CHAPTER 2.—SAMPLING TO QUANTIFY RESPIRABLE DUST GENERATION

By Jay F. Colinet[1]

The respirable fraction of the airborne dust is the dust that reaches the lungs and leads to the development of CWP or silicosis. Respirable dust cannot be seen with the eye. Conversely, if a dust cloud is visible, it is likely that a portion of the airborne dust will be in the respirable size range. To quantify the amount of harmful respirable dust in the mine air, sampling instrumentation must be used.

New cases of lung disease in miners have been occurring at increased rates since 2000. As a result, accurate respirable dust sampling is important to quantify worker exposures and identify dust sources. Sampling results can then be used to implement control technologies in the most problematic areas.

RESPIRABLE DUST SAMPLERS FOR USE IN COAL MINING

The most common type of sampler used in the mining industry is the gravimetric sampler (Figure 2-1). This device is designated for use in compliance dust sampling by the Federal Coal Mine Health and Safety Act of 1969. It consists of a constant-flow sampling pump, a size-selective cyclone, and a filter cartridge. For coal mining operations, the sampling pump should be calibrated to operate at 2 lpm. In metal/nonmetal mining operations, the pump should be operated at 1.7 lpm. The 10-mm Dorr-Oliver cyclone separates the oversize dust from the respirable fraction (usually considered to have an aerodynamic diameter of 10 µm or less). The oversize dust is deposited into the grit pot at the bottom of the cyclone, while the respirable fraction is deposited onto a 37-mm-diam polyvinyl chloride (PVC) filter. The filter collects the respirable dust and should be weighed by a qualified lab to determine the mass of dust that has been collected during sampling. The mass of dust and the volume of air sampled are used to calculate the concentration of respirable dust in milligrams per cubic meter. Care must be taken after a sample is collected to ensure that the cyclone assembly stays in an upright position. Otherwise, the oversize dust particles in the grit pot can be deposited onto the filter and invalidate the sample.

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[1]Supervisory mining engineer, Office of Mine Safety and Health Research, National Institute for Occupational Safety and Health, Pittsburgh, PA.

Figure 2-1.—Gravimetric sampling pump, cyclone, and filter cassette.

To determine the silica content of a gravimetric sample, the filter must be sent to an accredited laboratory for analysis. For samples collected in coal mines, the MSHA P7 infrared analytical technique [Parobeck and Tomb 2000] is used to determine silica content. For samples collected in metal/nonmetal mines, x-ray diffraction using NIOSH Method 7500 [Schlecht and O'Connor 2003] is used.

Because of the great number of variables encountered in mining operations that can impact airborne dust levels, it is highly desirable to place multiple gravimetric samplers at a single location and calculate an average dust concentration. The use of multiple samplers increases the confidence that the measured dust levels are representative of the true dust concentration.

In addition to gravimetric samplers, a real-time dust sampler has been approved by MSHA for use in underground mines, but not for compliance sampling purposes. The personal DataRAM (pDR) has dust-laden air pass through a sensing chamber and passes a light beam through the dust. A sensor measures the amount of light scatter caused by the dust and relates this scatter to a relative dust concentration. This concentration is correlated to the time when the sample was measured and stores this information in the internal data logger. The sample data can then be downloaded to a computer for analysis. Figure 2-2 illustrates a typical graph obtained with the pDR, as well as a photo of the pDR. Mobile sampling was used to collect the data (this sampling technique will be discussed in the next section). The time-related dust data can be analyzed for specific time intervals (e.g., head-to-tail passes on longwalls), with average dust concentrations calculated for these intervals.

Unfortunately, the accuracy of the light-scattering monitor can be compromised by dust clouds with different size distributions, different dust compositions, and/or water mist in the air. Consequently, when NIOSH uses pDR samplers, a field calibration is completed. Gravimetric samplers are placed adjacent to the pDR, and individual pDR dust measurements are adjusted based on the ratio between the average gravimetric concentration and the average pDR concentration [Thermo Scientific 2008]. For example, if the gravimetric concentration was 1.3 mg/m^3 over a 6-hr measurement period and the pDR average concentration was 1.0 mg/m^3 for the same 6 hr, then all individual pDR measurements would be multiplied by 1.3.

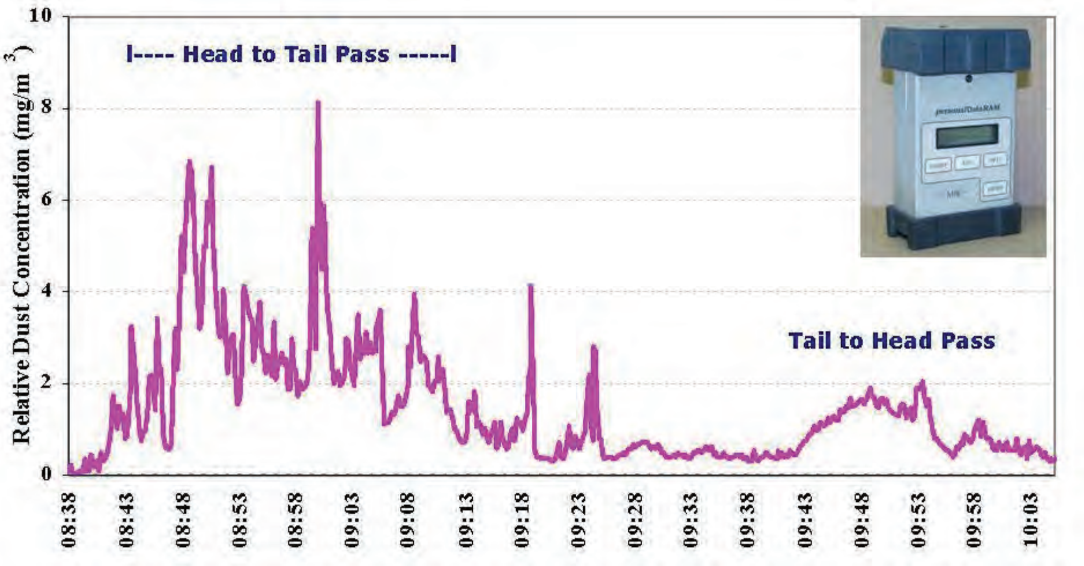

Figure 2-2.—Example of dust measurements obtained with the pDR.

The personal dust monitor (PDM) is another real-time sampler that has been developed and tested by NIOSH, approved for use in underground coal mines by MSHA, and reached commercial production [Volkwein et al. 2006]. The PDM uses the tapered-element oscillating microbalance (TEOM) to obtain a real-time, gravimetric-based measure of respirable dust concentrations. The TEOM is a hollow tube that vibrates at a known frequency with a filter mounted on the end. As respirable dust is deposited onto the filter, the TEOM frequency changes, which can be related to a dust concentration. The PDM provides the wearer with a readout that displays the cumulative dust concentration to that point in the shift and the percent of the permissible exposure limit that has been reached. This information can be used by the wearer to monitor dust exposure during the shift to prevent overexposure. The sampler is incorporated into standard cap lamp housing and has the sampling inlet located at the cap lamp (Figure 2-3).

Figure 2-3.—PDM with TEOM removed *(shown on right)*.

SAMPLING STRATEGIES

To effectively control the respirable coal and silica dust exposure of mine workers, it is necessary to identify the sources of dust generation and quantify the amount of dust liberated by these sources. Once the dust sources are identified and quantified, dust control technologies that offer the greatest protection to the mine workers can then be applied.

To quantify the amount of dust liberated by a source, dust sampling must be conducted in a manner that isolates the identified dust-generating source. This is achieved by placing dust samplers upwind and downwind of the source in question. The difference between these measurements is used to calculate the quantity of dust liberated by this source.

For example, in an underground coal mine, samplers can be placed in the immediate intake and return of the continuous miner to determine the amount of dust liberated by the miner while cutting and loading in the face. In this case, samplers are positioned upwind and downwind of the miner to sample the airborne dust levels throughout the cut. Figure 2-4 shows these sampling locations. If gravimetric samplers are used for this evaluation, it will be necessary to ensure that sufficient mass is collected during sampling. As a result, it may be necessary to sample during multiple continuous miner cuts. In this case, the sampling pumps should be started when the continuous miner has been positioned in the face and begins cutting the coal. After the first cut has been completed, the sampling pumps are turned off during the time the miner is repositioning into the next face. While off, the sampling pumps should be repositioned into the second cut in the same relative locations as for the first cut sampled. When the miner is ready to resume mining, the sampling pumps can be restarted.

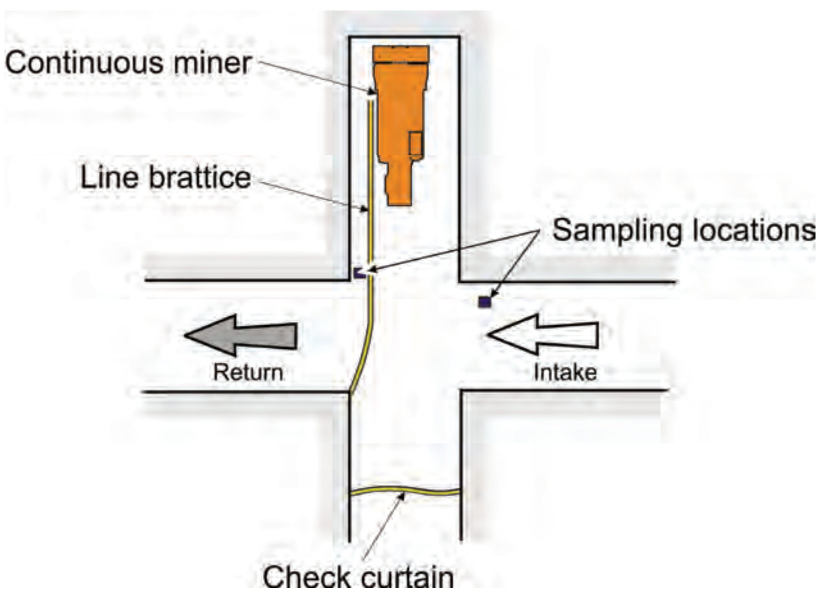

Figure 2-4.—Sampling locations used to isolate dust generated by a continuous miner.

For a more mobile piece of equipment, such as a longwall shearer, a mobile sampling strategy must be used to isolate the dust generated by the equipment. Two sampling personnel would be required to travel with the shearer as it mines across the longwall face. One person would be located upwind of the shearer, while the second would be located downwind. These sampling personnel would maintain their respective distances from the shearer as it mines across the face. Figure 2-5 illustrates this mobile sampling strategy.

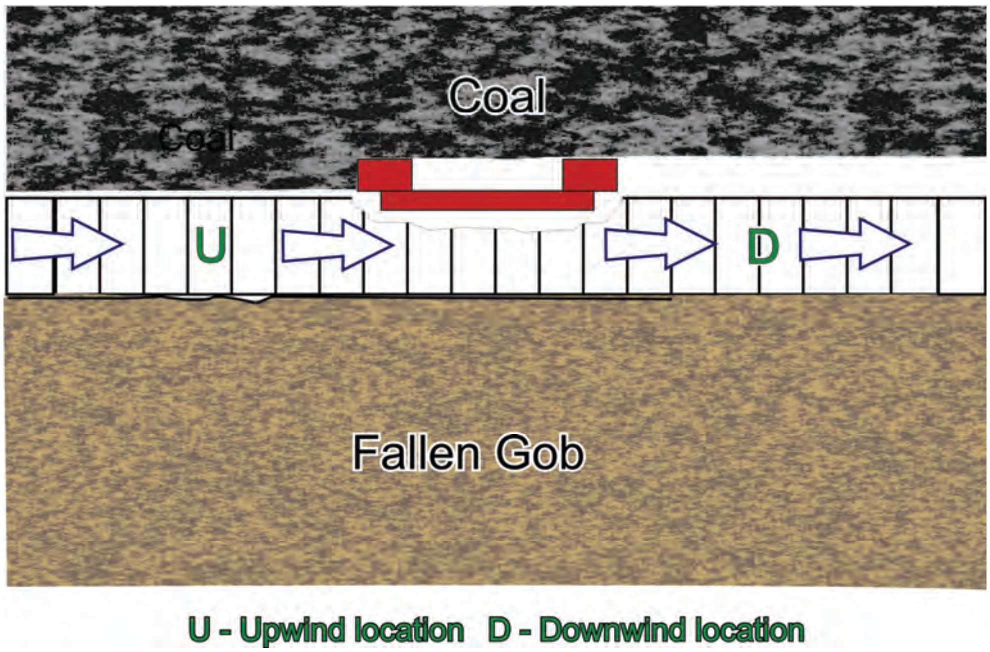

Figure 2-5.—Mobile sampling used to quantify shearer dust.

Both of these sampling examples represent underground coal mines where a well-defined ventilation pattern is typically present. However, this is not always the case. For example, to quantify the amount of respirable dust generated by a drill at a surface mine, it would be necessary to place an array of samplers around the drill to account for dust liberated during changing wind directions. The dust concentrations from these samplers would be averaged to quantify dust liberation around the drill. It would also be necessary to place a background dust sampler far enough away from the drill, so that it is not impacted by drill dust, to monitor ambient dust levels. The dust levels from the ambient sample would be subtracted from the drill samples that have been averaged to determine dust liberated by the drill. Figure 2-6 shows sampling locations around a surface drill.

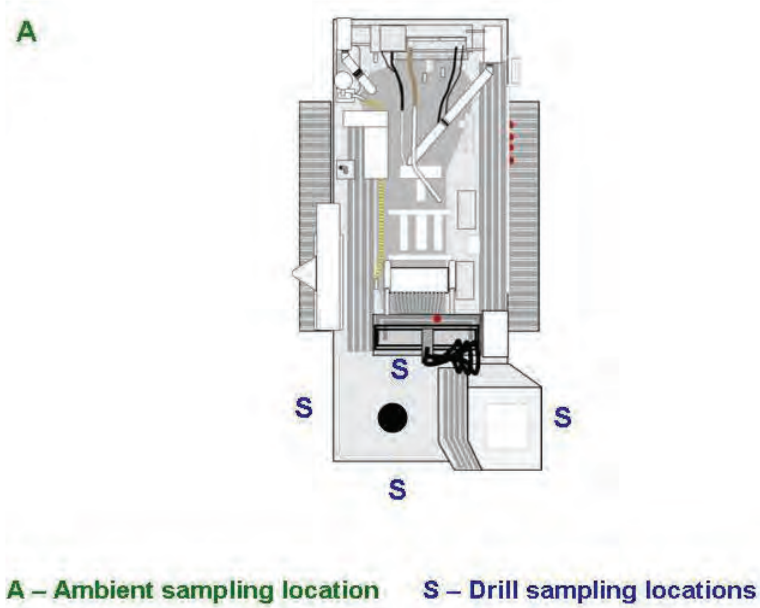

Figure 2-6.—Sampling locations around a surface drill.

After identifying and quantifying the most significant dust sources, appropriate dust controls should be selected and implemented. To determine the impact of the added controls, sampling would once again be conducted. Typically, an A-B comparison would be needed to quantify the impact of added control technologies. The A-portion of the sampling would be conducted with the original operating conditions to establish baseline dust levels. The control technology of interest would then be installed and the B-portion of the testing completed. To maximize the validity of the test results, both portions of the testing should be completed under similar operating conditions. The dust levels measured under each test condition would be compared to quantify the effectiveness of the installed control.

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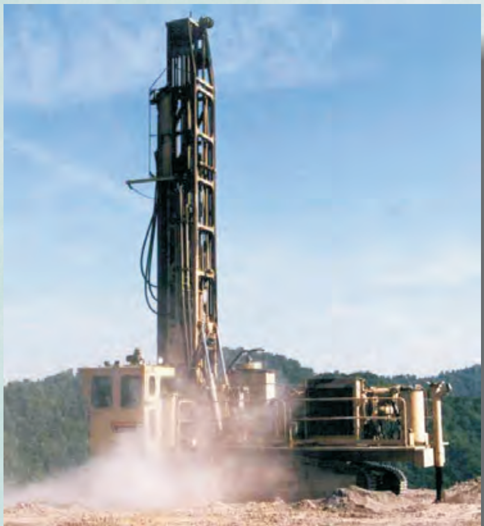

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Information Circular 9517

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By Jay F. Colinet, James P. Rider, Jeffrey M. Listak, John A. Organiscak, and Anita L. Wolfe

DEPARTMENT OF HEALTH AND HUMAN SERVICES
Centers for Disease Control and Prevention
National Institute for Occupational Safety and Health
Office of Mine Safety and Health Research
Pittsburgh, PA • Spokane, WA

January 2010

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DHHS (NIOSH) Publication No. 2010–110

January 2010

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ACRONYMS AND ABBREVIATIONS USED IN THIS REPORT

CWHSP	Coal Workers' Health Surveillance Program
CWP	Coal workers' pneumoconiosis
DO	designated occupation
HVAC	heating, ventilation, and air conditioning
IARC	International Agency for Research on Cancer
ILO	International Labour Office
MSHA	Mine Safety and Health Administration
NIOSH	National Institute for Occupational Safety and Health
PDM	personal dust monitor
pDR	personal DataRAM
PEL	permissible exposure limit
PMF	progressive massive fibrosis
TEOM	tapered-element oscillating microbalance

UNIT OF MEASURE ABBREVIATIONS USED IN THIS REPORT

cfm	cubic foot per minute
cm	centimeter
fpm	foot per minute
ft	foot
ft/min	foot per minute
gpm	gallon per minute
hr	hour
in	inch
in w.g.	inch water gauge
kPa	kilopascal
lpm	liter per minute
m/sec	meter per second
mg/m^3	milligram per cubic meter
mm	millimeter
mph	miles per hour
$\mu g/m^3$	microgram per cubic meter
psi	pound-force per square inch
sec	second

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