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Coal Mine Respirable Dust

Characterization of coal mine dust is part of a wide-ranged project to combat respirable disease in mine workers

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One of the most serious long-term health problems associated with underground mining is Coal Workers' Pneumoconiosis (CWP), more commonly known as Black Lung Disease. It occurs in some coal workers, normally after 15 or more years of exposure to coal mine dust, and leads to a variety of respiratory problems. Two types of pneumoconiosis are recognized—simple CWP, which has been estimated to affect 6.9 percent of miners and is a condition that does not impair the miner's ability to work nor reduce life expectancy; and a more severe form of black lung (called progressive massive fibrosis) that occurs in about one percent of the cases and results in severe lung damage.[1]

Although the relationship between coal dust and CWP has long been recognized, detailed knowledge of the relationship is insufficient for setting up authoritative guidelines to reduce the health risks for those employed in dusty underground environments. CWP is not only a health problem for workers that causes considerable distress, it is also a very expensive problem—the total annual costs associated with CWP approach two billion dollars.

As part of its efforts to combat CWP, the U.S. Bureau of Mines in 1983 established a Generic Mineral Technology Center to carry out basic research into all aspects of respirable coal dust:
— control of dust generation
— the behavior of dust in the mine
— characterization of dust particles
— interaction of dust and lung
— the relationships among dust generation and mobility and the mine environment, geology, and seam characteristics.

Penn State, West Virginia University, the University of Minnesota, and the Massachusetts Institute of Technology are involved in this research, which is administered from the Department of Mineral Engineering at Penn State.

Our work is one of the seven projects to be conducted at Penn State. We are concerned particularly with the characterization of dust and its relationships with the mine environment, and our main goal is to establish standard procedures for describing and measuring these variables.

Coal Dust

Coal dust is a very complex material that varies greatly in chemical and mineralogical properties. Moreover, it is not the only constituent of respirable dust in the mine. When a coal seam is mined, it is inevitable that rock particles other than coal are included in the material. This rock comes from the mine roof, the floor, and the partings and inclusions within the coal seams. Since the roof and floor strata, the partings and inclusions are often stronger than the coal, mining them frequently causes more dust than mining the coal itself. One of the objectives of our research is to find the relationships between a specific coal's characteristics before it is mined and the respirable dust characteristics after it is mined. We are particularly interested in the size distribution of particles, the chemical properties, and the mineralogical properties.

Many studies have been made of the variables associated with CWP in West Germany, Great Britain and the United States, where engineers, scientists and medical personnel have tried to relate the incidence of CWP to the coal characteristics. They have measured the quantity of free silica in the coal, its ash content, its rank (a classification based on the coal's fixed carbon and calorific content), the mass of respirable dust in the mine atmosphere, and the trace elements found in the coal and the lungs of miners.

For many years, researchers have known that metal miners subjected to respirable dust that is high in free silica have a higher incidence of silicosis than those exposed to dust low in free silica. However, in coal mines the relationship between CWP and free silica is not clear. Studies made by Leiteritz and his associates[2] indicate that greater changes in lung tissue occurred in cases where the respirable dust was high in silica, but other work by Jacobsen[3] and by Naeye[4] and their co-workers indicates that the silica content of coal does not have any clear effect on CWP incidence. In fact, some researchers believe that free silica has little effect unless it constitutes more than 10 percent of the coal seam. Little is known about the effect of other mineral constituents.

A clear relationship between the rank of coal and the incidence of CWP has been demonstrated by Hart and Aslett[5] in Britain, by Reisner and Robock[6] in West Germany, and in the United States by Thakur[7] and Morgan[8], but others believe that the causal factor may be some variable correlated with the rank of coal rather than the rank itself.

In recent years, the relationship between the mass of the respirable dust in the work environment and the prevalence of CWP has been studied extensively, again with mixed results. Jacobsen et al.[9] and Reisner and Robock[6] report strong statistical evidence of the effects of dust mass on CWP incidence; but Morgan et al.[10] report a less concrete conclusion. Nonetheless, the overwhelming nature of the evidence points to the mass of the respirable dust in the working place as one of the CWP causal variables.

The possibility that trace elements in the coal contribution to CWP has so far been investigated in only a few studies. However, research by Sweet et al.[11] in West Virginia and by Sorensen et al.[12] in Pennsylvania and Utah indicates that certain trace elements could possibly influence the development of the disease.

Thus, the previous research has provided some insights into the possible causes of CWP but many additional questions have been raised concerning the actual causal factors. These are the questions we will attempt to answer in our work for the Generic Center on Respirable Dust.

Penn State Studies

The Penn State investigations are being carried out in the field, in the laboratory, and through statistical analyses. The statistical work is based on samples of Pennsylvania coal from the Penn State Coal Sample Bank.

A total of 97 coals have been analyzed for ten trace elements (Ba, Be, Cr, Cu, Ni, Rb, Sr, V, Zn, and Zr). Initially, the 97 samples were grouped by rank into the three major coalfields (the anthracite coalfield of northeastern Pennsylvania, the medium-volatile and low-volatile bituminous coalfield of central Pennsylvania, and the high-volatile bituminous coalfield of western Pennsylvania). The ten trace elements were then analyzed using discriminant and factor analysis techniques to see if any of the trace elements indicated a relationship with CWP incidence.

The results of this study[13] indicate that both chromium and zirconium have a positive correlation with rank, while strontium has a negative correlation. These trends were consistent throughout each of the coalfields, which suggests a possible causal relationship with the incidence of CWP. The interesting aspect of this research is the fact that CWP is also positively correlated with the rank of coal in these Pennsylvania coalfields.

The Dust Laboratory

A respirable dust laboratory has been established in the Department of Mineral Engineering and equipped with an Elpram Systems Inc. aerosol test chamber, shown in Figure 1. This equipment will be used to calibrate dust sampling equipment, establish standard sampling strategies, and test the experimental field procedures. In the photo, the chamber is being used to establish optimal sampling times for an eight-stage aerosol impactor, a dust collecting device that also determines the particle size distribution.

With the possibility that CWP is related to both the coal rank and the mass concentration of respirable dust, a project has been initiated to find out if the standard Hardgrove Grindability Index (HGI) can be used to predict the amount of respirable dust a coal seam might generate. Because the Hardgrove Index can be readily determined for any coal, the relationship between HGI and dust generation is of great practical value.

To test this idea, the standard procedure used to determine the HGI of a coal was first modified to deal with dust in the respirable size range, Figure 2. The PSU Coal Sample Bank supplied 25 coal samples representing each of Pennsylvania's three major coal regions and the HGI value of each coal was statistically related to the coal seam's apparent dustiness.

A linear regression equation indicated that the highest ranked coals produced the least amount of dust. This result conflicts with the findings of others and may indicate that some external variable is producing this effect.[14] Indeed, the mining process may be a candidate for explaining this apparent contradiction with past research.

Numerous references have been made in the literature to the higher incidence of CWP in the anthracite coalfields of Pennsylvania and in the low-volatile bituminous coalfields of southern West Virginia. Because these coals are high in rank, a correlation between rank and the incidence of CWP appears to be evident. However, the underground mining of anthracite often requires mine development in hard rock sediments, and the extraction of the thin low-volatile seams of southern West Virginia often requires the mining of a great deal of the roof and bottom rock to provide adequate clearance for men and machinery. Perhaps this noncoal material represents the contributing factor to the problem. In both cases, the noncoal material is often high in free silica.

This question is still under investigation. Because it is also generally believed that high mass concentrations of dust contribute to the incidence of CWP, in all our field studies we will make every attempt to analyze both the mass concentration of respirable dust and the amount of noncoal material mined in order to answer this question.

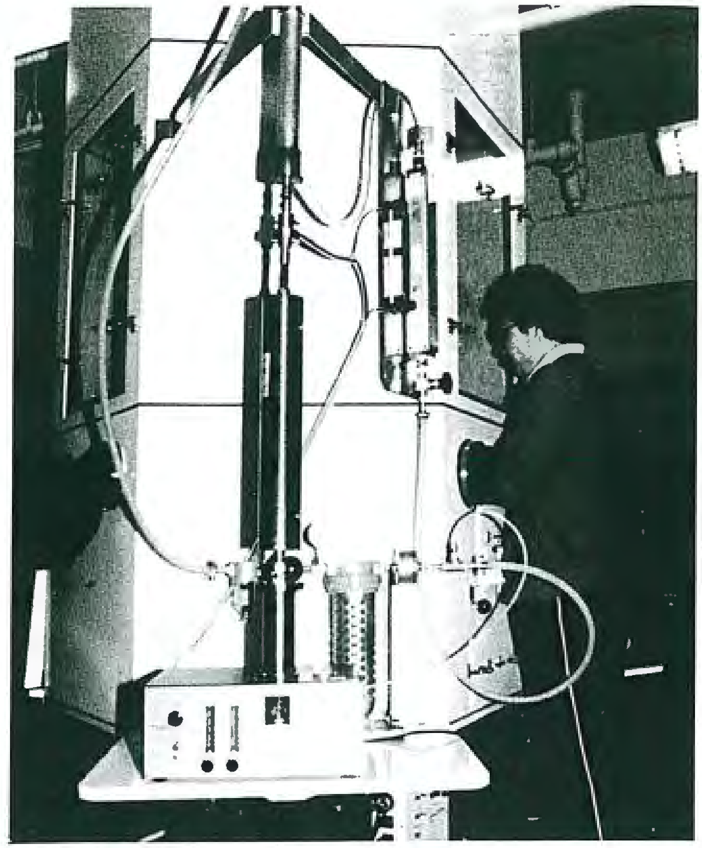

Figure 1. Graduate student C. Lee demonstrates the capabilities of the dust chamber in the Respirable Dust Laboratory.

Future Research

We are now moving into the coal mines with some of this work. Most of the effort is concentrated on studying the relationship of the properties of the coal and geologic materials and the properties of the respirable dust that is generated when the coal is mined. We hope to collect channel and respirable dust samples in a variety of mines in Pennsylvania to provide data for laboratory and statistical analysis. Eventually we will extend this work into neighboring states.

Meanwhile, other researchers in mineral processing are working on the mineralogical and morphological characteristics of the respirable dust. These analyses coupled with those of the researchers at the other universities, who are concentrating on engineering and medical aspects of respirable dust, should give us a firm basis for understanding this problem in underground mines, and hopefully point the way for reducing the incidence of pneumoconiosis in mine workers.

Penn State Respirable Dust Projects

Establishment of Standard Procedures for Characterization of Respirable Coal Mine Dust Potential.
Principal Investigators: J.M. Mutmansky, C.J. Bise, and R.L. Frantz.

A Fracture Mechanics Study of Crack-Propagation Mechanism in Coal, Utilizing Fracture Toughness and Fracture Velocity Concepts.
Principal Investigator: Z.T. Bieniawski.

Prediction of Ambient Dust Concentrations in Mine Atmospheres.
Principal Investigator: R.V. Ramani.

Computer Modeling of Longwall Face Ventilation.
(to begin October 1985)
Principal Investigator: R.V. Ramani.

Characterization of Dust Particles.
Principal Investigators: R. Hogg, P.T. Luckie.

Figure 2. Graduate student Michael P. Moore working with the Hardgrove apparatus in the Mineral Processing Lab.

Wetting Characteristics of Dust Particles in Relation to Dust Abatement. Principal Investigators: S. Chander, F. Aplan.

Analysis of Coal Particles on a One-by-One Basis, Using an Automated Computer-Controlled SEM with X-Ray Fluorescence.
Principal Investigator: L. Austin.

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CHRISTOPHER BISE holds degrees in mining engineering from Virginia Tech and Penn State, and is a registered professional engineer in Pennsylvania. He previously worked for Consolidation Coal Company and was a resident engineer at two underground mines in Ohio. Dr. Bise received the College's Wilson Award for Outstanding Teaching earlier this year.

JAN MUTMANSKY has been with Penn State since 1977, and prior to 1981 served as mining center coordinator at the Fayette campus. He holds three degrees in mining engineering from Penn State. Dr. Mutmansky has worked with the U.S. Bureau of Mines and Kennecott Copper Corp., and held faculty appointments at the University of Utah and West Virginia University.

COLLEGE NEWS NOTES

College Holds Commencement

This year, in an attempt to counteract the disconcerting feeling of mass production that inevitably accompanies the graduation of a class at a large public university, Penn State has changed to a system of separate graduation ceremonies for each college. The college commencements held in May 1985 were so successful that this will probably become the standard pattern for the University.

The College of Earth and Mineral Sciences conducted a ceremony in Eisenhower Auditorium for its approximately 270 students of the Class of 1985 who had earned bachelor's degrees. In the presence of Dr. Bryce Jordan, president of the University, Edward R. Book of the Board of Trustees, and a large number of impressively robed faculty, individual recognition was given to each of the graduating students. The student marshal was Lynn D. Dietz, geosciences, and the engineering honor graduate was Gary, J. Carinci, metallurgy.

The commencement address was given by Dr. Charles L. Hosler, former dean of the college and now vice president for research and dean of the Graduate School, who spoke on the vital role played by negotiation in our society, and the importance of students acquiring the negotiating skills that will allow them to operate effectively in their careers.

Dr. Bryce Jordan, president of the University, speaking at the Spring 1985 commencement of the College of Earth and Mineral Sciences.

Ceramic Scientists Honored

With more than 5,600 people in attendance, the 1985 meeting of the American Ceramic Society was the largest technical ceramics event ever held in the United States. At this 87th annual meeting of the society, Penn Staters chaired 8 individual sessions, and 48 papers were presented by Penn State faculty, researchers and students from the College's Department of Materials Science and Engineering and the University's Materials Research Laboratory. **Richard E. Tressler**, chairman of the College's Ceramic Science and Engineering Program, was installed as chairman-elect of the ACerS Basic Science Division.

Honors were awarded to several Penn State faculty. **Rustum Roy**, Evan Pugh professor of the solid state, delivered the annual Edward Orton Jr. Memorial Lecture, speaking on "The Ambivalent Role of Technology in the Future of America and the World." **John J. Mecholsky**, associate professor of ceramic science and senior research associate in the University's Applied Research Lab, received the 1984 Karl Schwarzwalder Award for Professional Achievement in Ceramic Engineering. The 1985 Ross Coffin Purdy Award was presented

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