AUGUST 1989

MINING ENGINEERING

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BOND GOLD COLOSSEUM

- Grade Control and Ore Selection
- Ore Crushing and Grinding

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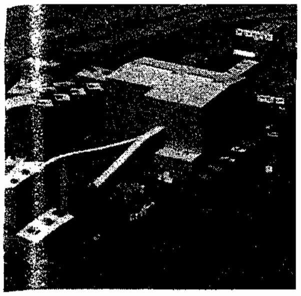

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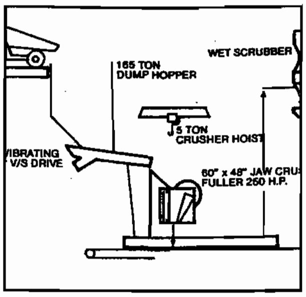

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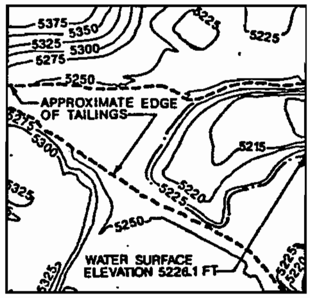

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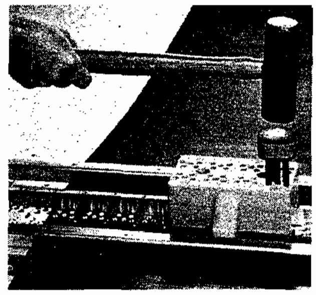

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COVER
Bond Gold overcame crushing and grinding difficulties as well as ore selection and grade control problems at its Colosseum mine in Nevada. Articles begin on page 823. Photo courtesy of Bond Gold Colosseum Inc.

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TECHNICAL NOTE

Elemental composition of coal dust created by mining and laboratory size reduction: A comparison

C. J. Johnson and C. J. Bise

Introduction

Coal extraction by continuous miners (CM) is currently the most common underground method in the US industry and accounts for slightly more than two-thirds of the nation's deep mining production (National Coal Association, 1987). Even if longwall mining should become more commonplace, it can proceed only after ventilation and access entries have been driven by CMs. Since an area of concern continues to be the effects of the dust generated on the health of mineworkers, this paper discusses the relationship between the elemental compositon of mining-generated airborne dust sampled from the immediate ventilation return of a CM and laboratory-generated dust derived from channel samples taken from the mines.

There are several potential contributions of this type of study to the coal mining industry. First, after more fundamental knowledge of the causes of Coal Worker's Pneumoconiosis (CWP) is learned, the laboratory-generated respirable dust could be used to identify a potentially hazardous coal seam. Also, this study could possibly aid in understanding the fundamental causes of CWP by producing mining-simulated samples of coal dust that could be used in epidemiological studies.

Further, assuming that there is no difference in the elemental composition of a drill-core sample and a channel sample from the same location, a mining company could predict a new mine's respirable dust elemental composition in the immediate ventilation return by using exploratory drill core samples of the roof, coal, and floor rock to prepare the laboratory dust. Ventilation engineers could then use engineering design and control measures during premine planning to reduce the incidence and severity of CWP by better ventilating the potentially hazardous coal seam. If this proper planning prevented any future changes to the ventilation equipment and mine design, much time and money could be saved.

Scope of work

To investigate the variability of the chemical characteristics of respirable dust, airborne dust samples from eight underground coal mines located in the eastern and midwestern United States were collected with eight-stage Sierra Model 298 Marple cascade impactors, as well as 25 channel samples of mined material. Each channel sample was removed from the middle of the coal face before mining occurred. Sampling of the mining-generated dust was conducted by Lee (1986) by sampling the entire working sections, primarily for characterization purposes, to obtain information on the locational variability of dust characteristics. Research performed for this study used the elemental analyses of the mining-generated dusts he sampled in the immediate ventilation returns of CMs.

The procedure that was used to produce the laboratory-generated respirable dust was based on the Hardgrove grindability test since it reflects the pulverizing characteristics of coal. This test was chosen for several additional reasons.

First, it is repeatable and reproducible. A consistent amount of input energy is used as well as a specified size range of feed material to be crushed (the channel samples). Second, it is thought to generate secondary dust in a way similar to that of the crushing and grinding of the coal and rock as they pass through the arc-shaped cutting path of the CM's cutter head. The potential effect on dust generation by this secondary grinding mechanism may be at least as much as that produced by primary fragmentation, which is dust produced by the cutting action of the bit against the coal or rock (Roepke, 1984). Finally, the Hardgrove grindability test is well known and is used in the coal industry to guide mineral processing engineers in estimating the capacity of mills used to grind coal.

One hypothesis of dust researchers in the Generic Technology Center for Respirable Dust is that the elemental as well as the physical characteristics of coal mine dust will make a difference in the incidence and severity of CWP. Coal mine dust is generated not only from coal, but also from any rock partings contained within the seam or any roof or floor material mined with the coal. Thus, coal mine dust may not have the same elemental characteristics as the coal being mined.

Given that hypothesis, mixtures proportional to each thickness mined of roof, coal, and floor rock derived from the channel samples of the face areas from which the respirable dusts were generated by the CMs were used to produce the feed material that was pulverized in the Hardgrove machine.

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The fraction -37 m (-400 mesh) that was collected after pulverization was placed in a fluidized-bed aerosol generator, manufactured by TSI Inc., and dispersed in an aerosol test chamber, manufactured by Elpram Systems Inc. While the -37 m (-400-mesh) fraction was being dispersed in the aerosol test chamber, it was also being sampled with the eight-stage cascade impactors in the same manner that the dust in the immediate ventilation return of the CM was sampled.

The elemental composition of the mining-generated dust and the laboratory-generated dust were determined from stages 3, 5, and 7 (10 µm, 3.5 µm, and 1 µm aerodynamic diameter, respectively, or 1250, 2500, and 12,000 mesh) of a cascade impactor by the Proton Induced X-Ray Emission (PIXE) method by the Element Analysis Corp. To perform a PIXE analysis, a beam of protons is used to excite the atoms in the dust mass of a particular impactor stage. The X-rays emitted as a result of this excitation are analyzed to determine the elements that originated the various wave lengths. The number of X-rays that are emitted in a particular range are counted and the amount of each element in the dust can be calculated with an error that can be determined statistically for each element.

The PIXE method quantifies the mass of all elements simultaneously but had one limitation: the commercially available analysis is set up to determine only those elements that have an atomic number greater than or equal to sodium. The PIXE analysis is also a nondestructive method. Therefore, any elements contained in the volatile material of the dust samples are not lost by an ashing procedure and dust samples can be archived for future use. The PIXE method easily gives a multi-element analysis from small dust masses which ranged from 5 to 120 µg.

Description of the analysis

After receiving the elemental analyses from the outside company, the data were grouped by mine, channel-sample location, and stage according to their identification as a laboratory-generated dust or a mining-generated dust. Since each element's weight fraction of the total dust mass had an associated error +/- its weight fraction, a range of values occurred for an element's weight fraction.

For example, if iron's weight fraction of a dust mass was 2.50E-3 (0.00250) with a ±10% error, then the range of iron in the dust mass was from 2.25E-3 to 2.75E-3. For a few elements in quantities near the PIXE analysis' detection limits, an error of more than 100% occurred. This presented no problem when adding more than 100% of the original weight fraction to itself. When subtracting it, however, the weight fraction of the particular element was entered as zero, since a negative quantity of an element cannot physically exist.

After a range of values for a particular element was calculated, all weight-fraction ranges of the mining-generated and the laboratory-generated dust from the same mine and particular impactor stage were sorted for a minimum and a maximum weight fraction value. Once these two values were identified, their average value could be calculated and column graphs drawn. The height of the column represented the average value, and the difference between the maximum value and the average value represented the error bar value. Figures 1 and 2 show examples of some of the elemental values.

In those cases where the weight fraction of the laboratory-generated dust fell short of or exceeded the range of the mining-generated dust, or did not appear at all as in the case for Na, Sb, and Ba, they were considered unsuccessful predictors (Johnson, 1988). Thus, for the 32 elements detected by the PIXE method, the laboratory-generated dust was considered a successful predictor 73% of the time for stage 3, 65% of the time for stage 5, and 57% of the time for stage 7. This resulted in an overall predictability of 65%.

Conclusions

Although various researchers have differing opinions concerning the elements that they believe have an impact in contracting CWP, evidence indicates that elements such as Pb and Ni are contained in greater amounts in bituminous coal miner's lungs than normal concentrations of these elements (Sorenson, Kober, and Petering, 1974; Sweet et al., 1974). As such, the standard procedure developed to produce a laboratory-generated dust appears to predict well the concentrations of Pb and Ni (with 100% and 85% accuracy, respectively) in the immediate ventilation return of a CM (Figs. 1 and 2). Thus, potential problem mines or coal seams may be identified during planning stages.

Ba, Sb, Cd, and Na were the most difficult elements for the laboratory-generated dust to produce in detectible amounts.

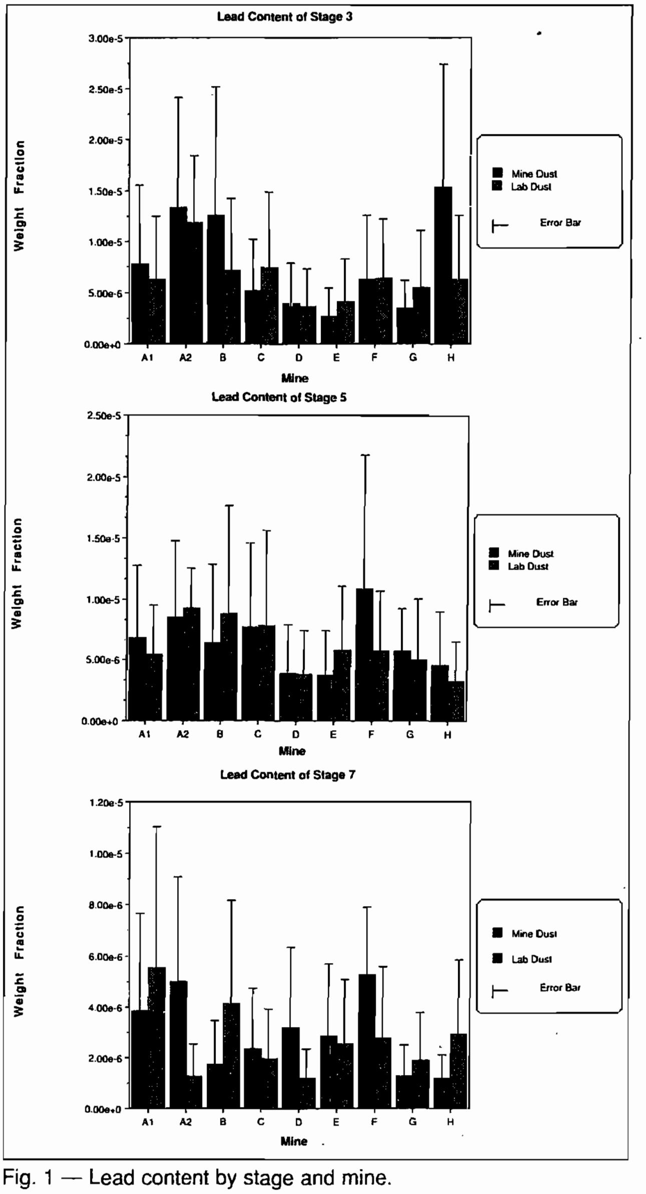

Fig. 1 — Lead content by stage and mine.

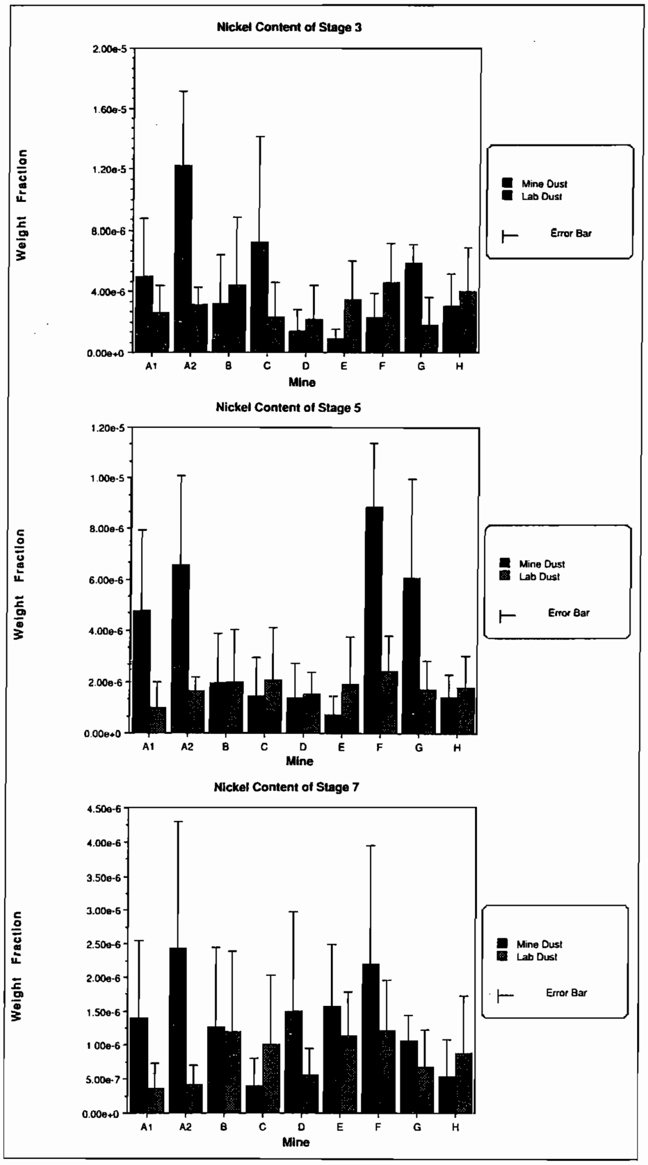

Fig. 2 — Nickel content by stage and mine.

They were detected in the mining-generated dust in mines where roof and floor rock were mined with the coal seam. Poor detection of these elements in the laboratory-generated dust may be due to inadequate grinding of the rock component during sample pulverization. It is recommended that a refined procedure of the one used in this study be developed to better predict the mining-generated dust when rock is concurrently mined with the coal seam.

An important contribution of this research is the development and description of a standard procedure, or a tool, which has shown promise for measuring the variability of the elemental composition of coal mine dust in the immediate ventilation return of a CM through the use of a laboratory-based process (Johnson, 1988).

To make the successful technology transfer in which a coal mining company is able to predict a proposed mine's airborne dust elemental characteristics in the immediate ventilation return of a CM by using the standard procedure presented in this paper, it is recommended that core samples of a coal property be used to prepare the laboratory-generated dust that would be compared to the mining-generated dust sampled as close as possible to the core location after mine development. This would allow verification of the assumption that a core sample could successfully be used in place of a channel sample to produce laboratory-generated dust that has elemental characteristics similar to those of dust sampled in the immediate ventilation return of a CMM.

Finally, it is recommended that researchers investigating the significance of elements and chemical variations on cell cultures and live animals use a laboratory-generated dust that is similar in composition to actual mine dust to perform their studies. This would better represent the dust that miners actually breathe.

As medical investigations continue to find the causes of CWP, and if a portion of the causes are found to be certain elements or particular concentrations of those elements in the mine dust, then the successful application of this research should contribute to the reduction in incidence and severity of CWP. ♦

Acknowledgments

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