

CHAPTER 9

BUREAU OF MINES RESPIRABLE DUST MEASUREMENT AND MONITORING PROGRAM

K. L. Williams and G. H. Schnakenberg, Jr.

Pittsburgh Research Center
Bureau of Mines
U.S. Department of the Interior
Pittsburgh, Pennsylvania

ABSTRACT

This chapter will review current projects and discuss the future direction of the program. Projects presently underway include the development of a mining machine-mounted respirable dust monitor based on light scattering; the development of direct-indicating personal dust exposure monitors, one using light scattering and the other using a tapered element oscillating microbalance technique; a feasibility study of a light reflectance technique for measuring the mass of dust deposited on a filter; an in-house evaluation of various existing dust monitors; and two projects related to the determination of the quartz content of dust samples. The technical aspects of the various developments will not be discussed in detail; rather, the philosophy and rationale behind the development or investigation will be explained. Also, the chapter will point out the need for and nature of a planned respirable coal mine dust monitoring strategy study.

INTRODUCTION

This chapter discusses the Bureau of Mines (BOM) respirable mine dust monitoring and measurements program. Although some technical discussion is included, the chapter is meant primarily to present and discuss the rationale

behind the program. Most of the research and development effort is directed toward monitoring respirable coal mine dust, because of the great number of coal mining operations and because of the well known dangers of coal-worker's pneumoconiosis. Often, however, technology or methodology used in coal mines can be applied to other dust monitoring situations as well.

Coal mine dust personal sampling units (CMDPSU) have long been used to determine mineworker exposure to airborne respirable coal mine dust. The CMDPSU, often referred to simply as a "personal sampler," is a gravimetric device that can be worn by the worker or placed in the vicinity of work. A small battery-operated air pump draws dusty air through a dust precollector and filter cassette combination. The precollector, a 10-mm-diameter Dorr-Oliver nylon cyclone, captures large particles, such as those that deposit in the upper respiratory passages. Small particles, such as those that penetrate to the lower respiratory passages, pass on to a preweighed filter. After sampling is completed, the filter is reweighed. Knowing the mass of dust collected, the sampling flowrate, and the total sampling time, one can calculate the average airborne respirable dust concentration over the sampling period. Since health effects are not believed to be related to short-term excursion levels of dust concentration, the CMDPSU gravimetric approach served well to enforce the 2-mg/m^3 mass concentration standard for personal exposure and to gather epidemiological data. However, since sampling is usually performed over an entire 8-hr shift, and since days or even weeks may pass before dust level information is made available to the workers, emphasis has not been placed on using the CMDPSU to monitor dust for control purposes. However, since fast response technology for the measurement of airborne respirable mine dust is available today, BOM is taking a much closer look at the possibilities of monitoring for the purpose of dust control.

RESEARCH PROGRAM

The respirable dust section of the Instrumentation Group of Electrical Safety and Communications at the Pittsburgh Research Center conducts dust instrumentation and measurement methodology research, either in-house or under contract to the private sector. Presently, the work we perform generally falls into one of three categories:

1. direct requests from the Mine Safety and Health Administration (MSHA), U.S. Department of Labor;
2. feasibility studies of measurement technologies as applied to the mining industry;
3. development of hardware where a need is apparent or application appears very likely.

The first category needs little discussion. Occasionally in the conduct of its mission to enforce the 2-mg/m³ respirable dust standard, MSHA identifies a specific monitoring problem or need. Once MSHA communicates that need to BOM, it makes every reasonable effort to develop new instrumentation or suggest existing instrumentation that will meet MSHA needs.

Feasibility studies may take one of two forms. BOM researchers may investigate a new or existing measurement technology to determine whether or not it can be used to sense airborne respirable mine dust, primarily coal dust. Once a technology has been identified, BOM determines if the technology is adequate for the intended monitoring purpose, if it can be incorporated into a device that would withstand the rigors of the mining environment, if it can be made intrinsically safe for operation in explosive methane atmospheres, etc. Feasibility studies might also involve evaluating existing aerosol monitors designed for more general monitoring applications. The objective of these evaluations is, of course, to see if the instruments could be used in the mining environment. The final category is self-explanatory. Hardware development takes place when fairly well defined specifications for the device can be cited.

Projects currently underway include the development of a mining machine-mounted respirable dust monitor; development of direct-indicating personal dust exposure monitors using two distinctly different technologies; a feasibility study of a light reflectance technique for measuring the mass of dust deposited on a filter; an evaluation of various existing dust monitors; and two projects related to the determination of the quartz content of dust samples.

MACHINE-MOUNTED RESPIRABLE DUST MONITOR (MMRDM)

The concept of putting a monitor on a mining machine to measure respirable coal mine dust has been discussed for a number of years. Strong recent interest by MSHA, however, has brought about a concerted effort to produce hardware. The technical details of the device are discussed by Lilienfeld [1983]. Briefly, however, MSHA requested a device that would be mounted on and obtain power from the mining machine. The device under development uses light scattering to measure airborne respirable coal mine dust. Both instantaneous and shift average dust concentrations can be displayed to the mining machine operator. The shift average is defined by:

$$\text{shift average} = \int_0^t \frac{C(t)dt}{480}$$

102 STATUS OF WORK-ENVIRONMENT AEROSOLS

where $C(t)$ = instantaneous dust concentration
 t = sampling time (min)

The constant 480 is in minutes and corresponds to a full 8-hr shift. Shift averages will be stored in memory for later retrieval. The device will incorporate a filter system to make an average gravimetric measurement to verify average light scattering measurements or to facilitate calibration of the light scattering sensor. MSHA has also requested the MMRDM have the ability to shut off the production function (the cutting head in the case of a continuous miner) of the mining machine if the shift average for a particular shift exceeds a predetermined level. Hardware is being developed to meet these specifications.

BOM sees this MSHA-requested development as a great opportunity to investigate the merits of monitoring for control. Mining under the present monitoring program has been likened to driving a car down the highway without a speedometer. Occasionally, the driver of the car exceeds the speed limit. However, the only way the driver learns of the misdeed is by a police officer stopping the driver to issue a citation. Displaying the dust level to the mining machine operator would be like providing the driver of that car with a speedometer.

What type of information can best be used by the miner? Would instantaneous readout of dust levels help the miner to promptly correct dusty conditions by improving water spray systems, ventilation or mining habits? Or would random short-term high-level excursions of dust levels cause too much confusion? In that case, would a longer integrated value, a running average or a shift average be more appropriate? A record of about a month of shift averages will be stored in the memory incorporated in the MMRDM. Could that information be useful to mine health officials for performing trend analysis to identify mining practices that, on the average, produce less airborne dust? We hope the experience gained during field tests of the prototype MMRDM will answer these questions.

PERSONAL DUST EXPOSURE MONITORS (PDEM)

The need for a PDEM was conceived almost concurrently by researchers at the National Institute for Occupational Safety and Health (NIOSH) and at BOM. For that reason, PDEM development contracts were initiated under an interagency agreement between NIOSH and BOM. Like the MMRDM, the PDEM was originally intended to make instantaneous measurements of airborne respirable coal mine dust and to have the ability to display instantaneous and shift average concentrations. The important differences are that the device must be small enough to be worn by the worker and must have its own power source.

Two types of PDEM are being developed. The first utilizes light scattering as does the MMRDM, but does not make use of a mechanical size separator for respirable dust. The light-scattering configuration is being designed to emphasize the respirable fraction of the aerosol that enters the sensing chamber by convection. The details of this device are covered by Lilienfeld [1983]. If successful, the light-scattering PDEM will provide a rapid-response PDEM to aid workers in controlling their exposure to respirable dust. Equally as important, however, this work will serve to:

1. study the feasibility of measuring respirable coal mine dust using this passive, open-cell, light-scattering approach;
2. provide a relatively inexpensive device that can be used for purposes other than personal exposure monitoring (e.g., a hand-held survey instrument for locating dust sources); and
3. provide a basic building block for other less size- and power-restrictive monitoring applications, since the sensor will necessarily be miniaturized.

The other PDEM will utilize a tapered-element oscillating microbalance (TEOM) technique. The active element of a TEOM consists of an elastic tube constructed of a material with a high mechanical quality factor (Q) and having a special taper. A material with a high Q does not dissipate energy readily, and thus will not damp out quickly when oscillating at a resonant frequency. In the case of the PDEM, the tube is firmly mounted at the wide end while the other end supports an exchangeable filter cartridge. Dust-laden air is drawn through the filter and the resulting filtered air is pumped down the hollow tube. The tapered tube with the filter at the free (narrow) end comprises an oscillating system whose natural frequency will change in relation to the mass deposited on the filter. The tapered element is kept in oscillation by an electrical feedback system. The oscillation of the elastic element is converted into an electrical signal by a light emitting diode (LED)-phototransistor combination. The output of the phototransistor is modulated by the light-blocking effect of the vibrating element.

The TEOM technology originally was intended to be used in a PDEM having the same instantaneous onsite measurement capabilities as the light scattering PDEM. The response time and sensitivity of the technique are adequate. Since the TEOM indiscriminantly measures mass, however, moisture presented a challenging, but not insurmountable, engineering problem. Funding limitations have prevented us from pursuing the contractor's suggested design to overcome those problems. Instead, we have opted to obtain six "end-of-shift" prototypes with the monies available.

The end-of-shift concept consists of six TEOM canisters and an electronic readout system. Each TEOM canister will consist of the specially tapered tube with a filter mounted on top, the appropriate electronic hardware to condition the dust sample and tapered element before reading the frequency, and the oscillatory feedback circuitry. This canister will be designed to replace the filter in a typical CMDPSU.

In use, the canister will be placed in a readout system that will:

1. recognize the canister;
2. control the humidity and temperature around the device until the device is in equilibrium with its surroundings;
3. measure and record the resonant frequency of the tapered element system;
4. record the resonant frequency as a type of preweight for the next sampling session; and
5. alert the user if the filter should be changed.

The canister would then be used only as a filter in a CMDPSU during the working shift, i.e., the sampling pump would draw dusty air through the cyclone size selector and deposit respirable dust on the nonoscillating filter. After sampling is finished, the canister would be reinserted into the interface system to determine the change in frequency and thus the weight gain. The filter could be used over and over, each final weight (resonant frequency) serving as the preweight for the next session until the collected mass is too much for the measurement system. The filter would then be replaced.

The development of this PDEM, like the light scattering unit, may provide a very useful PDEM for respirable coal mine dust, and may also serve as a building block for other types of monitors. More importantly, however, we will extensively lab-test the prototypes to determine the capabilities and limitations of a technique for direct measurement of the mass of airborne respirable dust. Light scattering, of course, suffers from the fact that the intensity of the scattered light is not directly proportional to the mass of the particles. In monitoring applications other than PDEM, electrical power could be relatively plentiful. Such power could be used to more easily control moisture problems, and thus provide a means for nearly instantaneous mass measurements.

LIGHT REFLECTANCE

BOM recently concluded a feasibility study of an on-filter light reflectance technique in which the contractor had proposed that the amount of light reflected from a coal-dust-laden filter could be related to the mass of the dust on that filter. The laboratory prototype eventually delivered to BOM made use of a reflective object sensor (ROS) as the light source and detector. A ROS is essentially a LED and phototransistor detector mounted on the same head. The ROS used in the prototype instrument was a commercially available near-infrared device. As a result, the response of the measurement system was strongly dependent on the type of coal dust (anthracite, bituminous, subbituminous, lignite) being viewed. Differences of up to 12% were evident between two different samples of bituminous coal dust. The contractor presented data, obtained using separate yellow LED and detectors, that suggested that a ROS operating in the yellow range would greatly reduce

the system's sensitivity to coal dust type. Unfortunately, a yellow ROS in the proper configuration was not commercially available. We may attempt to have such a ROS specially made and test the prototype instrument in-house to determine if the instrument is more acceptable.

Although the prototype light reflectance instrument cannot at present perform acceptably well for most applications, we are now aware of the capabilities and limitations (response time, precision, interferences) of the measurement technique. The technique promises to be simple, durable and probably inexpensive to apply should a measurement need be uncovered that requires a technique with the qualities defined in this study.

EVALUATION OF INSTRUMENTS

A very important activity within the program is the evaluation of dust monitoring instrumentation. Evaluation work serves three purposes:

1. It measures the performance and success of our development contracts.
2. It determines whether or not commercial dust monitors meet manufacturer specifications.
3. It helps determine if a particular monitor is suitable for the mining industry.

Some evaluation work is done in-house. This year, the RAM-1 portable light scattering respirable dust monitor was subjected to extensive aerosol testing in our lab. Two reports will soon be released: The first discusses instrument response to various dusts (two types of coal dust, two types of limestone dust, and Arizona road dust), and the second discusses problems encountered when the instrument is exposed to high concentrations of small water droplets. Such evaluation of the RAM-1 was warranted, because the optical system of the instrument (or a slight modification) is being used in the MMRDM, the light scattering PDEM and other monitoring systems.

Although some evaluation work is conducted in-house, limited facilities and workforce have required that much of the work be contracted. A contract has been awarded to the University of Minnesota to evaluate various dust monitors.

QUARTZ PROJECTS

Another important area of work is the rapid, convenient and accurate measurement of silica (quartz) in dust samples. Two projects in this area of work will be concluded sometime in fiscal year 1982. The first involves the fabrication of a rapid X-ray device to measure quartz. The second project involves developing a method for measuring the quartz content of dust samples that involves the use of an on-filter infrared technique.

MONITORING STRATEGIES

Most of the BOM dust-monitoring program discussed so far consists of projects already underway or completed. As mentioned earlier, these projects were initiated:

1. to satisfy an MSHA request;
2. to study the feasibility of applying a measurement technology to the mining industry; or
3. to develop hardware.

Although these criteria for research and development have served sufficiently well in the past, they can be greatly improved. For example, when studying a novel measurement technique or evaluating an instrument for measuring dust, the researcher can certainly determine such variables as response time, accuracy, precision, sensitivity to interfering agents, noise and durability. The problem arises when deciding, on the basis of the test results, whether or not the device can be applied to the mining industry.

The key word is "application." The need or application, once identified, makes certain requirements on the measurement system. What type of information is needed? Instantaneous readout? Shift averages? Measurements averaged over several days, weeks or months? What limits are required for accuracy? Precision? The important and often difficult step is to properly identify the application. One way to proceed is to make a calculated guess based on past experience as to how a measurement device can best be applied. Occasionally, however, this procedure can result in "gadget" development—instrumentation with little or no real worth or utility in the industry.

We recently initiated a high-priority project to deal with the problem of monitoring applications. Beginning in October 1981, we took the first steps in developing a detailed monitoring strategy for control purposes. We began by examining the mining process to determine those elements that most strongly affect the level of airborne respirable coal mine dust in the mine air. Possible examples might be ventilation, spray water pressure, depth of cut and so on. The most influential elements must be monitored and controlled. The nature of the element (e.g., continuous, intermittent, random) will define the quality and nature of data that is needed. Once these needs are ascertained, one can refer to existing technology and available instrumentation to see if they can satisfy the monitoring needs defined by the monitoring strategy. When the strategy identifies a monitoring need for which there is no existing hardware, then hardware development can be easily justified and the specifications for the device will be clearly definable.

Development of the strategy for control monitoring purposes will not be trivial and is expected to extend over several years. The description of the work has, of course, been greatly simplified; however, the importance of such a strategy must not be underemphasized.

REFERENCES

- Lilienfeld, P. (1983) "Current Mine Dust Monitoring Developments," in *Aerosols in the Mining and Industrial Work Environment, Vol. 3, Instrumentation*, V. A. Marple and B. Y. H. Liu, Eds. (Ann Arbor, MI: Ann Arbor Science Publishers).

AEROSOLS

In the Mining and Industrial Work Environments

VOLUME 1

Fundamentals and Status

Edited by

**Virgil A. Marple
Benjamin Y. H. Liu**



ANN ARBOR SCIENCE
THE BUTTERWORTH GROUP

TD884.5

.A252

Vol. 1

Copyright © 1983 by Ann Arbor Science Publishers
230 Collingwood, P.O. Box 1425, Ann Arbor, Michigan 48106

Library of Congress Catalog Card Number 82-70701
ISBN 0-250-40531-8

Manufactured in the United States of America
All Rights Reserved

Butterworths, Ltd., Borough Green
Sevenoaks, Kent TN15 8PH, England