

PERSPECTIVES IN CURRENT RESEARCH FOR CONTROL OF AIRBORNE DUST IN COAL MINES

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INTRODUCTION

The Federal Coal Mine Health and Safety Act of 1969 specified that the maximum allowable concentration of airborne respirable dust in bituminous coal mines in the United States be 2 mg/m^3 by the final deadline of December 30, 1975.* Although the actual operational deadline for imposition of the 2 mg/m^3 level is uncertain because the Interim Compliance Panel (ICP) can issue or refuse noncompliance permits that allow operation at an interim 3 mg/m^3 level, it is generally expected that the ICP will refuse noncompliance permits if the available dust control technology is deemed adequate and is not being fully used.

The 1969 Act also directed that the Departments of the Interior and Health, Education, and Welfare shall "develop new or improved means and methods of reducing the concentration of respirable dust in the mine atmospheres of active workings of the coal mines." Advanced technology would assist the mine operator in meeting the stringent dust limits imposed by the Act. The United States Bureau of Mines was assigned the responsibility for designing and implementing a research and development program to provide the advanced technology for reducing coal mine respirable dust. This paper briefly describes the Bureau's program.

BACKGROUND

Historically, attempts to control coal mine dust in the United States have generally used the brute force approach of ventilation and water sprays; they have been only marginally successful. For example, water sprays mounted on the continuous mining machine typically reduce the respirable dust level only 30% or so, and the use of different types of water sprays or wetting agents has not significantly increased dust suppression.

In mid-1970 it was generally thought that most coal-producing sections could probably meet the 3 mg/m^3 level by using available spray and ventilation technology but probably could not meet the 2 mg/m^3 level specified by the Act. However, by mid-1971, detailed field surveys of 50% of the working sections indicated that about one-half of the sections sampled were already meeting the 2 mg/m^3 level through the careful use of available technology. The sections sampled represented about 80% of the United States coal production.

* The Department of Health, Education, and Welfare will also adjust the permitted dust level if the silica content of the dust is greater than 5 wt % and can reduce the permitted dust to the 2 mg/m^3 level (or below) at an earlier date.

Such success is indeed encouraging. Certain coal producing sections, however, continue to be excessively dusty despite remedial actions, and any dust can be considered a health hazard. Field sampling indicates, moreover, that the ventilating air stream entering a producing section sometimes contains as much as 0.5 mg/m^3 of respirable dust; such a high dust loading reduces the effectiveness of the air as a dust suppressant at the face.

The Bureau program to develop advanced technology to control respirable dust in the underground environment is therefore oriented toward (1) providing improved remedial techniques for trouble spots, (2) reducing the concentration of the airborne respirable dust to an absolute minimum, and (3) reducing the dust level of the incoming ventilating air stream. Implementation of this program by the Bureau is accomplished by internal activities, primarily at the Pittsburgh Mining and Safety Research Center and the Twin Cities Mining Research Center, but also at other Bureau stations and especially by contracts and grants outside the Bureau. The internal programs were initiated in late 1969 to conduct research and development in exploratory areas and to maintain technical competence in order to assist the outside contracts and grants effectively. The major technical effort, however, is conducted by the outside programs, e.g., approximately 25% of the fiscal 1972 budget is tentatively allocated to the internal programs and 75%, to the outside activities.

The Bureau has used a Task Force to formulate its outside program. The Task Force is composed of technical personnel who develop a master list of recommended technical items for outside contracting for the next fiscal year based upon the proposed budget, planned internal Bureau items, and their assessment of the problem areas and the current state of the art. This assessment includes contributions from the mining industry and the scientific community and is continually reviewed during the year. The technical program recommended by the Task Force is of course reviewed by the Bureau in order to integrate the recommendations concerning respirable dust with other Bureau health and safety activities.

TECHNICAL PROGRAM

Coal mining involves continuous (ripper and borer), conventional, long-wall, and strip and other mine operations, including operations such as shuttle cars and belt haulage. In conventional mining, dust formation during blasting is presently being investigated by internal Bureau work, whereas other aspects such as dust formed during cutting and loading can seemingly be solved by present spray and ventilation technology, if properly used. Additional sampling studies are being conducted for the various mining operations, but it is already obvious that the ripper-type continuous mining operation is an especially dusty operation. The main emphasis in the Bureau's plan to control respirable dust has therefore been given initially to adapting the present ripper-type machine to create a less dusty operation.

The respirable dust aspect of the 1969 Act is interpreted by the Bureau in terms of developing advanced technology in five major categories: dust control at face; dust control at secondary locations, such as transfer points; personal protection; instrumentation; and chemical analysis. In addition, miscel-

laneous research items intended to give guideline insight into dust phenomena could be classed into a sixth or general category. These categories are discussed below.

General

The items in this category can be divided into fragmentation, dust characterization, and dust behavior. Results from this work are intended to give guideline insight into dust phenomena in the other major categories, which are oriented toward applied research or prototype development.

Fragmentation is concerned with dust formation during cutting. Dust during cutting can arise from crushing (compression) at the point of the bit, propagation of microfractures outside the compression zone, abrasion, and perhaps the release of latent particles (fusain?) imbedded in the parent coal seam. Dust formation during cutting is of course the basic problem, and the Bureau is purposely including some duplication of efforts in this area in view of its importance and the severe technical difficulties in obtaining meaningful results. The use of chemical additives to reduce the formation of respirable dust during cutting was explored but did not seem fruitful and was not continued.

Once respirable dust particles are formed, their characteristics and especially their behavior must be considered in applying techniques of dust control. An automated technique for measuring the size, shape, and chemical element distributions of respirable-size dust particles in the scanning electron microscope is being developed by Professor E. W. White at Pennsylvania State University and will be discussed in a later paper in this monograph. An exploratory survey by the Bureau of respirable-size coal mine dust from several mines has indicated a large variation in particle size, shape, and chemical composition. The particles had approximately log normal size distributions with geometric mean particle diameters of 1.0–1.3 μm but were highly irregular in shape, with aspect ratios from 1 (circular silhouette) to 40 (rod). Individual particles often contained appreciable amounts of various chemical elements (Ca, Fe, Si, S, Al), and the presence of pyrite, iron oxide, quartz, rock dust, and shale particles was deduced. The automated counting technique avoids tedious manual counting and severe subjective error and will be useful for determining the efficacy of a dust control technique and any relationships between the dust characteristics and the various mining operations and mines. A current program with Professor Corn at the University of Pittsburgh uses conventional laboratory techniques to characterize coal mine dust; this program has already been discussed by Professor Corn in this monograph. The electrical characteristics of coal dust particles and the feasibility of capitalizing upon these characteristics in a control technique are being explored in an internal Bureau program; this approach is discussed by Stein and Ryback in this monograph.

The behavior of the resulting particles, such as adhesion, agglomeration, and particle aerodynamics, is obviously important. Adhesion seems to be an especially important phenomenon, e.g., present Bureau work suggests that sufficient respirable dust is adhering to 20 lbs of run-of-face coal to contaminate 1,000,000 ft^3 of air to the 2 mg/m^3 level if it should become airborne. The Bureau work also suggests that only about 10% of this adhering dust is shaken

off during a dropping operation such as occurs at a belt-transfer point, but the dangerous potential of secondary handling operations as dust sources is evident. Physical and electrostatic adhesion is being investigated by several Bureau programs. Particle aerodynamics influences the dust level of the incoming ventilating air stream, the relevance of the dust monitors used in sampling, the sedimentation behavior of the dust particles outby the face, and so forth. For example, "gentle" sampling with a thermal precipitator by the Bureau indicates that the parent dust particles in a mine atmosphere often are appreciably agglomerated, and the possibility of deagglomeration during "vigorous" sampling arises. In view of their importance, particle aerodynamics and sampling phenomena are being investigated by several Bureau programs. Enhancement of agglomeration of respirable-size dust particles by sonics has not proved attractive in the past but is being reexamined.

Dust Control at the Face

At present, dust develops mainly when respirable-size particles that are formed at the producing face in the mine by the cutting bits of the mining machine become airborne and escape into the ventilating air stream and from there move to the miners. These particles can be "suppressed" through the use of adhesive forces, water, or other means that keep them on the surface of the newly-mined coal; and when airborne, they can be collected by agglomerating them to larger coal dust particles or water spray drops (that rapidly settle out) or perhaps by other techniques. Bureau laboratory work investigating the suppression of dust particles during cutting and the collection of airborne dust with water spray and steam is described by Tomb and colleagues in this monograph; it indicates that in the laboratory (1) 75% or so of the dust formed during cutting can be suppressed and (2) up to 75% or so of airborne dust can be collected. An immediate problem therefore is to clarify why water sprays at the head of the underground mining machine are only 30% effective, not 75% effective—the figure suggested by the Bureau's laboratory work. The Bureau hopes to obtain this clarification by using a "microminer," where one full-scale cutting wheel is taken off the commercial continuous mining machine and operated underground in a controlled manner, i.e., with controlled rpm, advance rate, and so forth. This approach avoids scaling problems and also includes aspects unique to underground operations such as roof pressure and the high pressure methane imbedded in the parent coal seam. The efficacy of water sprays and other dust control techniques can then be examined. A parallel program will use the microminer to investigate cutting parameters such as pick force and pick design.

Although the above Bureau efforts are designed mainly to provide guidelines to improve face control techniques, an outside contract is surveying previous engineering type efforts by coal mine companies to control respirable dust. A program to explore the effect of machine cutting parameters on the formation of respirable dust in an underground coal mine was largely unsuccessful due to insufficient underground testing. A contract was recently initiated for the engineering design of a system to flush the cutting bits with water and for the underground testing of the system. In addition, a program with Monsanto to determine the effectiveness of foam as a dust suppressant at the face is described by Schwendeman and colleagues in this monograph.

In any event, some dust particles will always escape capture and be transported out into the main ventilating air stream and to the miner. This transport process is being examined.

The feasibilities of new mining techniques to reduce or avoid the respirable dust problem are also being explored, such as water infusion to precondition the coal seam, high velocity pulsed water jets, and the use of modern electronic technology such as TV and sensors to develop a remote mining system wherein the miner can be physically located away from the producing face and other dusty locations. These programs are new; there has not yet been sufficient time for them to demonstrate feasibility.

Control of Secondary Sources

This area is primarily directed toward (1) investigating the usefulness of dust collectors, (2) controlling the secondary formation of dust, and (3) developing demonstration units that implement dust control techniques. The collector would, for example, reduce the exposure of downstream mine personnel (such as roof bolters) to respirable dust, permit reuse of the cleansed air at an adjacent working face (if its methane content is sufficiently low), and reduce the necessity of rock dusting in the return airway. A large assortment of dust collectors is already commercially available. However, a state-of-the-art contract by Garrett, described by Legatski and Brady in this monograph indicated that a new collector is required for coal mines. Initial aboveground testing of dust collectors is advisable in view of the cost and awkwardness of underground testing and the inevitable interference with mining operations. The Bureau will provide the required aboveground test facility in order to reduce total cost to the Bureau (several expensive components are already available) and especially because of technical problems associated with measuring dust concentrations in such a system.

Under an ongoing contract, the general effectiveness of foam to suppress secondary dust at belt-transfer and other locations is being explored. An internal program is also obtaining general guideline insight into the dust aspects of secondary handling, e.g., the dust adhering to run-of-face coal, the dust shaken off during dropping, and the new dust formed because of secondary fragmentation.

Personal Protection

Although the Bureau does not consider personal protective devices such as face masks to be a primary approach for reducing the miner's exposure to dust, such personal protection is visualized as an interim measure and also as a "last alternative" for certain dusty operations in case remedial measures are unsuccessful. The present filter-type face mask is physically uncomfortable and undesirable because of (1) an excessive pressure drop during use due to loading, (2) an imperfect match to the facial contour, (3) the possibility of day-to-day poor refit in the field, (4) irritation from dust and perspiration at the mask-face juncture, and (5) interference with oral communication, spitting, and so forth.

At present, for example, the National Institute of Occupational Safety and Health is funding a powered air supply unit (that avoids the pressure-drop problem), and a private company is funding a face-shield type of mask that is also supplied with powered cleansed air; the feasibility of providing cryogenic air to the machine operator is also being explored. The Bureau is considering fiscal 1972 programs to improve the fit of the face mask, a long range program in filtration phenomena to reduce pressure drop, and a "blue-sky" type of program to explore the feasibility of an air-curtain face mask, which would avoid all of the above problems. The Bureau has completed an internal program investigating penetration performance of respirators and is presently funding the development of an automated breathing simulator that can be used to test respirator behavior.

Instrumentation

Improved dust monitors for the mine inspector and company and also for research purposes are urgently required.

The new beta-absorption dust monitor funded by the Department of Health, Education, and Welfare is attractive as a fast-response research monitor but must be tested underground and, because of its intermittent sampling cycle, is not useful for the inspector or company interested in continuously monitoring an 8-hour exposure.

At present, the Bureau is sponsoring the development of dust monitors based upon forward and radial light scattering. Light scattering is attractive because the electrical output signal should be amenable to insertion in control circuitry and to telemetry. A light scattering technique measures number concentration, however; and the results must be converted to respirable dust mass concentration (mg/m^3) to satisfy the 1969 Act. Conversion is fraught with problems, for the mine dust particles are highly irregular in shape and often contain significant (and variable) amounts of noncoal materials, such as pyrite, that have different densities. Detailed underground testing of such monitors is therefore planned by the Bureau.

Chemical Analysis

Ongoing efforts are oriented toward developing laboratory analytical techniques to measure (1) silica in a small amount of respirable dust such as is presently collected on the 8-hour filter sample; (2) major inorganic elements in the filter sample, such as Mg, Al, Si, S, Fe, and Ca at 1 wt% or greater; (3) trace inorganic elements in the small filter sample, such as Hg in the ppm and ppb range; (4) several organic constituents in coal dust which are anticipated to be especially toxic, especially in conjunction with other constituents; (5) rock dust in the filter sample.

Current efforts were reviewed by Freedman and colleagues in this monograph.

Silica analysis is specifically required by the 1969 Act. The other analyses are anticipated to be of value to future medical research investigating the cause of pneumoconiosis, although the Bureau is not aware of any specific requirements for these items at present.

SUMMARY

Although the present Bureau program purposely includes fundamental and applied research efforts, the final objective of the program is to provide advanced technology to control airborne respirable dust in the mines by 1975 and preferably earlier. Specific final new technologies that are presently being actively explored or considered are as follows:

(1) *face control*: preconditioning, machine with advanced water sprays and ventilation, machine with improved cutting action, machine with foam, jet mining, remote mining; (2) *secondary control*: suppression with water spray, suppression with foam, dust collection, demonstration units; (3) *personal protection*: comfortable physical face mask, air-curtain face mask; (4) *instrumentation*: fast-response, high-volume dust sampler; (5) *chemical analysis*: improved silica analysis, major elements, minor elements.

In conclusion, the Bureau's program consists of a few large efforts in the above areas in addition to several separate supporting efforts. The net result is that the Bureau is the "prime contractor" with the responsibility of integrating these individual work items. It should be noted that, because of the complex and almost unique natures of the present respirable dust problems, the Bureau must devote a very appreciable effort to assisting even limited-scope outside efforts.