PERFORMANCE OF A LIGHT SCATTERING DUST MONITOR AT VARIOUS AIR VELOCITIES: RESULTS OF SAMPLING IN THE ACTIVE VERSUS THE PASSIVE MODE

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The Respiratory Hazards Control Branch of NIOSH routinely conducts laboratory and mine-site evaluations of dust control technologies. Gravimetric and instantaneous dust sampling instruments are used in these evaluations to measure and document dust levels to determine worker exposure. The Thermo personal DataRam (pDR) is an instantaneous sampler that uses light-scattering technology to provide relative measures of airborne respirable dust. The pDR can be used in active and passive modes to measure respirable dust levels. Tests were conducted to evaluate the sampling performance of active and passive pDR operation relative to each other and against a gravimetric sampler (the accepted standard for respirable dust measurement). The purpose of the test was to determine if the pDR can be used effectively in the passive mode in higher velocity airflows (up to 5.1 m/s (1000 fpm)). Studies of the pDRs in both modes of operation were conducted in a controlled laboratory environment and in field situations. Dust measurements using pDR units in both modes of operation were recorded in velocities ranging from 1.0 to 5.1 m/s (200 to 1000 fpm). Tests were conducted in ambient air and in air with the addition of moisture. Results show that, although the units measure different concentrations in their respective modes of operation as compared to a gravimetric sample, the relative readings can be corrected to yield accurate dust measurements.

1. Introduction

It is not uncommon in many underground coal mines, especially those using longwall mining methods, to experience airflow velocities of 5.1 m/s (1000 fpm) or higher. Typical air velocities for room-and-pillar mining (the most common method of underground coal mining) range from 1.3 m/s to 3.0 m/s (250 to 600 fpm). To design effective engineering controls for dust mitigation for each of these mining methods, the source and location of dust concentrations must be determined. For regulatory respirable dust requirements, the standard for respirable dust sampling in coal and metal and non-metal mines is the personal respirable-dust sampler. This gravimetric sampling instrument collects preclassified respirable dust on a filter, which is then desiccated and weighed to determine the mass of collected dust. Average dust concentrations are then calculated based upon collected mass, sampling flow rate, and operating time. Gravimetric methods of dust measurement provide levels of worker exposure to dust over the course of an entire working shift, however, this method cannot show the variations in dust levels over the course of that shift or what activities may cause higher levels of dust during the shift. Not all activities during a working shift produce the same amounts of dust. Determining the activities that cause higher dust levels can benefit researchers seeking engineering control measures to combat respirable dust. A real-time dust monitor is capable of showing dust level variation. The advantage of real-time respirable dust sampling instruments is their ability to monitor short term variations in dust levels and to determine dust trends during activities that generate dust. To better evaluate and subsequently reduce worker dust exposure, it is beneficial to determine when dust levels are high or peak during certain work activities. Different mining methods may have several dust producing sources, and it is, from a research perspective, advantageous to isolate and identify the activities that are producing the dust. The personal DataRAM (pDR) (Thermo Electron Corp) is currently used in a number of research studies to isolate mine dust sources. Belle[1] showed that three different pDR units operated under similar conditions differ significantly in measured concentrations. Therefore, while not accurate enough for regulatory compliance sampling, these monitors are excellent for showing relative patterns and trends of high or peak dust levels during worker activities. These instruments are robust and suited for harsh mine environments. The instrument has two modes of operation, passive and active, depending on ambient sampling conditions. A previous mine study shows that for determining relative real-time concentrations of dust from an operation or piece of equipment during a shift, the pDR in the active mode and an accompanying gravimetric sampler can be related using a ratio of the gravimetric concentration and the average pDR concentration[2]. After using this instrument in numerous studies, there appeared to be similarities in dust measurements between using the units in the active and the passive modes. For logistical purposes, the passive units are more desirable for research efforts. Eliminating the need for a pump, cyclone, seals, and filter on each unit makes the instrument much more efficient for use in field studies. Therefore, a study was conducted in a controlled environment to determine how the units, in both passive and active modes, measure a controlled infusion of dust into a wind tunnel at air velocities of 1.0, 2.0, 3.0, 4.1, and 5.1 m/s (200, 400, 600, 800, and 1000 fpm). The lab results were then compared to active and passive units that were used in field studies.

2. Background

The evolution of the RAM-1 (Realtime Aerosol Monitor 1, MIE Inc.) to the personal DataRam (pDR) has made it possible to conveniently collect personal dust samples in real time. The pDR is a photometer or nephelometer. A nephelometer is an instrument for measuring suspended particulates in a liquid or gas. It does so by using a pulsed, high output, near-infrared light emitting diode source, a silicon detector/hybrid preamplifier, and collimating optics and a source reference feedback PIN silicon detector. The intensity of the light scattered over the forward angle of 50 to 90° by airborne particles passing through the sensing chamber is linearly proportional to their concentration. This optical configuration produces optimal response to particles in the size range of 0.1 to 10 μm. The unit has a concentration measurement range of 0.001 to 400 mg/m^3. Particle measurement is a function of the light reflected into the detector from the particles.

Two modes of operation of the pDR are offered by the manufacturer, passive and active. According to the manufacturer, for the usual nearly quiescent intramural monitoring applications, and if no pre-selection of particles is desired, there is essentially no difference between the air sample sensed by an active monitor and that sensed by a passive one. However, they go on to say that outdoor monitoring generally requires active sampling, in combination with an appropriate inlet configuration in order to prevent wind induced particle size discrimination effects[3]. A study by Willeke and Degarmo concluded that air velocity may affect the aerosol sampling and transport efficiencies so that the active sampling may differ from passive sampling[4]. Consequently, passive units are recommended by the manufacturer for use in stagnant or near stagnant ambient conditions whereas active units are used in windy conditions or conditions that warrant high velocity air (e.g., ventilation systems in underground mines).

Both the passive, pDR-1000AN and the active, pDR-1200 are aerosol photometers. The only difference between the two units it that the active unit requires a vacuum pump, a cyclone, a filter, and active sampling seal plates. In the passive mode, the unit uses the natural movement of the ambient air to enter the chamber for measurement. The active mode uses a pump to draw the aerosol through a fixed flow inlet (cyclone) into the chamber to prevent wind-induced particle size discrimination effects. An inline filter is also used in the active mode to collect the dust after it has passed through the light scattering chamber. However, when using pDRs in the active mode, the seals on the units must be tight so that the cyclone is not by-passed by air being drawn into the dust chamber through leaks. Maintaining effective seals is difficult on active units[2]. When using multiple units in the field, the active units are more cumbersome than passive ones because of the need for pumps, cyclones, seals, and filters.

Several studies have been conducted to evaluate the performance of the pDR under different conditions and modes of operation. Chakrabarti et al.[5] found that the pDR in an active mode is more accurate than in the passive mode when sampling outdoor particulate matter. A study by Willeke[3] using the MIE Miniram, a predecessor to the pDR, was conducted in a passive and an active mode using different pump flow rates to evaluate the transport of aerosols to the sensing chamber. The results showed that the instrument needs to be calibrated against a gravimetric sample for the specific dust used at a specific flow configuration. Lui et al.[6] compared the pDR in passive mode against gravimetric sampling devices in short-term monitoring of particulate in residences and found that the pDR overestimated dust levels by 27%. However, these studies were conducted in ambient outdoor or indoor air conditions. The unit has not been tested in both modes for accuracy in a variety of air velocities or in high velocity airflows (up to 5.1 m/s (1000 fpm)).

3. Test Methods

3.1 *Laboratory test apparatus*

The laboratory tests were conducted at the Pittsburgh Research Laboratory of the National Institute of Occupational Safety and Health (NIOSH). A wind tunnel, equipped with a variable speed fan and a vibrating dust feeder, was constructed for the tests. The dimensions of the tunnel were 0.6 x 1.2 m (2 x 4 ft), providing an area of 0.7 m^2 (8 ft^2). The length of the wind tunnel was 12.2 m (40 ft) with a 1.5 m (5 ft) long evase at the open end to reduce head loss and turbulence as air entered the tunnel. Air velocity was controlled with a 29.7 kw (40 hp) Joy axial vane fan capable of producing air velocities in the tunnel in excess of 10.2 m/s (2000 fpm). This variable speed fan provided a means to adjust air velocity in the tunnel to test dust measurements at various velocities. The fan is positioned behind the dust insertion point and the dust sampling location, making it an exhausting ventilating system. Velocity profiles for each of the test velocities were established using fixed-point traversing over a cross-section (16 quadrants) of the wind tunnel at the sampling point. After each profile, the fan speed was set and additional tests were conducted to ensure repeatability.

Dust was introduced into the tunnel by means of an injection nozzle that was connected to a screw feeder (Vibra Screw Model SCR-20) and a compressed air-eductor (Penberthy Model LH Eductor). The vibratory dust feeder fed at a constant mass flow rate for all velocities tested. The dust feed was measured at 16.1 g/min (.57 oz/min) with an air pressure through the eductor of 206.8 kPa (30 psi). The dust feed was introduced into the tunnel at the mouth of the evase. The sampling location is located at a distance of 10.7 m (35 ft) from the dust feed, which allowed for adequate dispersion and mixing of dust. The test apparatus is shown in Figure 1.

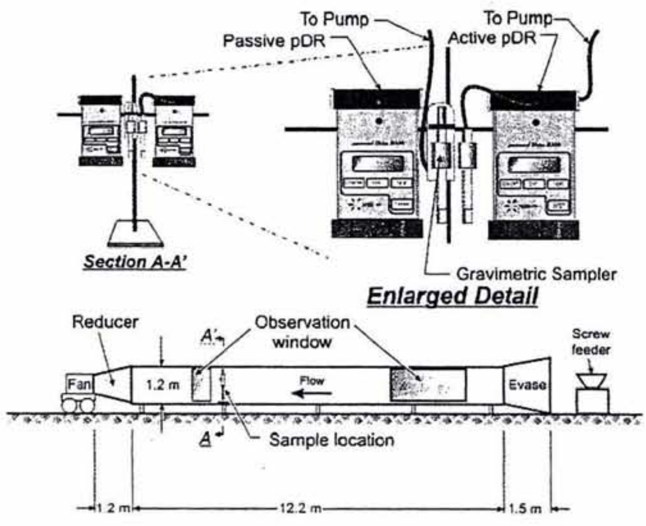

Fig. 1. Dust sampling wind tunnel.

The pDR units were located in the wind tunnel with a gravimetric sampler for side-by-side comparisons. Both active and passive mode pDRs were positioned on either side of the gravimetric sampling unit as shown in Figure 1. The samplers were positioned as close as physically possible along the centerline of the wind tunnel where dust concentration gradients were minimal, as determined from a previous study[7]. The gravimetric sampler consisted of a Dorr-Oliver cyclone, a 37 mm filter, and a pump. The active pDR unit used a Dorr-Oliver cyclone and pump. The pumps were operated at 2 l/min. The pDR unit operating in the passive mode did not require a pump, cyclone, or filter.

It is important to note that there is an accuracy bias between these instruments. That is, two instruments located side-by-side recording a known quantity of dust in the same mode of operation will not yield identical dust levels, nor will they accurately record the known quantity of dust. For the purposes of evaluation, the same two active and passive units were used in their respective modes for each laboratory test. Similarly, during field evaluations, the same two units were always located at the same sampling point on each day of testing.

3.2 *Sampling Methods*

The comparison tests were made at five different air velocities 1.0, 2.0, 3.0, 4.1, and 5.1 m/s (200, 400, 600, 800, 1000 fpm). The pDR units were set to measure dust at 5 second intervals for a duration of 15 minutes. The two units were initialized to simultaneously record dust concentrations at each of the 5 velocities. Six tests were conducted at each velocity for a total of thirty tests. Zeroing of the pDR units was performed after every test according to manufacturer's specification using the zeroing bag. For calibration purposes, a gravimetric sampler is used with the pDR during each dust sampling survey, and then the pDR is calibrated against the gravimetric measurement to arrive at dust concentrations for the unit. The authors feel this is a more accurate way to sample with the pDR because it takes into consideration that the dust cloud may not be consistent from test to test or from survey to survey.

The coal dust used for sampling, Keystone Mineral Black 325BA, is commercially available and manufactured by Keystone Filler and Manufacturing Company. The material is finely crushed bituminous coal. The physical properties of this material are consistent, having a maximum particle size of 50 microns, 65% of which is <10 microns, and a moisture content of <1%. The dust passes from the screw feeder into a compressed air-eductor which causes particle separation and allows for dispersion of the material into the air stream.

Gravimetric dust samples were collected on 37 mm PVC (polyvinyl chloride) filters located in a 10-mm Dorr-Oliver cyclone (Mine Safety Appliances, Pittsburgh, PA). The filter and cyclone assembly use a vacuum pump (Model Escort Elf, Mine Safety Appliances, Pittsburgh, PA) operated at 2 l/m for collection of dust on the filters. Gravimetric analysis of the filters was performed on a Mettler-Toledo microbalance (precision, 5 μg) (Model UMT2, Mettler-Toledo, Columbus, OH). Weighing was conducted in the NIOSH weighing lab at the Pittsburgh Research Laboratory (PRL) at 22.7 ± .4 deg C (73 ± 0.7 deg F) and 53 ± 2 % relative humidity (RH). Pre-weighing procedures employ ambient equilibration and control filters. Post-weighing procedures employ desiccation, equilibration, and control filter correction.

In order to minimize turbulence to obtain accurate air velocity measurements, it is recommended that readings be taken at least 10 duct diameters downwind of changes in the ductwork The dust sampling and air monitoring station was approximately 13 duct diameters away from the evase and dust injection point. Fine water droplets and humidity have been found to affect dust measurement readings from light-scattering samplers[8]. Although Quintana et al found false high readings above 85% relative humidity (RH), dry air tests were conducted in February and March with a recorded laboratory test RH range between 20 and 40% and temperatures ranging between 21.7 and 23.9 deg C (71 and 75 deg F). To determine the effects of high RH, additional measurements were taken in high RH conditions (73 to 84%, conducted in July and August) in which atomizing sprays (raising RH to 99%) were introduced into the tunnel to simulate a humid mine atmosphere.

4. Data Analysis

Raw data from the units were graphed on the same set of axes to compare each unit's measurements and trends in dust levels over the 15-minute tests. These comparisons were made at each velocity to determine how the units behaved in the different modes of operation in the different air velocities. Plots of passive vs. active modes show similar trends in all of the tested velocities. At 1.0 m/s (200 fpm), the graph of the passive and active pDR measurements show that the two units log different dust levels throughout the test. However, as seen in Figure 2A, the signature of each curve has similarities in trends as dust levels increase and decrease, even though the levels are different. To determine how close these trends are, the ratio of the average of the active to the passive

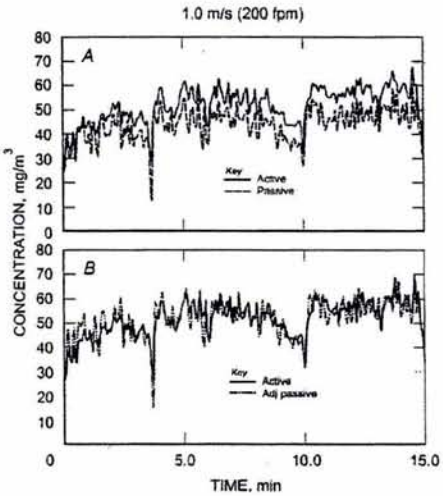

Fig. 2. A-Active and passive dust measurements. B- Passive related to active after ratio adjustment at 1.0 m/s (200 fpm).

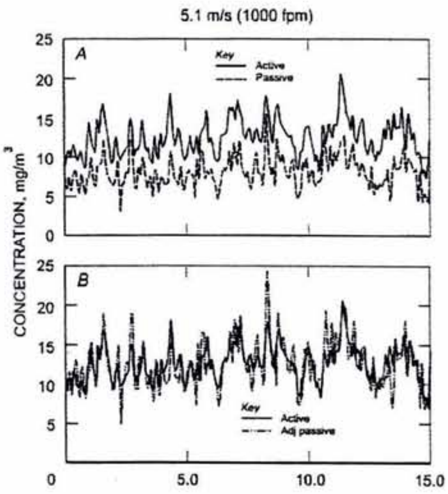

Fig. 3. A-Active and passive dust measurements. B- Passive related to active after ratio adjustment at 5.1 m/s (1000 fpm).

measurements was calculated. Then, each passive measurement was multiplied by the ratio to get an adjusted passive measurement for each sampling interval. This data set was then graphed with the original active measurements to evaluate the curves against one another. Figure 2B shows the curves at 1.0 m/s (200 fpm). The graph shows that the trends of the units follow closely as dust concentrations increase and decrease. The graph also shows that, although average active measurements are higher, the passive unit records more exaggerated measurements when the concentrations spike higher or lower. However, since the units record relative rather than absolute dust levels, as long as the trends are the same, the units are measuring similarly. This pattern is typical of the six tests conducted at 1.0 m/s (200 fpm) as well as tests conducted at the other velocities. Figure 3A and B show this same pattern at 5.1 m/s (1000 fpm).

5. Tests in Dry Air

Table 1 shows the average sampler concentrations of the tests at each velocity for the pDRs in passive and active modes along with the gravimetric concentration and the ratio of the active to passive averages and gravimetric sampler ratios. For each sampler, the table shows decreasing concentrations as the velocity increases, as can be expected due to dilution in the increased quantity of air. The table also shows ratios of the average sampler dust concentration measurements. The ratio of the active to the passive mode ranges from 1.3 to 1.8 over all velocities and a standard deviation of 0.2, with both end point velocities having ratios of 1.5. The consistency of the ratio suggests that regardless of the velocity, the manner in which both units record dust measurements can be related. When comparing each unit with the gravimetric sampler by ratio, the table shows an excellent relationship of 0.6 and 0.9 above 1.0 m/s (200 fpm) between the gravimetric and the active and passive pDRs respectively.

Table 1. Dust Concentrations Averages and Ratio From Sampling Units in Dry Air.

	Average Sampler Concentration, mg/m^3			Average Ratio		
Velocity m/s (fpm)	Passive	Active	Gravimetric	Act/passive	Grav/passive	Grav/active
1.0 (200)	37.7	55.5	28.3	1.5	0.8	0.5
2.0 (400)	16.3	29.3	17.9	1.8	1.1	0.6
3.0 (600)	13.3	17.9	10.8	1.3	0.8	0.6
4.1 (800)	8.4	14.3	8	1.7	0.9	0.6
5.1 (1000)	7.5	11.3	6.2	1.5	0.9	0.6

Figure 4 shows a graph with a log-log scale of the average concentrations of each sampler at each velocity. The pDR in the active mode always records higher measurements than both the passive pDR and the gravimetric sampler. As velocity increases, dust levels go down with similar slopes over the range of velocities.

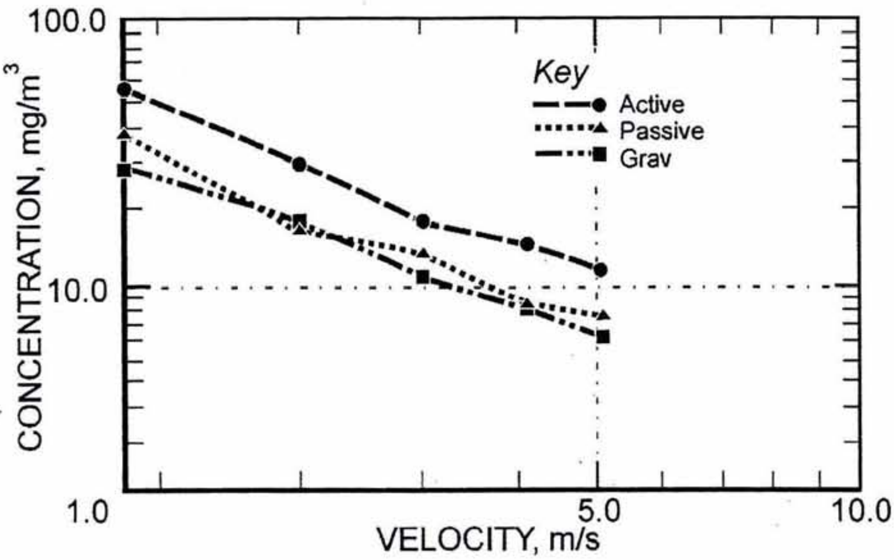

Fig. 4. Average concentrations of sampling units for all test velocities.

The passive pDR measures dust concentrations similar to the gravimetric sampler at all velocities higher that 1.0 m/s (200 fpm).

An Analysis of Variance (ANOVA) was performed to test the hypothesis of no difference among the ratios across the five velocities. Since the F-statistic establishes that there is or is not a difference between group means[9], this test was employed to determine if the instruments are measuring the same dust levels based on the ratio of the active to the passive modes of operation. Based on the assumptions that the measured dust quantities are normally distributed and that the distribution of the variances is the same for each instrument, the hypothesis that the instruments are reading the same cannot be rejected at the 95% confidence level. The Shapiro-Wilk test for normality[10] verifies that the data do come from a normal distribution, and the Levene test[11] was performed to verify that there is no difference among the variances of the ratios within each of the five velocities. Ratio means of all five velocities are centrally located about a mean of 1.5. An F-ratio of 1.389 and at a significance level of 0.266 establishes that there is no significant difference in the means of the ratios for the two instruments over the range of all velocities.

ANOVA was also performed on the ratios that relate each mode of operation to the gravimetric sample taken during each test. Gravimetric to both active and passive ratios were calculated as shown in Table 1. Making the same assumptions as with the active to passive ratio analysis, the analysis relating each unit to the gravimetric sample shows again that there is no significant difference in the ratios over the range of velocities at a 95% confidence level.

6. Tests in Humid Air

As previously stated, water droplets can affect the ability of the pDRs to measure dust particles accurately. Mines use water sprays as means of dust suppression. Therefore, tests were conducted with water sprays to further compare the pDRs and to simulate a damp or very humid environment. Two atomizing sprays nozzles (Bete Fog Nozzle, No P54) were installed at the mouth of the evase approximately 25.4 cm (10 in) above and below the dust injection tube (Figure 5). These nozzles, operating at 20.7 kPA (30 psi), produce a cone-shaped fog spray with a 90 degree spray angle at a flow of 1.7 l/m (0.46 gpm). The sampling station inside the wind tunnel had a respective temperature and relative humidity of 21.1° C (69.9° F) and 71.7 % before the addition of the sprays, and 19.2° C (66.5° F) and 99.5 % after the sprays were activated.

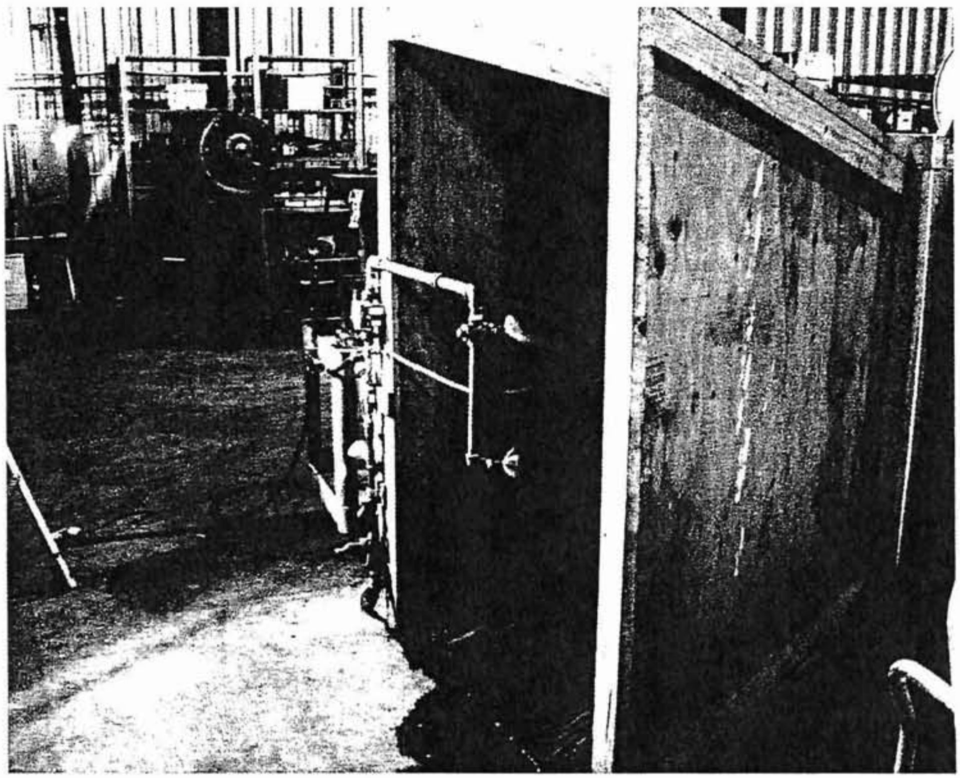

Fig. 5. Atomizing mist nozzles positioned above and below dust feed.

Table 2 shows average dust concentrations and ratios when an atomizing mist was introduced into the tunnel along with the dust. Even though the measured concentrations have been reduced from the addition of moisture, the ratios are very similar to those from the dry dust tests. From these tests, it appears that the added moisture had little effect on the relative measurements of the pDR units.

Table 2. Dust Concentration Averages and Ratios from Sampling Units with High Humidity.

Average Sampler Concentration, mg/m^3				Average Ratio		
Velocity m/s (fpm)	Passive	Active	Gravimetric	Act/passive	Grav/passive	Grav/active
1.0 (200)	37.7	55.5	28.3	1.5	0.8	0.5
2.0 (400)	16.3	29.3	17.9	1.8	1.1	0.6
3.0 (600)	13.3	17.9	10.8	1.3	0.8	0.6
4.1 (800)	8.4	14.3	8	1.7	0.9	0.6
5.1 (1000)	7.5	11.3	6.2	1.5	0.9	0.6

7. Field Tests

The pDRs operating in the passive and active modes were evaluated at two different field sites. As with the lab evaluations, the units were positioned side by side during mining activities to record dust. The conditions at each of the mines were very different (in the interest of maintaining anonymity, the mines will be designated as Mine A and Mine B). Mine A is an underground limestone mine with a low air velocity of approximately 0.5 m/s (100 fpm) found in the large 12.2 m x 12.2 m (40 ft x 40 ft) entries. Dust measurement at this mine was conducted over a 3-day period to determine the dust generated by haul trucks traversing between the loading and dumping points within the mine. Six pDR units were used over the 3-day period at various locations along the truck route with an additional pair used on the final day of monitoring. Two units were positioned at the crusher, two at the belt and two in the return air entry. The additional units were placed at the dump on the third day. A total of 85 test intervals were collected over the 3-day sampling period. The positioning of the units allowed for varied dust levels throughout the monitoring period. For instance, average dust measurements (mg/m^3) at the three monitoring sites during the first day of testing for the passive and active units respectively are as follows: crusher 4.8, 7.2; belt 2.1, 5.6; return 0.6, 1.0. This pattern was similar for each day of testing and allowed for an evaluation of the units measuring in different dust concentrations in the same airspeed.

Mine B is an underground coal mine utilizing longwall mining methods for coal extraction. Measured velocities along the longwall face were approximately 5.1 m/s (1000 fpm) and flowed from the headgate entries to the tailgate entries. The crew and equipment along the 305 m (1000 ft) longwall face were protected by 165 shields (hydraulic roof supports). Dust measurements at this mine were conducted over a 3-day period to determine dust generated by the longwall shearing machine during the headgate to tailgate passes and then from the tailgate to headgate passes. A total of 16 passes was sampled over the 3-day period, five the first day, five the second day, and six the third day. The pDR units were positioned at two locations along the longwall face, at shield 10 (closest to the headgate entries) and at shield 150 (closest to the tailgate entries). As with the units in Mine A, the dust levels at the two locations varied over the monitoring periods.

Whereas the gravimetric samplers were measuring dust continuously over the duration of the shift, the pDR units measured intervals during certain activities for shorter durations. Therefore, the pDR units at the field sites were not compared to the gravimetric samplers as they were in the lab tests.

Table 3 shows the ratio of the active to the passive units at the two mine sites for each of the 3-day testing periods. Ratios and standard deviations are shown at Mine A for the four sampling stations and at the two sampling stations for Mine B. The ratios at both mines, while not as consistent as those from the lab study, show that the units read closely in both mine atmospheres over each of the three sampling days for each location that was sampled. The other difference from the laboratory samples is that the active units read consistently lower concentrations than the passive units at each location at each mine site making the active to passive ratios less than 1 in all field measurements. This result may be attributed to over sampling in the lab due to the orientation of the units to the direction of airflow.

Table 3. Active to Passive Ratios and Standard Deviations at Mine Sites.

	Mine A								Mine B			
	Crusher		Belt		Return		Dump		Shield 10		Shield 150	
Day	Ratio	s.d	Ratio	s.d.	Ratio	s.d	Ratio	s.d	Ratio	s.d	Ratio	s.d
1	0.7	0.02	0.4	0.01	0.6	0.05			0.3	0.1	0.5	0.03
2	0.7	0.02	0.4	0.01	0.6	0.03			0.2	0.03	0.5	0.1
3	0.5	0.02	0.3	0.02	0.6	0.04	0.4	0.1	0.3	0.03	0.5	0.03

8. Discussion

Real-time sampling of dust trends is beneficial for research studies. The pDRs measure relative rather than absolute dust levels in real time. Although recorded relative dust levels are different between these two units, the trends are the same in all velocities tested. Results of the laboratory study reveal that, given the same two pDRs positioned side-by-side in a known concentration of dust and measuring in active and passive modes, a calculated ratio of measurements of the active to the passive unit show that both modes of operation are consistently related in all test velocities. In addition, relating each of the units to the gravimetric sample as a ratio showed consistency of dust measurements in each of the test velocities for both modes of operation. This relationship has been confirmed before[2] with the pDR sampling in the active mode but not in the passive mode and not at different air velocities. Operation of the water sprays during the second series of tests did not impact the ratio between the active and passive samplers. Field measurements also showed consistent ratios when sampling at sites with two velocity extremes (0.5 m/sand 5.1 m/s (100 fpm and 1000 fpm)).

Although the active unit measured higher levels of dust in the lab, this was not the case for the pDRs that were used in the field measurements. Both field site results show that at the lowest and highest velocities, the passive units read higher levels of dust than the active units. This result may be attributed to the active unit's cyclone inlet efficiency and its orientation to the air stream in the lab tests versus the field. All of the test velocities in the lab were lower than the inlet velocity of the active sampler (approximately 6.6 m/s (1300 fpm)). Therefore, the active sampler was not sampling isokinetically, i.e. the inlet velocity of the cyclone was not equal to the velocity of the air stream being sampled. When sampling isoaxially (directly into the air stream) and inlet velocities are greater than the air stream being sampled, super-isokinetic sampling occurs and the sampler will over sample the aerosol[12]. When sampling in the field, the units were consistently perpendicular to the direction of the airflow, to provide greater clearance (protection) between the samplers and mining equipment. When cyclone inlets of sampling units are perpendicular to the airflow, under sampling may occur.[13, 14]

Another possibility for the differences from lab to field sampling may be the dust measured and environmental factors. The characteristics of the dust used and the controlled conditions of the lab varied from the field. The pDR relates dust concentration to scattered light inside the sensing chamber. The scattered light is dependent on the size, size distribution, shape, density and optical properties of the particles being measured in the chamber. While lab dust material is pure bituminous coal with consistent physical properties, field dust samples may contain rock, diesel particulate, moisture, and vary in size distribution. These characteristics will elicit a different response from the units. A study of the RAM-1, a real-time dust monitor that uses light scattering to measure dust, showed the differences in response between coal dust and limestone dust[15]. Results of the study showed that the higher reflective properties of the coal dust sampled produced higher dust level readings than the limestone dust. The differences in the characteristics of the dust used in the lab and those measured in the field could cause the units to respond differently in the lab versus the field. Regardless of which unit read higher and regardless of the type of dust being measured, the consistency of the ratios between the units shows that there is a relationship in the readings for each mode of operation.

Test data also indicate that operation of the pDRs in either the active or passive modes results in dust levels that deviate from dust levels measured with gravimetric samplers. Typically, the dust levels obtained with the active sampler were higher than the gravimetric results, while the passive samplers were closer to the gravimetric concentration. However, when used with the accompanying gravimetric samplers, dust readings from either the active or the passive samplers could be adjusted to be more representative of the actual dust levels and very similar to each other. Therefore, the authors would recommend that gravimetric samplers be used in all applications in order to develop a gravimetric/pDR ratio to adjust the relative pDR readings. Consequently, the pDRs can be effectively used to identify major dust sources, trends in dust generation, and relative differences in the dust levels resulting from the implementation of control technologies.

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