINED ON LONGWALL MINING OPERATIONS

| OCCUPATION | NUMBER OF SAMPLES | AVERAGE ($mg/m^3$) | % GREATER THAN 2.0 $mg/m^3$ |
|---|---|---|---|
| LONGWALL OPERATOR (TAILGATE SIDE)* | 83 | 1.7 | 25 |
| Longwall Operator (Headgate Side) | 69 | 1.5 | 16 |
| JACK SETTER | 160 | 1.4 | 15 |
| Headgate Operator | 75 | 0.7 | 1 |
| Maintenance | 34 | 0.7 | 0 |

TABLE 2. – OCCUPATIONAL EXPOSURES ON CONTINUOUS MINING OPERATIONS NOT ADVANCING GREATER THAN 20 FEET

| OCCUPATION | NUMBER OF SAMPLES | AVERAGE ($mg/m^3$) | % GREATER THAN 2.0 $mg/m^3$ |
|---|---|---|---|
| CONTINUOUS MINER OPERATOR* | 250 | 1.8 | 21 |
| CONTINUOUS MINER HELPER | 142 | 1.4 | 23 |
| Roof Bolter (Twin Head) Intake Side | 101 | 1.8 | 7 |
| OTHER ROOF BOLTER** | 256 | 1.3 | 16 |
| ROOF BOLTER HELPER | 32 | 1.4 | 22 |
| Section Foreman | 40 | 0.9 | 10 |
| Electrician | 20 | 0.5 | 0 |
| Shuttle Car Operator (Standard Side) | 295 | 0.7 | 5 |
| Shuttle Car Operator (Off Standard Side) | 204 | 0.8 | 6 |
| Scoop Car Operator | 91 | 0.8 | 8 |
| Tractor Operator/Maintenman | 91 | 0.4 | 0 |
| Mobile Bridge Operator | 39 | 0.9 | 10 |
| Utility Man | 82 | 0.6 | 2 |

TABLE 3 – OCCUPATIONAL EXPOSURES ON CONTINUOUS MINING OPERATIONS ADVANCING GREATER THAN 20 FEET

| OCCUPATION | NUMBER OF SAMPLES | AVERAGE ($mg/m^3$) | % GREATER THAN 2.0 $mg/m^3$ |
|---|---|---|---|
| CONTINUOUS MINER OPERATOR* | 179 | 1.2 | 14 |
| CONTINUOUS MINER HELPER | 90 | 1.1 | 9 |
| Roof Bolter (Twin Head) Intake Side | 63 | 1.0 | 8 |
| OTHER ROOF BOLTER ** | 180 | 1.0 | 7 |
| Section Foreman | 23 | 0.7 | 4 |
| Shuttle Car Operator (Standard Side) | 187 | 0.8 | 6 |
| Shuttle Car Operator (Off Standard Side) | 67 | 0.8 | 4 |
| Scoop Car Operator | 33 | 0.8 | 3 |
| Mobile Bridge Operator | 34 | 0.8 | 3 |

TABLE 4. - OCCUPATIONAL EXPOSURES OBTAINED ON CONVENTIONAL MINING OPERATIONS

| OCCUPATION | NUMBER OF SAMPLES | AVERAGE (mg/m³) | % GREATER THAN 2.0 mg/m³ |
|---|---|---|---|
| Coal Drill Operator | 64 | 1.1 | 14 |
| CUTTING MACHINE OPERATOR* | 70 | 1.9 | 27 |
| LOADING MACHINE OPERATOR | 27 | 1.6 | 26 |
| ROOF BOLTER (SINGLE HEAD) | 90 | 1.3 | 17 |
| Scoop Car Operator | 93 | 1.1 | 12 |

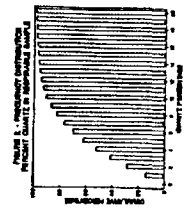
TABLE 5 - QUARTZ CONTENT OF SAMPLES OBTAINED ON LONGWALL MINING OPERATIONS

| OCCUPATION | NUMBER OF SAMPLES | % OF SAMPLES GREATER THAN | | |
|---|---|---|---|---|
| | | 5 % | 10 % | 15 % |
| LONGWALL OPERATOR (TAILGATE SIDE) | 91 | 16 | 2 | 1 |
| Longwall Operator (Headgate Side) | 47 | 13 | 0 | 0 |
| JACK SETTER | 158 | 18 | 1 | 0 |
| Headgate Operator | 73 | 4 | 0 | 0 |
| Mechanic | 34 | 6 | 0 | 0 |

TABLE 6 - QUARTZ CONTENT OF SAMPLES OBTAINED ON CONTINUOUS MINING OPERATIONS

| OCCUPATION | NUMBER OF SAMPLES | % OF SAMPLES GREATER THAN | | |
|---|---|---|---|---|
| | | 5 % | 10 % | 15 % |
| CONTINUOUS MINER OPERAT | 491 | 38 | 8 | 2 |
| CONTINUOUS MINER HELPER | 226 | 39 | 8 | 4 |
| Roof Bolter (Twin Head) Intake Side | 160 | 46 | 13 | 4 |
| OTHER ROOF BOLTER | 510 | 59 | 20 | 6 |
| ROOF BOLTER HELPER | 36 | 64 | 22 | 3 |
| Section Foreman | 61 | 20 | 3 | 3 |
| Electrician | 21 | 14 | 10 | 10 |
| Shuttle Car Operator (Standard Side) | 453 | 22 | 4 | 2 |
| Shuttle Car Operator (Off Standard Side) | 252 | 24 | 6 | 3 |
| Scoop Car Operator | 113 | 27 | 3 | 2 |
| Tractor Operator/Motorman | 34 | 26 | 3 | 0 |
| Mobile Bridge Operator | 69 | 28 | 0 | 0 |





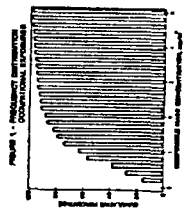


TABLE 7 - QUARTZ CONTENT OF SAMPLES OBTAINED ON CONVENTIONAL MINING OPERATIONS

| OCCUPATION | NUMBERS OF SAMPLES | % SAMPLES GREATER THAN | | |
|---|---|---|---|---|
| | | 5 % | 10 % | 15 % |
| COAL DRILL OPERATOR | 90 | 12 | 3 | 0 |
| CUTTING MACHINE OPERATOR | 67 | 7 | 3 | 3 |
| LOADING MACHINE OPERATOR | 26 | 8 | 0 | 0 |
| ROOF BOLTER (SINGLE HEAD) | 84 | 37 | 10 | 0 |
| SCOOP CAR OPERATOR | 91 | 9 | 0 | 0 |

* USUALLY THE DESIGNATED OCCUPATION
** INCLUDES TWIN HEAD (RETURN SIDE), SINGLE HEAD AND DESIGNATED AREA