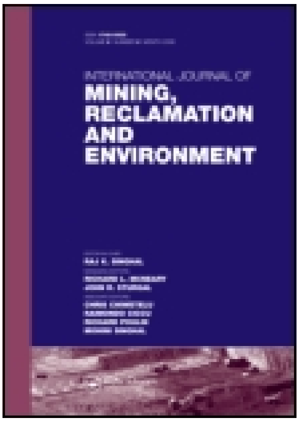

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Development of a dust collector inlet hood for enhanced surface mine drill dust capture

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Surface mine drill operators have the highest frequency of overexposure to quartz dust, and drilling is one of the occupations associated with the highest incidence of silicosis. Previous field assessment studies of drilling machines indicate that they can emit some of the highest airborne respirable quartz dust concentrations found at surface mining operations. Typically, the surface mine drills are equipped with dry dust collector systems to capture the dust being flushed with compressed air from the hole during the drilling process. The overall control effectiveness of the dust collector system is initially dependent on capturing the dust cloud at the source via the collector inlet. To assist the initial capture of the dust being flushed from the drill hole, the bottom of the drill deck is typically shrouded or enclosed on all sides to help contain the dust for the collector inlet plenum located on the underside perimeter of the drill deck. Openings, gaps and breaches in the shroud enclosure permit dust to escape dust collector capture.

The National Institute for Occupational Safety and Health (NIOSH) has developed a collector inlet hood that reconfigures the inlet plenum around the drill steel and above the hole to enhance dust capture. Laboratory development and testing show that this inlet hood improves dust capture by an average of nearly 50% over a wide range of collector flows and shroud leakage areas. This report describes the laboratory and subsequent field testing of this inlet hood concept.

Keywords: Surface drill; Dunt collector; Respirable dust; Silica

1. Introduction

Overexposure to airborne respirable crystalline silica dust can cause serious or fatal respiratory disease. A higher prevalence of silicosis is usually associated with worker occupations that mine,

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process, use or manufacturer materials containing silica-bearing minerals (NIOSH 2003). Mining has, and continues to have, some of the highest incidences of worker-related silicosis, with mining machine operators the most commonly associated occupation with the disease (NIOSH 2003). In particular, some of the most severe cases of silicosis has been observed in surface mine rock drillers (NIOSH 1992). A voluntary surface coal miner lung screening study conducted in Pennsylvania also indicated that silicosis is related to age and years of drilling experience (CDC 2000). Thus, rock drillers' exposure to silica dust is of specific concern in the surface mining sector.

The US Mine Safety and Health Administration (MSHA) enacts and enforces mine worker safety and health standards to mitigate mine worker injuries and occupational diseases. MSHA's permissible shift exposure limit is 2.0 mg/m^3 of airborne respirable dust for coal mine workers as defined by the Mining Research Establishment (MRE) Criteria (US Office of Federal Regulations 2002). If more than 5% quartz mass is determined to be in the coal mine worker dust sample using MSHA's P7 infrared method (Parobeck and Tomb 2000), the applicable respirable dust standard is reduced to the quotient of 10 divided by the percentage of quartz in the dust. MSHA's nuisance dust limit (total dust) for non-coal miners is 10 mg/m^3 as defined by the American Conference of Governmental Industrial Hygienists (ACGIH 1973). If more than 1% quartz mass is determined to be in the non-coal mine worker dust sample using the NIOSH X-ray Method (Parobeck and Tomb 2000) the applicable standard is then a respirable dust standard of 10 divided by the sum of the quartz percentage plus 2. Both of these dust standards are designed to limit worker respirable crystalline silica (quartz) exposure to 0.1 mg/m^3 or less for a shift.

One of the occupations most frequently exceeding the respirable quartz dust standard is the surface mine drill operator. NIOSH analysis of MSHA's surface mine commodity data during the years 1996 to 2000 show that between 10 and 33% of the rotary drill operator dust samples exceeded the respirable quartz dust standard (Hale 2002). In particular the most frequently sampled drill operator during this period was the surface coal highwall drill operator—an occupation that exceeded the quartz dust standard 31% of the time (Hale 2002). In general, overexposures are usually related to inadequacy of engineering controls.

2. Background

Previous assessments of dry and wet primary drill dust control systems show that they can range from very effective to ineffective depending on their operating parameters. Both systems can achieve greater than 95% dust control efficiencies given optimum operating parameters, but have been shown to fall below 42% effectiveness with notably degraded operating parameters (Zimmer and Lueck 1986). Dry dust collection systems tend to be the most common type of dust control incorporated into drilling machines by original equipment manufacturers because of the machines' capability for operation in various climates.

Figure 1 shows a typical dry dust collection system on a drill. Drill dust is generated by compressed air (bailing airflow) flushing the cuttings from the hole. The dust collection system is usually composed of a self-cleaning (compressed air back pulsing filters) dry dust collector sucking the dusty air from underneath the shrouded drill deck located over the hole. Dust emissions in this type of system can be from multiple sources such as the dust collector exhaust, drill stem bushing leakage, shroud leakage and dust collector dump discharge. Damaged or non-functional dust collector filters are the root cause of dusty exhaust air. The severity of the other emission sources is caused by damaged or worn collector system enclosure components and/or operational conditions impeding the enclosure components to contain and capture dust. A previous drill study has indicated that over half of the dry dust collector emissions are from shroud and drill stem bushing

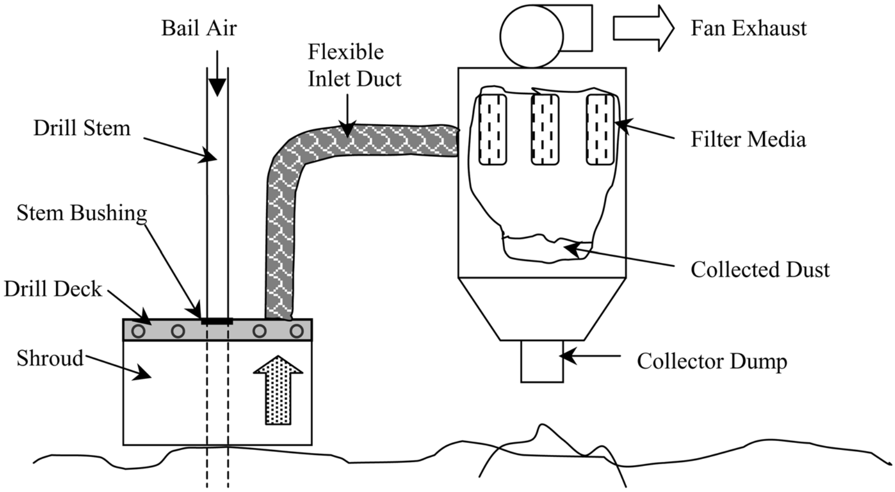

Figure 1. Drill dry dust collection system.

leakage (Maksimovic and Page 1985). Other field evaluations have shown that openings or gaps greater than 15.2 cm (six in) between the drill deck shroud and ground can significantly diminish the dust collector's inlet capture effectiveness (Zimmer and Lueck 1986, Zimmer *et al*. 1987). More recent field studies have shown that there continue to be control deficiencies with dust escaping the collector inlet (Organiscak and Page 1999).

One of the obvious factors related to dust escaping the collector's inlet capture is breaches or openings in the shroud or enclosure around the hole. Dust escapes through these openings when the inflowing air velocity is less than the velocity of the dust being blown from the drill hole. Since the collector inlet duct is commonly located on a remote side of the shrouded drill table to avoid large drill cuttings from being sucked into it, collector intake air capture velocities under the shroud enclosure are notably decreased after one duct diameter away from the inlet duct (ACGIH 1995). Thus, the amount of dust escaping through enclosure openings is dependent on many factors, such as the opening size, the drill hole flushing airflow, the collector airflow and the opening location from the inlet duct.

Some of the most commonly observed shroud enclosure openings are between the bottom of the shroud and ground, caused by uneven and/or sloping drill bench surfaces. Also, some shrouds have gaps at the corners of their front side of the shroud, which can be hydraulically lifted up so that drill cuttings are not dragged over the hole when the drill moves with its boom up. Finally, the bushing to seal the gap between the drill stem and deck systematically leaks dust with wear.

One concept studied to improve dust collector capture effectiveness is to move its inlet plenum closer to the dust source (ACGIH 1995). Although moving the collector inlet directly over the hole is expected to improve dust capture, the inlet needs to be designed to block out the larger drill cuttings from entering the collection system. To this end, this paper describes the research and development of a functional inlet hood surrounding the drill steel directly over the drill hole. The laboratory work was conducted at NIOSH's Pittsburgh Research Laboratory (PRL) with a retrofitted collector inlet hood field tested on a drilling machine at a surface mine site in Kentucky.

3. Preliminary hood design and development

Moving the dust collector inlet over the drill hole presents some design challenges to prevent large drill cuttings entering the dust collection system. The preliminary design was to surround the drill stem with the inlet hood enclosure under the drill table. The hood would incorporate an impaction plate facing the drill hole to deflect larger projected drill cuttings away from the hood opening above and around the perimeter of the plate. However, a gap needed to be left between the drill stem and deflection plate to allow the drill stem to rotate freely and the larger diameter bit to be drawn through the hood and drill deck for servicing.

During the initial development of this hood design several options were tested to control material flow into the hood through this gap. The deflection plate was designed with a triangular top section that traversed the circumference of the plate inside the hood surrounding the drill stem (see figure 2). This was intended to be self-cleaning so that any larger sized material entering the hood could slide back out through the perimeter of the hood inlet or the deflection plate stem gap. Other options that were examined to seal the gap between the deflection plate and drill stem were an air ring seal or a rubber seal. The air ring seal is a doughnut-shaped compressed air header with closely spaced holes along its inside perimeter, directed at the drill stem at a 45° angle towards the drill hole (Page 1991). This creates an air knife around the drill stem to direct drill cuttings out away from the drill stem and has been shown to reduce drill cuttings and dust emissions through the top of the drill deck (Page 1991). A circular rubber seal (made out of conveyor belting) was also examined to seal the deflection plate gap around the drill stem. Radial slits were cut into the inter perimeter of the rubber seal hole to allow for a tight but flexible fit around the drill stem.

Preliminary tests were conducted on these hood design options to determine if larger cuttings could be prevented from accumulating in the hood and restricting the dust collector inlet. A simulated drill hole setup was used in PRL's experimental mine to examine the size of material entering the collection system. This setup used crushed 1A limestone ($\leqslant$ 6.4 mm ($\sim$ ¼ in to dust)) as simulated drill cuttings, because crushed limestone has a similar density to most strata rock in surface mine overburden. The crushed limestone was fed into a compressed air supply using a sandblaster available at PRL's experimental mine. The compressed air and cuttings were blown through the centre of a 15.2 cm (6 in) diameter schedule 40 pipe (drill stem) and back up along the outside of the 15.2 cm (6 in) pipe inserted into a closed-end 20.3 cm (8 in) diameter schedule 80 pipe (see figure 3). The inlet hood was located around the 15.2 cm (6 in) pipe and above the open area of the 20.3 cm (8 in) pipe, as shown in figure 3. A centrifugal or vane axial fan was used to draw air through the inlet hood and a large particle dropout chamber 208 l (55 US gal.) drum to examine the particle sizes that would enter the collector system. The fan exhaust air was discharged into the mine return airstream.

The simulated drill hole and hood setup were operated at design parameters similar to actual drilling conditions. The key operating parameters controlled were drill hole bailing airflow (flushing velocity) and hood airflow (inlet velocity). The desirable flushing velocity to remove drill cuttings is around 20.3 m/s (4000 ft/min), with 25.4 m/s (5000 ft/min) frequently useful for normal drilling conditions and 35.6 m/s (7000 ft/min) sometimes used (Cummings and Given 1973). The bailing air quantities required to achieve 25.4–35.6 m/s with the laboratory drill hole test apparatus were 184–255 l/s (390–540 ft^3/min), respectively. All the preliminary hood testing was run within these bailing air quantities and velocities, averaging 236 $\pm$ 14.2 l/s (500 $\pm$ 30 ft^3/min) and 32.5 $\pm$ 2.2 m/s (6400 $\pm$ 430 ft/min) at the 95% confidence level, respectively. Pressure and temperature gages were used in-line with calibrated compressed air flow meters to determine bailing air quantities at various compressed air supply conditions. The compressed air supply

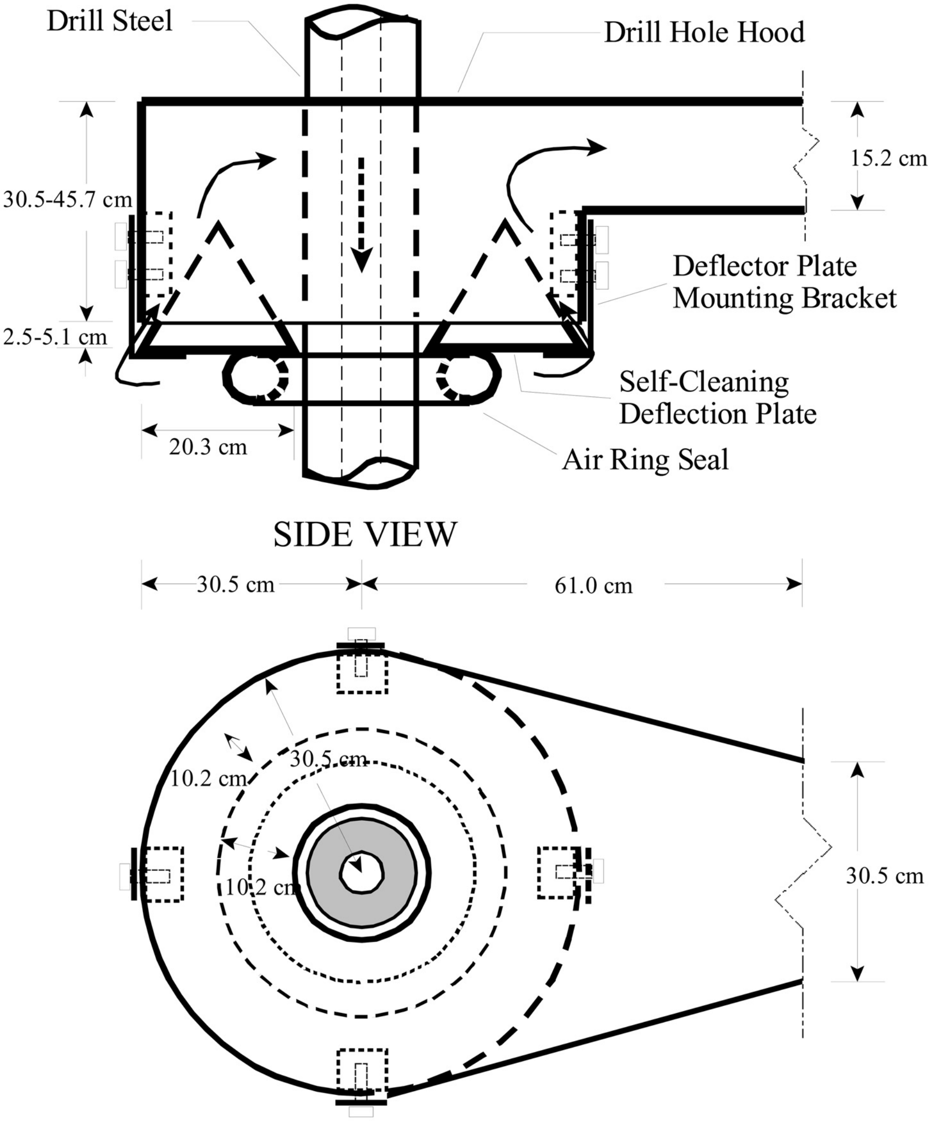

Figure 2. Self-cleaning inlet hood design initially tested.

conditions varied during these preliminary tests due to variations in mine temperature and other supply quantities used elsewhere within the PRL mine.

The hood design with and without the two drill stem sealing options was tested at a targeted airflow rate of 944 l/s (2000 ft^3/min) with the hood inlet velocity of approximately 10.2 m/s (2000 ft/min). The measured hood airflow for all the tests averaged 977 ± 33.0 l/s (2070 ± 70 ft^3/min). This airflow puts the hood inlet velocity at the upper range 2.5–10.2 m/s (500–2000 ft/min) recommended for capturing dust with high initial release velocities (ACGIH 1995). The initial

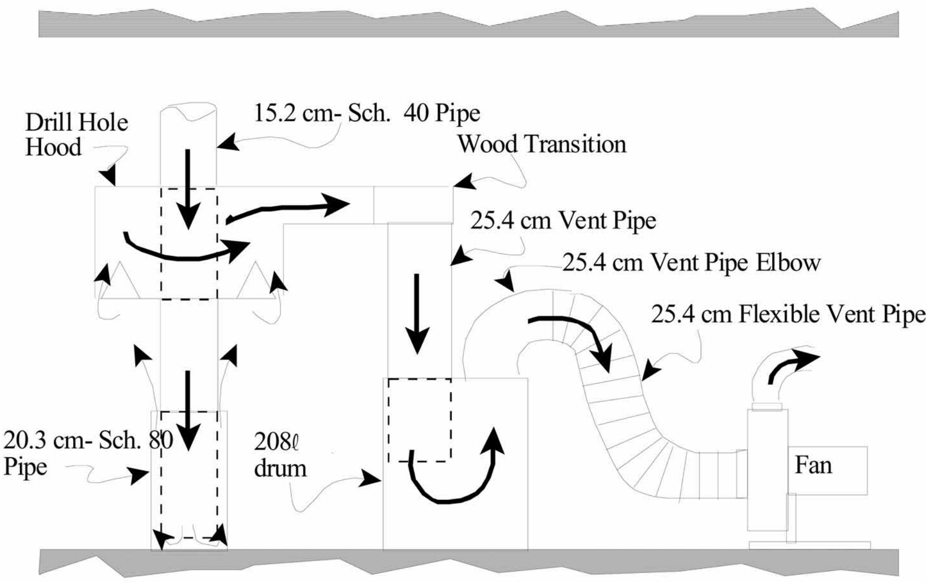

Figure 3. Preliminary hood testing apparatus.

hood design tested was 50.8 cm (20 in) high with 5.08 cm (2 in) of inlet opening above and around the bottom deflector plate. The hood height was subsequently reduced to 35.6 cm (14 in) with 5.08 (2 in) of inlet opening to examine any notable performance difference with a lower profile hood. Since the lateral surface area of the 5.08 cm inlet opening (gap) between the deflection plate and the 121.9 cm (2 ft) diameter round hood is 929 cm^2 (1 ft^2), the calculated hood inlet velocities are reflective of the operating air quantities.

The area around the hood and simulated drill hole was enclosed or shrouded with mine brattice to contain the flying material, with about 30.5 cm (1 ft) of open height/gap at the bottom of the enclosure for material flow observations during testing. Between 22.7 and 27.2 kg (50 and 60 lb) of limestone material was fed through the sandblaster over a several minute period for each test. The bulk 1A limestone feed material was randomly sampled, dry screened and size-classified by weight. The amount of the limestone material collected in the dropout barrel after each test was also screened and dry size classified by weight for size distribution comparisons with the bulk feed material. Sizing was done with a sieve shaker (Tyler, Ro-Tap Model B, Mentor, OH[1]) using US sieve sizes of 6.30 mm, 4.75 mm (#4), 2.80 mm (#7), 1.18 mm (#16), 600 μm (#30), 425 μm (#40), 250 μm (#60), 150 μm (#100) and 75 μm (#200). The weighing of the sized material was conducted on a PM30 Mettler Pan Balance.

Preliminary testing showed that the rubber seal notably reduced the size of the material passing through the hood into the dust collection system. Figure 4 shows the preliminary test results with and without the air ring and rubber seal on the 50.8 cm (20 in) hood height and with and without the rubber seal on the lower profile 35.6 cm (14 in) hood height. Each curve represents the average of two similar test conditions, except for the air ring seal curve which is the average of one test at 206.8 kPa (30 psi) and one test at 344.7 kPa (50 psi). Hood infiltration size distribution results

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[1] Mention of any company name or product does not constitute endorsement by the National Institute for Occupational Safety and Health.

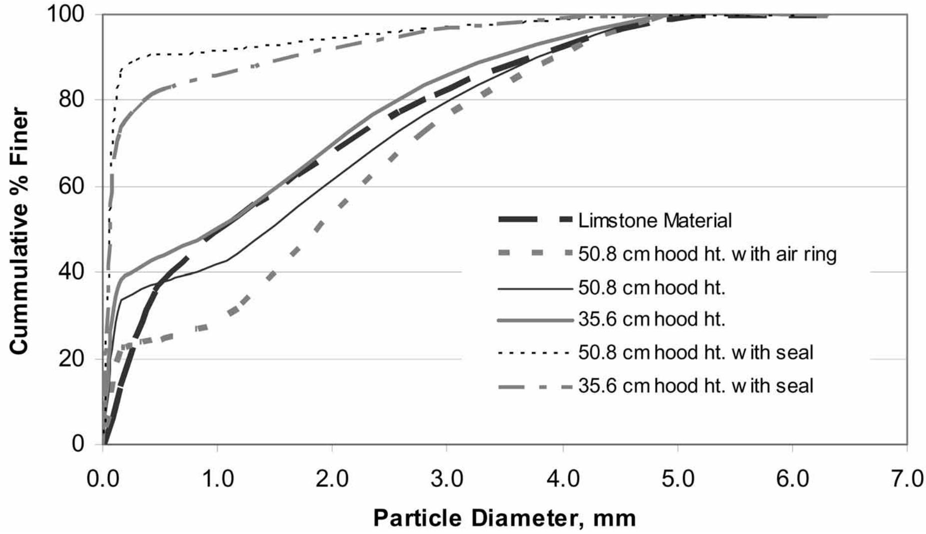

Figure 4. Size distribution of material that passed through the inlet hood.

were similar for the two different air ring seal pressures and were noticeably greater than size distribution results with no seal and with the rubber seal. The air ring seal visibly pushed dust away from being captured by the inlet hood and thus this option was abandoned. The size distribution of the material penetrating into the dust collection system without any seal between the deflection plate and drill stem seal was similar to the size distribution of the material used. The total amount of material that infiltrated the hood was no more than 0.68 kg (1.5 lb) with and without the air ring seal. Using the rubber seal between the drill stem and deflection plate notably reduced the size of the material penetration into the dust collection system and reduced the amount of material penetration to about 0.15 kg ($\frac{1}{3}$ lb) of mostly coarse and fine dust. Also, reducing the hood height to 35.6 cm had a marginal effect on additional material penetrating into the dust collection system with the rubber seal. Since the lower profile hood height is more desirable for ground clearance on a drill, the 35.6 cm high hood was further tested in a simulated drill dust chamber to determine its effectiveness over a range of collector airflow and shroud leakage parameters.

4. Hood dust capture performance experiments

Laboratory testing was conducted on the lower profile 35.6 cm (14 in) high hood design to determine its dust control impact as compared to the standard ventilated shroud arrangement. These tests were conducted in a large 3.66 m wide by 3.05 m deep by 2.44 m high (12 ft × 10 ft × 8 ft) dust chamber as shown in figure 5. The simulated drill hole shroud was located in the centre of the dust chamber with dimensions of 1.52 m wide by 1.22 m deep by 1.22 m high (5 ft × 4 ft × 4 ft). This shroud size is within the range found on medium-sized rock drills (rubber tire or track mounted), drilling holes 12.7 to 20.3 cm (5 to 8 in) in diameter with about 178 kN to 222 kN (40 000 to 50 000 lb) of drill pulldown pressure. The simulated drill hole and drill steel used in these experiments is the same apparatus that was used throughout the preliminary hood testing series. A series of tests was conducted on both the standard shroud arrangement, drawing air at

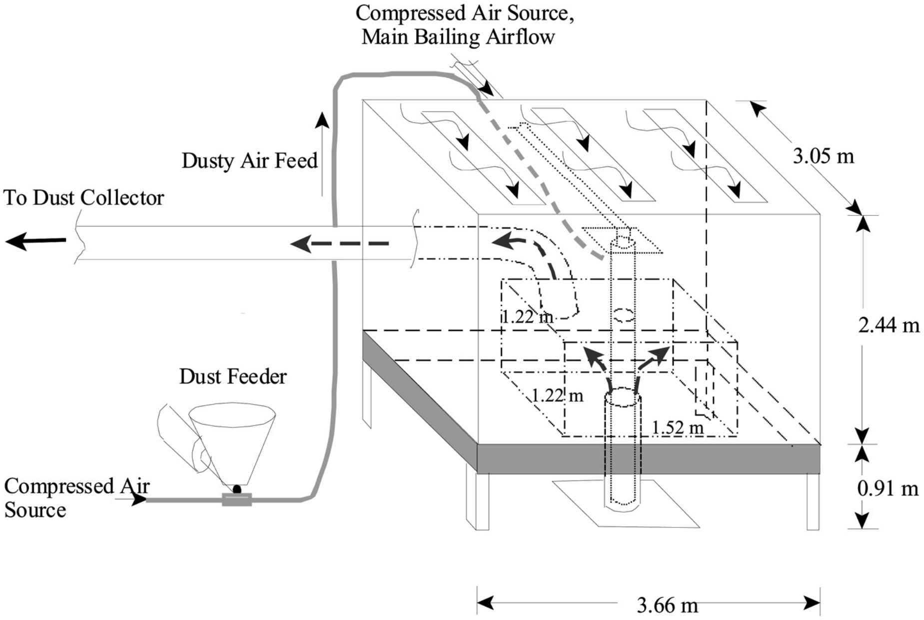

Figure 5. Laboratory dust chamber for testing shroud and inlet configurations.

the perimeter of the shroud (shown in figure 5), and on the 35.6 cm (14 in) high drill hole inlet hood (shown in figure 2), drawing air at the centre of the shrouded area.

The laboratory experiments investigated two key operating factors on the shroud's dust control performance with and without the drill hole inlet hood. These experimental control factors included: (1) the amount of open area or bottom gap between the ground and drill hole shroud; (2) the dust collector airflow to bailing airflow ratio. These two factors were previously identified in earlier research on the air ring seal as major contributors to dust leakage from the shroud (Zimmer and Lueck 1986, Zimmer *et al.* 1987).

Since down-the-hole bailing airflow is usually set for maximum drill penetration rate and bit cutter life, varying this parameter over a broad operating range for dust control is usually not a functional consideration. In these experiments, the drill hole bailing airflow was targeted at constant flow rate and the collector airflow was changed to achieve the desired collector to bailing airflow ratio. The drill hole bailing airflow varied between 170 and 179 l/s (360 and 380 ft^3/min) to yield a bailing air velocity between 23.4 and 24.9 m/s (4600 and 4900 ft/min), representing typical drilling conditions. This constant bailing airflow rate was expected to improve experimental control over the dust feed rate and reduce airborne dust generation variability.

A Vibra-screw feeder metered about 6 to 7 g/min of limestone rock dust into a compressed air eductor, operating on a small separate split ($\sim$11.8 l/s or 25 ft^3/min) of the bailing airflow. This dust was mixed with the remaining bailing airflow near the top of the 15.2 cm (6 in) pipe and blown out of the concentric opening between the 15.2 cm pipe and the 20.3 cm (8 in) pipe (simulated drill hole). The respirable dust escaping the shrouded area over this simulated drill hole was the response variable measured during these experiments. The 6 to 7 g/min dust feed rate generated on average 14 mg/m^3 of airborne respirable dust leakage from the shroud at the poorest level of control factors studied or worst-case conditions (no inlet hood, largest shroud-to-ground gap and lowest collector airflow). This 6 to 7 g/min dust feed rate was targeted for all the control factors studied and the airborne dust leakage from the shroud was responsive to the control factors. A multimeter was wired into the feeder speed control potentiometer to provide millivolt feedback on feeder speed. The dust feed was collected for a three-minute period and weighed before and after each test to measure the average dust feed rate for the test. Adjustments were only made, if needed, at the beginning of each test for the target 6 to 7 g/min dust feed rate.

A face centre cube experimental design with a centre point was conducted to examine the response of variable factor effects (Myers and Montgomery 1995). The two inlet configurations (hood and no hood) were conducted in two separate blocks of randomized experiments over the same operating parameters. The centre point test parameters of the experiment targeted a 20.3 cm (8 in) ground-to-shroud gap height and a dust-collector-to-bailing-airflow ratio of 3:1 (collector volume of about 529 l/s or 1120 ft^3/min). The ground-to-shroud gap was varied from a minimum of 5.1 cm (2 in) to a maximum of 35.6 cm (14 in). The dust-collector-to-bailing-airflow ratio was varied from a minimum of 2:1 (collector volume of about 349 l/s or 740 ft^3/min) to a maximum of 4:1 (collector volume of about 698 l/s or 1480 ft^3/min). At least three replications were performed for each experimental test condition. Both the inlet hood and conventional inlet area openings were kept at 929 cm^2 (1 ft^2), so all the collector inlet air velocities were comparable between inlet configurations; they were above the 2.5 m/s (500 ft/min) recommended minimum for capturing high initial dust source release velocities (ACGIH 1995). The conventional collector inlet for the baseline conditions was located at the top perimeter of the shroud (see figure 5). The experiments with the collector inlet hood were conducted first because it was more practical to insert the hood around the simulated drill steel pipe when assembling the simulated drill hole and shroud. After the inlet hood experiments were conducted the hood was cut away and removed from under the shroud.

Respirable dust measurements were made on each side of the shroud. Dust sampling was conducted with MSA gravimetric dust samplers and a GCA real-time aerosol (RAM) instrument. The MSA gravimetric dust samplers comprised a 10 mm Dorr Oliver cyclone assembly, a 37 mm coal mine dust cassette and an Elf sampling pump operating at a flow rate of 2.0 l/min. Two gravimetric respirable dust samplers were positioned 61.0 cm (2 ft) from the floor (ground level) and 61.0 cm (2 ft) away from the middle of each shroud side. The cyclone inlets were facing toward each side of the shroud. Instantaneous respirable dust sampling was conducted with a real-time aerosol (RAM) instrument on the opposing inlet duct side of the shroud with the cyclone also facing the shroud. This side of the shroud had the highest levels of dust leakage during the preliminary shakedown tests of the dust chamber, since it was the furthest from the collector inlet duct.

Other air quantity and pressure parameters for these experiments were measured and recorded. The main bailing airflow quantity and the dust feed airflow were measured with calibrated compressed air flow meters and were corrected for variations in compressed air pressure and temperature. The static pressure difference inside the collector duct (upstream of the curved flexible tubing) and outside the drill hole shroud enclosure were measured to compare the static pressure losses (primarily shock losses) of the collector inlet and shroud configurations. The collector inlet airflow quantity was determined from a centreline duct velocity or velocity pressure (Pitot tube) measured in a straight section of duct between the dust chamber and collector over a five-minute period before and after each experimental run.

Thirty-one collector inlet hood experiments and 31 baseline experiments (without the inlet hood) were conducted. The average gravimetric dust concentration[2] around the shroud with its

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[2] None of these respirable gravimetric dust concentrations has been adjusted to a MRE equivalent.

standard deviation for each experimental condition is shown in figure 6. An analysis of variance (ANOVA) for all the experimental test conditions was made to determine the statistical level of influence that these experimental factors (inlet configuration (blocked), collector-to-bailing airflow ratio and shroud gap height) had on the respirable dust escaping the drill hole shroud. Since the measured dust concentration variance was observed to increase for the higher experimental concentrations, a square root transformation of the dust data was carried out in order to spread out more uniformly the random error variances assumed in ANOVA analysis. The square root of the dust data appeared to be the best transformation for uniformly spreading out the ANOVA model residuals. Assuming dust data population distributions are approximately normal, the equal-variance expectation of the square root data transformation for the ANOVA analysis could not be rejected at the 95% confidence level using the *F*-test statistic on the box transformation of the Bartlett test for this equal-variance assumption (Neter *et al.* 1985). Table 1 shows the ANOVA for these experiments using the square root transformation of the dependant dust concentration variable.

The laboratory test results show that all the experimental factors studied significantly affected the amount of dust that escapes the dust collector inlet. Figure 6 shows that the dust levels notably change with the collector-to-bailing airflow ratio, shroud gap height and inlet configuration. Figure 7 shows relative percentage dust reductions measured for the inlet hood (blocked) as compared to the conventional inlet (blocked) over all the other identical experimental factors studied. The ANOVA shows that these three factors are significant at the 0.05 level and that these main model effects explain about 89% of the dust concentrations measured in the laboratory experiments. A significant inlet configuration by shroud gap height interaction is also present in the analysis but does not dramatically change the main model effects over the experimental factors tested. Actually, the ANOVA sum of squares and *F*-values indicate that the collector-to-bailing airflow ratio and shroud gap height are the two more prominent factors affecting the dust collector inlet capture in these experiments. Figure 6 also illustrates this by showing that the dust

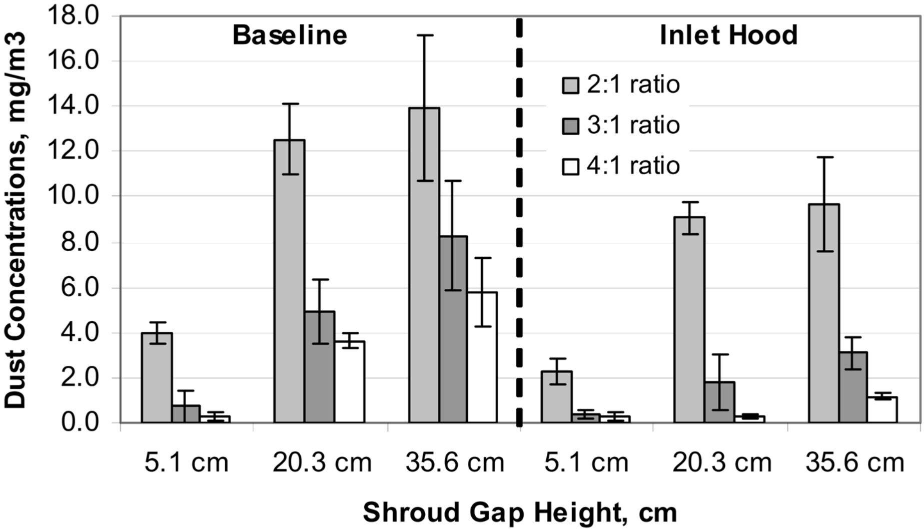

Figure 6. Laboratory dust concentrations escaping the shroud and inlet configurations.

concentrations escaping both inlet configurations were dramatically reduced by increasing the collector-to-bailing airflow ratio and reducing the shroud gap height.

Although the inlet configuration (blocked effect) showed a lesser influence on dust collector capture, the inlet hood still notably reduced the dust that escaped the collector inlet. Figure 7 shows the average percent dust reductions of the inlet hood over the conventional inlet arrangement for the various shroud gap heights and collector-to-bailing airflow ratios. The best inlet hood dust reductions ranged between 63 and 91% for the 3:1 and 4:1 collector-to-bailing airflow ratios at the higher shroud gap heights of 20.3 cm and 35.6 cm (8 and 14 in, respectively). For the lowest 2:1 collector-to-bailing airflow ratios tested, inlet hood dust reductions ranged from 28 to 43% at the various shroud gap heights. The least inlet hood dust capture improvement (4%)

Table 1. Analysis of variance (ANOVA) of experimental factors on dust escaping the drill hole shroud.

Variation source	Sum of squares	Degrees of freedom	*F*-ratio	Significance level
Main model effects	67.809	5	123.953	0.0000
Inlet configuration (blocked)	7.835	1	71.609	0.0000
Collector-to-bailing airflow ratio	30.257	2	138.273	0.0000
Shroud gap height	26.455	2	120.897	0.0000
Interactions	3.342	8	3.818	0.0015
Inlet configuration × airflow ratio	0.313	2	1.432	0.2487
Inlet configuration × shroud gap	2.020	2	9.230	0.0004
Airflow ratio × shroud gap	1.109	4	2.534	0.0522
Residual	5.252	48		
TOTAL	76.402	61		

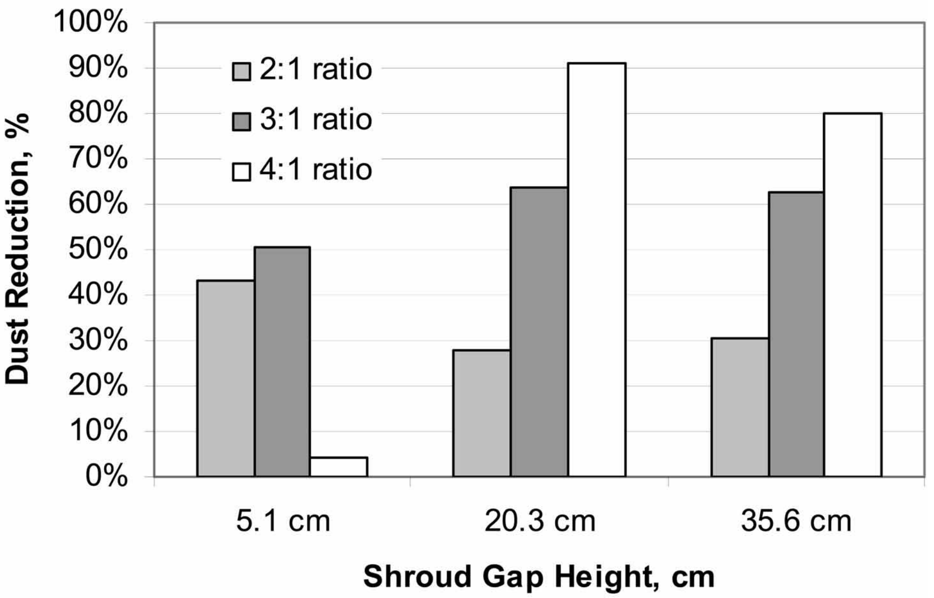

Figure 7. Laboratory dust reductions from the inlet hood.

measured was at the 5.1 cm (2 in) shroud gap height and the 4:1 collector-to-bailing airflow ratio, since these two experimental parameters were optimal for maintaining low dust concentrations for both inlet configurations (see figure 6). The significant inlet hood configuration and shroud gap height interaction observed in the ANOVA reflected this noticeable change in relative inlet hood performance between the 5.1 cm (2 in) and other shroud gap heights.

Higher dust collection system performance of the inlet hood was achieved, but at the expense of increased system energy requirements. The static pressure differentials measured across the shroud, inlet configuration and flex tubing at the same collector airflows show higher static pressure losses with the inlet hood. The average increases in static air pressure for the inlet hood at the 2:1, 3:1 and 4:1 collector-to-bailing airflow ratios were 74.7, 216.6 and 358.6 Pa (0.30, 0.87 and 1.44 in of water gauge), respectively. Much smaller differences in static pressures were observed by changing the ground-to-shroud gap heights. Thus the inlet hood added an appreciable amount of shock loss to the collection system.

5. Field evaluation of the inlet hood concept

Given the laboratory dust control benefits measured with the collector inlet hood, additional field testing of the inlet hood concept was conducted to examine its operational viability and performance. Preliminary visits were made to two potential surface mines to examine their drills for retrofitting an inlet hood. An Ingersol-Rand DM45E drill at a mountain top removal surface mine in Kentucky was selected for the study because it had good dust collector airflow and a reasonably streamlined and symmetrical drill deck underside structure for an inlet hood retrofit. This drill used a 12.7 cm (5 in) diameter drill stem and a 17.1 cm ($6\frac{3}{4}$ in) diameter tri-cone roller bit with three 1.27 cm ($\frac{1}{2}$ in) air flushing orifices. The collector airflow was measured at 1133 l/s (2400 ft^3/min) with an Alnor Series 6000P velometer inside a rectangular cardboard duct, fitted onto the exhaust side of the collector fan. The underside deck dimensions were also measured during the visit for the design of a retrofit hood.

The field study plan was to conduct area dust sampling around the drill shroud in its existing state for several shifts and resample after the inlet hood was installed. The inlet hood had to be significantly redesigned from the laboratory version to custom fit this particular drill deck underside. Figure 8 shows the test drill's deck underside in its original configuration and with the custom inlet hood retrofit. Basically, the inlet hood was designed as a three-sided topless duct to be welded onto the existing framework of the deck. A 41.4 cm (16.3 in) square opening was cut into the bottom of the duct 5.08 cm (2 in) below the original deflection structure surrounding the drill stem and protruding from under the drill deck. A 61.0 cm (24 in) square deflection plate with a central 22.2 cm ($8\frac{3}{4}$ in) diameter hole was mounted 3.8 cm ($1\frac{1}{2}$ in) below this opening around the drill stem. The inlet area around the 3.8 cm ($1\frac{1}{2}$ in) deflector plate gap was about one square foot, slightly larger than the original inlet duct opening of 836 cm^2 (0.9 ft^2). The original rubber drill stem seal was mounted to the inlet hood's deflection plate.

The baseline dust survey of the test drill without the collector inlet hood was conducted during 9–11 September 2003. The hood was installed on 23 September and follow-up dust sampling was conducted on 24 and 25 September. Respirable dust sampling was conducted with MSA gravimetric dust samplers and MIE Personal DataRAMs (PDR). The PDR is a portable instantaneous light-scattering instrument that records relatively precise indirect measurements of dust concentrations with respect to time. To improve the accuracy of the PDR measurements, a gravimetric dust sample was collected on a filter downstream of the light-scattering sensing chamber and could be used to calibrate the relative measurements to the gravimetric sample. The PDRs were operated actively during this study at a flow rate of 2.0 l/min with a 10 mm Dorr

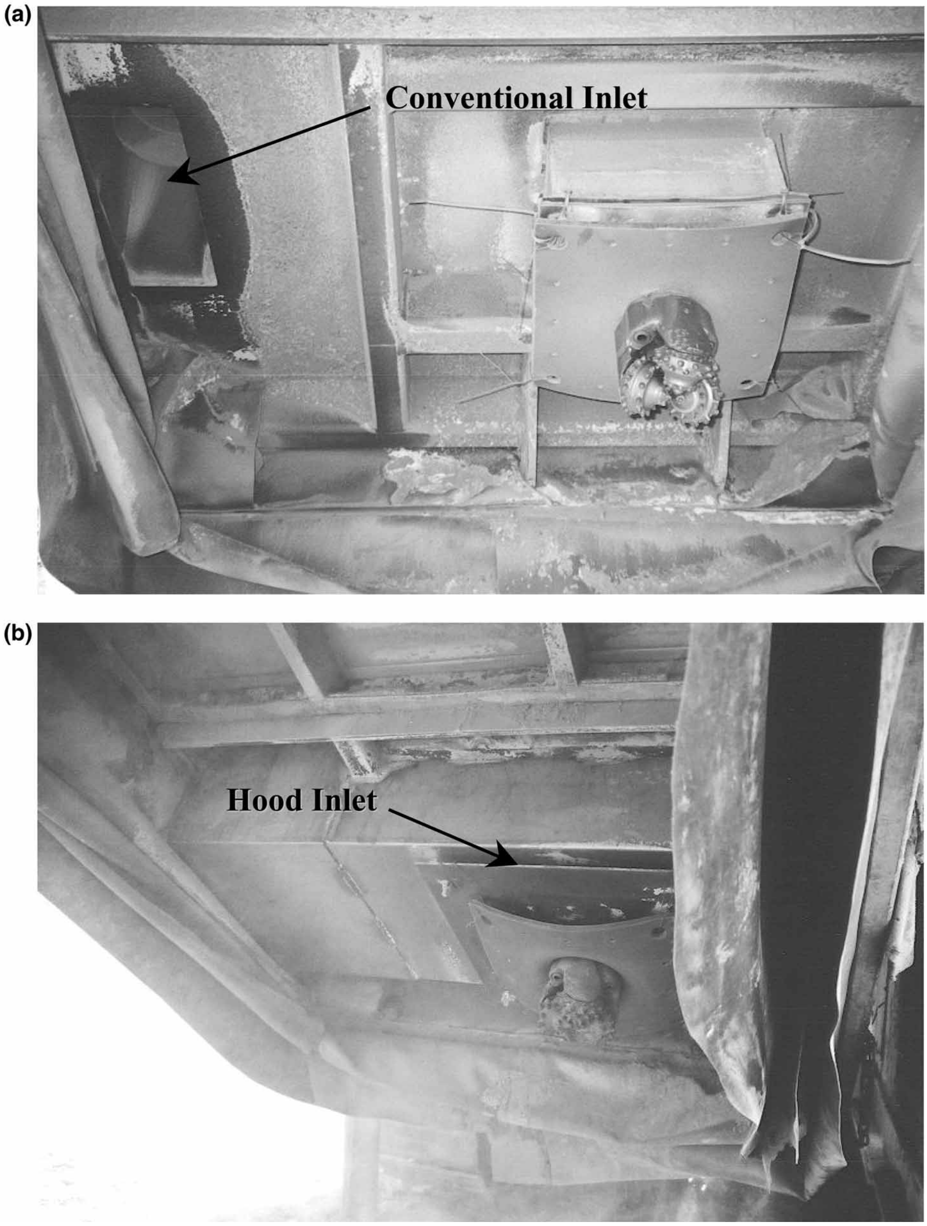

Figure 8. Conventional drill collector inlet (*a*) and inlet hood installed (*b*).

Oliver cyclone, a 37 mm coal mine dust cassette and an Elf sampling pump, in similar fashion to the MSA gravimetric dust samples. One PDR and two MSA samplers were placed on a 76.2 cm ($2\frac{1}{2}$ ft) high tripod stand and three of these tripod sampling packages were placed at multiple ground locations around the drill. A Young wind speed and direction instrument was also used on the drilling bench to measure wind conditions during the drilling operation. Single-channel Telog data loggers were used to record the wind data. The PDR dust data and Telog wind data were time logged over 30 s intervals during the survey.

Figure 9 shows the dust sampler locations and the median wind information collected during the sampling shifts. Two of the dust sampling tripods were placed adjacent to the drill and positioned downwind of the visual dust plumes around the drill. One dust sampling tripod was located either upstream of the test drill or by the collector dump on a similar drill operating on the drill bench. Figure 10 shows the average respirable dust concentration[3] measured at each sampling location.

A day before the baseline study began the drill was serviced, including dust filter replacement and repair of the shroud holes. The shroud enclosures used on all the drills at the mine were an angle drill curtain design that could be hydraulically raised and adjusted to seal with non-parallel ground surfaces with respect to the drill deck.

After the first day of baseline dust sampling (9 September) it was quickly realized that the largest dust source on this drill was the collector dump and not dust escaping the shroud. The dust was observed to be visually generated from the collector dump and migrated underneath the drill to the downstream samplers by the cab. The exit tubing on the collector dump was about 61.0 to 91.4 cm (2 to 3 ft) above ground level and dust was being generated from dumping at this unenclosed discharge height. During the next sampling shift (10 September) a longer piece of tubing was placed on the collector dump to reach ground level and the dust levels around the drill were notably reduced (see figure 10). For the following sampling shift (11 September), the tubing was cut by mine personnel to its original drop height and the dust levels on the dump side increased noticeably (see figure 10). Thus the larger dust source around the drill appeared to be from the elevated collector dump height rather than the shroud enclosure. The collector airflow measured at the end of the baseline survey was 1008 l/min (2135 ft^3/min).

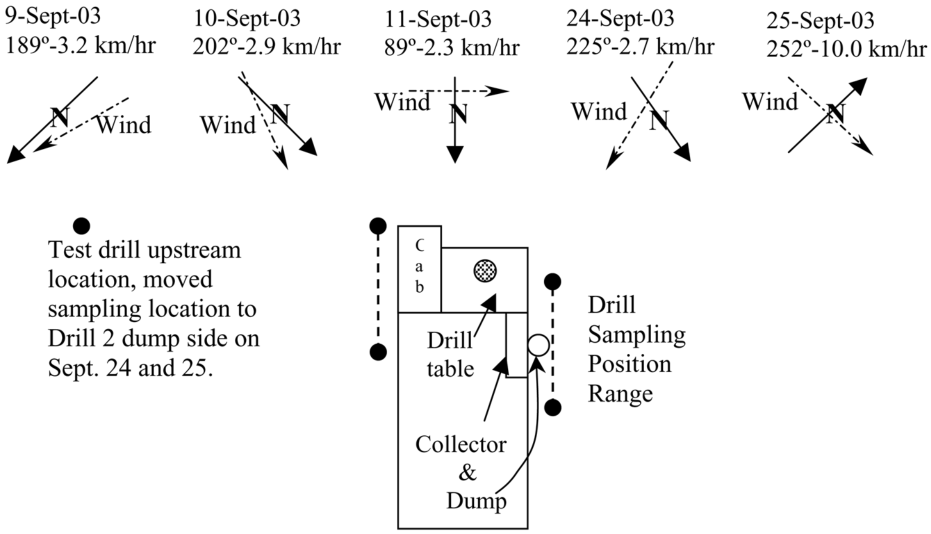

Figure 9. Median wind direction and speed during the field survey.

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[3] None of these respirable gravimetric dust concentrations have been adjusted to a MRE equivalent.

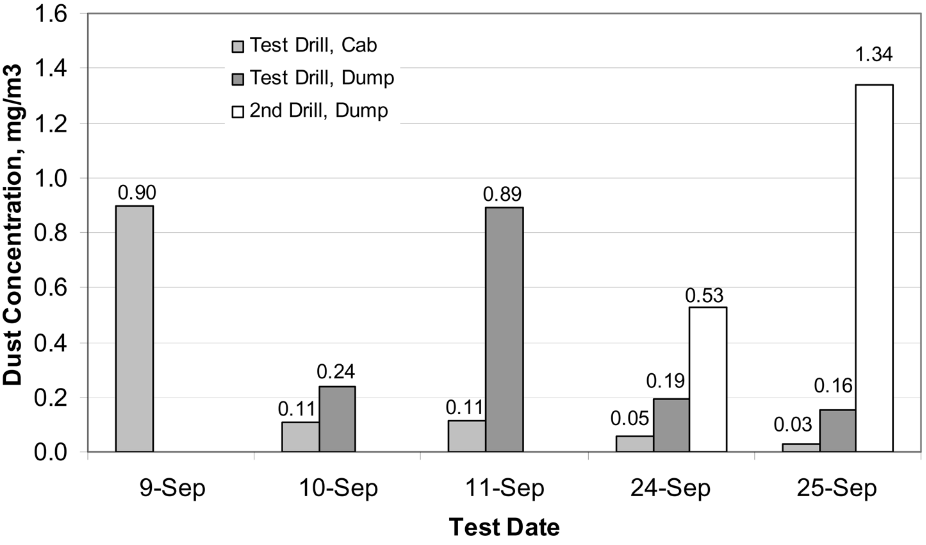

Figure 10. Dust concentrations from drill inlet hood field study.

Although a relatively low amount of dust was escaping the tightly sealed shroud, the inlet hood was installed to examine its operational functionality. The custom-fit inlet hood design committed its evaluation to this particular drill. The inlet hood was installed in a couple of hours on the morning of 23 September and was redeployed for production early that afternoon. During its installation the drill's bailing airflow was measured to be 380 l/s (805 ft^3/min) with a Dresser calibrated critical orifice flow measurement tool put in place of the bit. Immediately after the inlet hood installation, the collector airflow slightly dropped to 963 l/s (2040 ft^3/min) as compared to the previous measurement of 1008 l/s (2135 ft^3/min) made at the end of the baseline survey. Upon the drill's redeployment, NIOSH made some preliminary observations of its operation. After drilling about four holes, NIOSH inspected the hood and audibly detected some material buildup in the bottom of the duct with a hammer. The suction around the perimeter of the drill stem remained strong and a small amount of larger cuttings (chips) were found in the collector dump piles. After four hours of drilling, the collector airflow was again measured and found to be reduced to 833 l/s (1765 ft^3/min) with the deposited material on the bottom of the duct.

NIOSH returned on the following two days (24 and 25 September) to conduct a follow-up dust survey of the test drill. The drill continued to operate with the inlet hood during the day and night shifts. For the follow-up survey, the drill's collector dump was enclosed to the ground level to reduce this source of dust generation. Dust sampling was conducted on both sides of the test drill, similar to the baseline survey, except that the upwind tripod was positioned next to another drill's unenclosed collector dump operating on the same bench. The results from both days of sampling show that the dust levels on both sides of the modified test drill were low and the dust levels next to the other drill's dust collector dump were noticeably higher (see figure 10). The unenclosed collector dump height on the other drill generated the highest concentration of dust on 25 September when the median wind velocity was the highest and blew directly on the unenclosed collector dump. The other drill operated at an opposing 180° as compared with the modified test drill, so its collector dump was directly exposed to the wind.

The inlet hood appeared to have a negligible impact on dust emissions around the test drill given the tight shroud-to-ground seal maintained during the study. For average dust levels for both sampling stations around the test drill with the baseline configuration (10 September) and the inlet hood (24, 25 September) under similar conditions of the enclosed collector dump, there was a slight but negligible reduction from 0.18 to 0.11 mg/m^3 with the inlet hood. The adjustable angle drill curtain maintained a good enclosure seal with the ground and yielded low dust concentrations with both inlet configurations. There were no major breaches in the shroud enclosure during the field study, which would have allowed for the examination of the inlet hood's performance under the leakage conditions tested in the laboratory. Nearly 5000 ft of drilling was conducted with the inlet hood installed during the field study. The collector airflow decreased to 774 l/s (1640 ft^3/min) after sampling on 24 September.

Telephone discussions during the following weeks with the mine about the inlet hood's operating status indicated that the inlet hood eventually filled up and plugged after a week of operation. Thus, mine personnel cut an air inlet hole in the bottom of the duct under the original inlet on order to operate the drill temporarily. Mine personnel indicated that they wanted to try to fabricate a rubber flap device over the opening during a scheduled maintenance period. This would permit gravity flow of drill cuttings through the opening when the dust collector was turned off and seal the duct when the collector was operated. Before this modification could be made, however, material was accumulating in the inoperative hood around the drill stem with dust being emitted through the drill deck around the stem. Therefore, to rectify this problem mine staff removed the inlet hood.

6. Discussion

The one-week field operation of the inlet hood on this production drill provided some useful insights into functional design improvements. The inlet hood blocked the majority of cuttings from entering the collection system, but the small amounts of material that did make it into the system eventually built up over time. To rectify this problem for long-term operation the hood would need to be self-cleaning. However, this retrofit would not permit the hood height around the deflection plate and drill stem to slope the hood entrance greater than the cuttings' angle of repose. A possible solution with this retrofit would be to have a slot opening along the bottom and backside of the hood duct with a flexible bladder across this slot. When the drill deck is in its horizontal drilling position with the collector operating, the bladder will seal the side slot and pull air through the hood. When the drill deck is rotated back to its vertical traveling position (boom down), the material in the duct would have an opportunity to flow out between the slot and bladder. The week-long operation of this hood indicated that even infrequent lowering of the boom during the shift should reduce any long-term restrictions in the hood duct.

Finally, a low-profile inlet hood under the drill deck seems to be most desirable. The retrofitted inlet hood moved the intake plenum to just more than 33.0 cm (13 in) below the drill deck. Given the fairly horizontal benches at this mine, the drill was only slightly elevated with its ram jacks to level the drill table. The piles of drill cuttings were observed to build up in close proximity to the inlet hood opening and were theorized to be one of the key reasons for the larger chips found in the collector dump and long-term material buildup in the inlet hood. Reducing the profile or height of the inlet hood concept is expected to be very beneficial, but it would have to be designed and built into the drill deck as opposed to a retrofit.

7. Conclusions

Laboratory testing showed that the inlet hood concept notably improved drill dust collector system capture over the conventional inlet location with large leakage breaches at the bottom of the shroud enclosure. The most significant improvements were between 63 and 91% dust reductions measured at collector-to-bailing airflow ratios of 3:1 and 4:1 with shroud gap heights of 20.3 and 35.6 cm (8 and 14 in). The laboratory tests also showed that the two key influential factors on collector inlet capture were the collector-to-bailing airflow ratio and the shroud gap height for both inlet configurations. Approximately a one order of magnitude increase in dust leakage or dust concentration was observed when the shroud gap height was increased from 5.1 to 20.3 cm (2 to 8 in) with the conventional inlet configuration. The higher collector-to-bailing airflow ratios and inlet hood configuration mitigates this dust leakage at the higher shroud gap heights (20.3 and 35.6 cm or 8 and 14 in, respectively).

Field testing showed that a tight shroud enclosure minimizes the amount of dust that escapes the collector inlet with either inlet configuration. The operational functionality of the inlet hood shows promise, but requires a self-cleaning design modification for long-term usage (more than a week). The inlet hood concept is expected to function better if incorporated into a lower profile design within the drill deck as opposed to a retrofit. The retrofitted inlet hood tested appeared to collect drill cuttings that piled up close to the inlet opening, which was just more than 33.0 cm (13 in) below the drill deck. Thus, moving the inlet openings of the hood closer to the drill deck should also reduce cutting materials from being drawn into the intake plenum.

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