FIELD ASSESSMENT OF RETROFITTING SURFACE COAL MINE EQUIPMENT CABS WITH AIR FILTRATION SYSTEMS

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ABSTRACT

Operator cabs on a front-end loader and a rotary rock drill were retrofitted with ceiling mounted heating/AC units and air filtration systems. Subsequently surface coal mine field studies were conducted to evaluate the respirable dust protection these retrofitted cab systems offer to the equipment operator. A significant 10:1 respirable dust protection factor (ratio of outside to inside cab dust levels) was measured for the front-end loader cab with positive pressurization of the cab interior. Whereas an insignificant 3:1 respirable dust protection factor was measured for the drill cab without positive pressurization of the cab interior. These results indicate that achieving positive interior cab pressurization with retrofitted cab filtration systems is a key element to their dust control effectiveness.

INTRODUCTION

The Mine Safety and Health Administration (MSHA) permissible dust exposure for coal mine workers is a shift average of 2.0 mg of airborne respirable coal mine dust per cubic meter of air (2.0 mg/m^3) as defined by the Mining Research Establishment (MRE) Criteria (U. S. Code of Federal Regulations, 1998). If the airborne respirable dust (ARD) sample contains more than 5% crystalline silica, the dust standard is reduced to the quotient of 10 divided by the percentage of silica in the dust, limiting the respirable crystalline silica exposure to a maximum of 100 ì g/m^3 (MRE equivalent) for the working shift. Compliance with these respirable dust standards is expected to significantly reduce a worker=s risk of occupational lung disease over an average life expectancy.

MSHA=s dust enforcement program includes both inspector and coal mine operator dust sampling. MSHA=s surface coal mine dust program focuses its sampling efforts at designated work positions (DWP=s). These are particular areas or occupations that have been historically shown to either exceed 1 mg/m^3 of respirable dust or have high silica exposure. The local MSHA official has the authority to classify DWPs based on an operation=s dust sampling history or to classify non-designated work positions (NDWPs) based on a history of competent dust abatement. The most frequently sampled and classified DWPs at surface coal mines are the highwall drill operator, bulldozer operator, refuse/backfill truck driver, and highlift operator. MSHA dust exposure data from 1985-1992 showed that the percentage of the DWP dust samples containing more than 5% silica ranged between 81% for the highwall drill operator and 25% for the highlift operator [Tomb et al. 1995]. The percentage of these DWP dust samples that exceeded the 100 ì g/m^3 silica limit ranged between 77% for the highwall drill operator and 26% for the highlift operator [Tomb et al. 1995]. These data suggest that overexposure to silica dust is an ongoing surface coal mine dust problem for the highwall drill operator, bulldozer operator, refuse/backfill truck driver, and highlift operator.

An engineering control measure for surface mining equipment is enclosed operator cabs with air filtration systems. These cabs usually re-circulate and re-condition a majority of inside cab air with a smaller portion of the air added from the outside as makeup air. In order for the enclosed cab to protect the operator from the dust generated during excavation, the inside cab air must be efficiently filtered and the cab enclosure must be maintained under a positive ventilation pressure.

The agricultural industry has developed quality performance specifications for tractor cab enclosures. These enclosures are designed to protect equipment operators from pesticide exposures during their application. The premise for this standard is that a cab must act as an acceptable substitute for a respirator that adheres to the Worker Protection Standard (WPS) of the U.S. Environmental Protection Agency (EPA) [Heitbrink et al. 1998]. The American Society of Agricultural Engineers (ASAE) Standard S525 specifies that a cab enclosure will provide a 50:1 reduction in particles (commonly referred to as a protection factor of 50) with an aerodynamic diameter larger than 3 ìm [ASAE 1997]. This enclosed cab performance standard is equivalent to the protection offered by a full face respirator. The ASAE standard also specifies a minimum positive differential static pressure of 6 mm of water gauge for the cab enclosure and recommends ambient aerosol test procedures with optical particle counters to evaluate the performance of these enclosures [ASAE, 1997]. However, field evaluation of these agricultural cab testing procedures has shown that low ambient aerosol concentrations outside the cab can notably bias the evaluation to yield lower protection factors [Heitbrink et al. 1998; Heitbrink et al. 1999].

Recent surface mining dust surveys conducted by the National Institute for Occupational Safety and Health (NIOSH) on drills and bulldozers have shown that enclosed cabs can effectively control the operator=s dust exposure, but enclosed cab integrity problems still exist [Organiscak and Page 2000]. The enclosed cab protection factors measured on rotary drills ranged from 2.5 to 84, and those measured on bulldozers ranged from 0 to 45. Some of the newer equipment cabs tended to be better sealed and cleaner, while some of the older equipment tended to be more poorly sealed and dirtier. One of the least protective drill cabs did not include any heating, air conditioning, and air filtration systems. Some of the older surface mining equipment also possesses enclosed cabs with heating, but no air-conditioning, and/or air filtration systems.

To evaluate the respirable dust protection provided by retrofitting enclosed cab improvements, NIOSH recently conducted several dust control field studies of retrofitting old enclosed cabs with air-conditioning, heating, and air filtration systems. This paper describes these field studies conduced on a CAT 980B front-end loader and a Davey M8B rotary drill.

RETROFITTED CAB DEMONSTRATIONS

An enclosed operator cab field dust evaluation was conduced on a CAT 980B front-end loader and a Davey M8B drill before and after the cabs were retrofitted with roof mounted air- conditioner/heater units and external filtration units. This work was conducted as part of a mine demonstration project to improve the dust control integrity of enclosed operator cabs on mobile mining equipment. The two pieces of equipment studied originally possessed enclosed cabs with floor heaters and no air-conditioning and filtration systems. A baseline cab dust study was initially conducted on each piece of equipment for 3 to 4 production shifts before any cab modifications were made. A follow-up dust study was repeated for 4 to 6 production shifts after the cab modifications.

Each enclosed cab was retrofitted with a new ceiling-mounted Red Dot air-conditioner/heater unit (Model R-9757) with an external make-up air fan and Clean Air Filter[7] filtration system.[3] The external filter for the make-up air was a 2-stage Clean Air Filter[7] cartridge with a cellulose paper medium for the first stage and a final respirator medium as the second stage. A Clean Air Filter[7] housing with cyclonic inlets contained the filter cartridge and was connected to a centrifugal fan for blowing make-up air into the Red Dot air-conditioner/heater unit. A single-stage respirator media filter was also mounted on the Red Dot unit=s inside cab re-circulation inlet. The respirator media filter performance specifications are at least 99 percent capture efficiency for 0.1 ìm of mono-dispersed sodium chloride particles, as determined from TSI test method 85 lpm/dm^2.

Installation of each piece of equipment for the ceiling-mounted system took about a day, while another half day was invested on sealing the cab. The original floor heaters in the cabs were either removed or disconnected from operation, so that the Red Dot ceiling units and Clean Air Filter[7] units would consistently be used for both heating and air-conditioning functions. Cab enclosure structures on both pieces of equipment had numerous holes and cracks and thus positive inside cab air pressure was difficult to achieve. To enhance cabin air pressure, the CAT 980B cab enclosure cracks were sealed with silicon caulk and the door gaps were sealed with dense foam weather strip. A positive static cab pressure of 0.01" to 0.015" water gauge was achieved after several hours of sealing all the visible gaps/holes in the cab. The Davey M8B drill cab structure was in very poor condition, with large holes in the cab for the mechanical drill control linkages and a loosely fitted bi-folding door on the drill table side of the drill. Because of the numerous holes and gaps present in the cab enclosure, positive static cab pressure was not achieved on the Davey M8B drill. However, the discharge of the air-conditioning/heating unit was directed over the operator position in an attempt to provide him with a clean-air zone within the cab.

FIELD SAMPLING PROCEDURES

Dust sampling was conducted during multiple working shifts inside and outside the operator cabs to measure the enclosed cab dust control protection factor before and after the cab modifications were made. Data collected included: personal respirable dust samples; personal impactor dust mass size distributions; optical particle counter (OPC) size distributions; miniature real-time aerosol monitor (MINIRAM) respirable dust levels; weather conditions (wind speed, direction, temperature, humidity, etc.); and qualitative documentation of equipment operation.

***Gravimetric Sampling*:** Area airborne respirable dust sampling was conducted with personal samplers located inside the operator cabs and near the dust source outside of the cabs to assess the protection performance of these cabs in relation to operator dust levels. Each personal dust sampler included a Mine Safety Appliance (MSA) Flow-Lite pump, operating at 2.0 liters/min, with a 10-mm Dorr-Oliver nylon cyclone classifier to collect a respirable dust sample (U. S. Code of Federal Regulations, 1998). The respirable dust was deposited on a 37 mm MSA coal dust filter cassette. Three personal gravimetric dust samplers were used at each sampling location so that adequate amounts of dust could be collected for silica analysis. One

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

Sierra 298 personal impactor, operating at 2.0 liters/min, was also placed with the 3 personal samplers at the fixed sampling locations on each piece of equipment. Impactor dust size fractions of 21.3, 14.8, 9.8, 6.0, 3.5, and 1.55 ìm were collected on silicon greased filter substrates with smaller dust particles collected on a polyvinyl chloride final filter. The areas sampled are described below for the two pieces of equipment:

1. Highwall Rock Drill: 1) Inside front of the operator cab above control panel; 2) Outside back of cab; 3) Mobile tripod kept in the downwind dust plume near the drill hole shroud (*see figure 5, an impactor is not commonly used here due to dust overloading*).

2. Front End Loader: 1) Inside right side of the operator cab above bucket controls; 2) Outside the cab behind the left entrance door.

The MSA filters and impactor substrates were pre- and post-weighed to the nearest 0.001 mg on a microbalance. Personal dust sampling was usually conducted for more than 7 hours during the shift. The impactors were operated between 4 and 8 hours during the shift, depending on the dust concentrations or loading activity at the particular locations. Three shifts of baseline dust samples (March 29 - 31, 1999) and 6 shifts of controlled dust samples (Aug. 11 and 12, Sept. 14 and 15, and Oct. 20 and 21, 1999) were collected on the CAT 980B front end loader. Four baseline shifts of dust samples (March 29 - April 1, 1999) and 4 shifts of controlled dust samples (Aug. 11 and 12, and Oct. 21 and 22, 1999) were conducted on the Davey M8B rock drill.

The respirable dust mass collected on the filter cassettes were analyzed by PRL=s in-house analytical lab for crystalline silica by MSHA=s P-7 infrared spectrophotometer method [Ainsworth et al. 1989]. The silica content of the dust (in percent) is reported for at least 0.25 mg of dust mass and 25 ìg of silica. Many of the filter cassettes did not have 0.25 mg of dust mass, so multiple filter cassettes from the same sampling location were composited for silica analysis. Finally, some dust levels were so low that even the composite filter mass did not meet the minimum reportable range.

***Instantaneous Sampling*:** Supplemental airborne dust sampling was also conducted in the enclosed cabs using instantaneous dust monitors. A MINIRAM instantaneous dust instrument connected to a Metrosonics 331 data logger was placed with the gravimetric samplers in the operator cabs to examine real-time respirable dust level variations during the shift. The MINIRAM measures respirable dust by light-scattering techniques and was operated in the passive sampling mode. The Metrosonics 331 data logger recorded analog voltage output from the instrument which was downloaded to a personal computer for data analysis [Cecala et al. 1988]. Since the MINIRAM was not individually mass calibrated to the different dusts sampled, the instantaneous dust data is expressed in relative MINIRAM units to identify corresponding dust level changes influenced by particular operator practices during the shift.

As in agricultural cab testing procedures, instantaneous OPCs (GRIMM Technologies, Inc.) were also used during part of the sampling shift on the front-end loader on Aug 11^{th} and on the drill on Aug 12^{th} in similar fashion to the agricultural cab testing procedures [Heitbrink et al. 1998; Heitbrink et al. 1999]. OPC sampling was simultaneously conducted inside and outside the cab during a portion of the shift with the instruments alternated between these positions to remove any instrumental bias from the outside and inside particle counting. The OPC=s size data were used to determine the percentage and size of dust particle penetration into the enclosed cab systems.

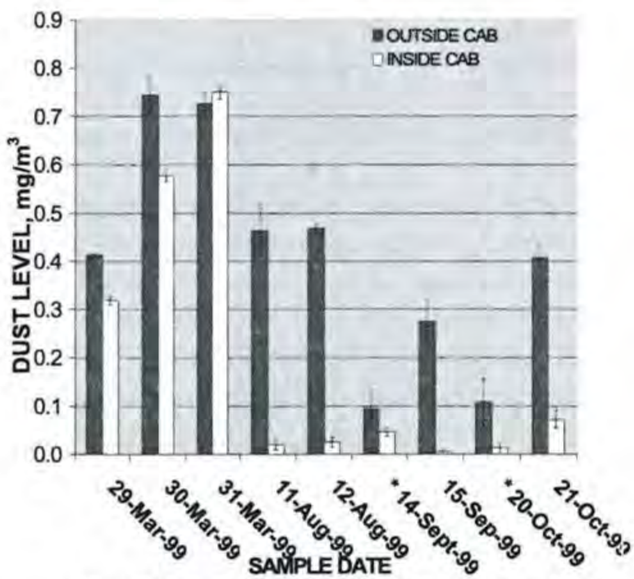
***Wind and Weather Parameters*:** A wind speed and directional instrument was positioned near the drilling operation to document the migration direction of drill dust. A Brunton Pocket Transit was used to align the instrument for proper azimuth readings. This instrument was also connected to two Metrosonics 331 data loggers to record both the speed and direction of the wind. Again the output stored in these loggers was downloaded to a personal computer for data analysis [Cecala et al.1988]. The drill location and orientation during the shift was drawn on a map to identify the dust migration of the drill dust with respect to the operator cab. Also, a description of weather conditions was recorded with wet and dry bulb temperatures taken during the shift. Because the loader is mobile, constantly changing its orientation with the wind, its cab dust protection effectiveness was anticipated to be a good long-term representative average for the various wind directions. Therefore, wind measurements were not taken around the front end loader.

FIELD STUDY RESULTS

***CAT 980B Front-End Loader*:** Figure 1 shows the CAT 980B front-end loader loading coal from a stockpile with the Red Dot and Clean Air Filter[7] units operating on top of the cab enclosure. The 980B loader was used for loading stockpiled coal into the portable crusher, removing the coal seam from the pit, and loading coal trucks for transport from the mine. The loader was commonly rotated among these multiple tasks during the same sampling shift. The operator kept the doors and windows shut during all the sampling shifts (baseline and modified cab), except to enter and exit the loader cab.

Average respirable dust levels (taken by 3 personal samplers) measured inside and outside the loader cab are shown in figure 2 with their respective standard error bars for the multiple samplers. Results from the 3 baseline shifts (March 29 - 31) and six controlled shifts (Aug. 11 and 12, Sept. 14 and 15, and Oct. 20 and 21) show that the refurbished enclosed cab had noticeably reduced respirable dust levels inside the cab as compared to outside the cab. Wet ground conditions on Sept. 14 and Oct. 20 from early morning rain lowered the outside loader cab dust levels as compared to the other four controlled shifts with dry ground conditions.

Figure 1 - CAT 980 loader studied.



·Note: the ground was wet from morning rain on Sept. 14 and Oct. 20

Figure 2 - Dust results from loader cab evaluation.

A typical instantaneous dust level history (MINIRAM) recorded inside the loader cab is shown in figure 3 for the March 31st baseline shift and the Aug. 12th controlled shift. These dust level histories illustrate the notable inside cab dust reductions achieved from the loader cab modifications. They also show that the pressurized cab air cleaning system maintained lower dust levels with very little variation during the work shift.

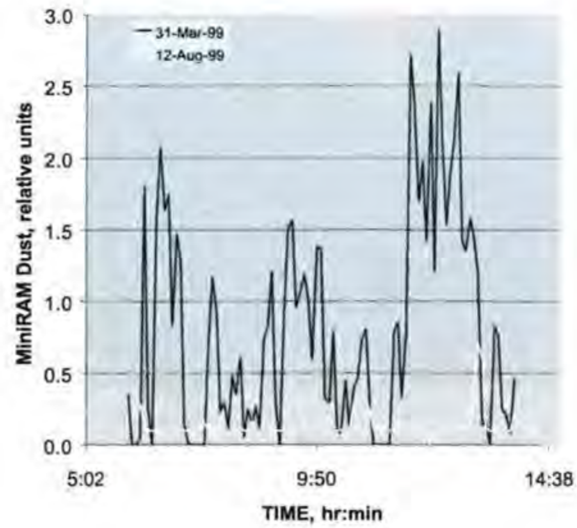


Figure 3 - Loader cab dust level histories.

Table I shows the average dust levels and cab protection factors with daily ranges for the baseline and modified cab on the CAT 980B front-end loader. The CAT 980B front-end loader showed a significant improvement in operator cab dust control effectiveness with the addition of the Red Dot and Clean Air Filter[7] units to the cab enclosure and the sealing of all the visual openings or cracks found in the cab enclosure. The inside cab dust levels were reduced by about one order of magnitude after these changes were made. The enclosed cab dust protection factors (outside/inside) was increased on average from 1.1 to 10.1. Similarly, the percentage of cab penetration of dust ((inside/outside) H100) was reduced from 87% to 10%, while the percentage of dust reduction (((inside ! outside)/outside) H100) increased from -13 % to -90 % with the cab improvements.

This cab improvement is considered to be statistically significant. The one-tailed t-test probability (*p*-value) that the inside and outside cab dust levels are the same notably decreased from 0.328 to 0.006 with the cab modification. Although this average improvement was significant, it must be noted that the day-to-day protection factors for the modified cab ranged from 2.1 to 50.1 (see table I), while the inside cab respirable dust levels consistently remained under 0.07 mg/m^3. This supports the work of others that field evaluation of cabs with low exterior dust levels tends to bias the cab=s protection factor towards lower levels because the relative differences approach the background levels inside the cab [Heitbrink et al. 1998; Heitbrink et al. 1999].

The particle size percentage of dust penetration (% of particle count inside the cab as compared to outside the cab) into the modified loader cab by particle size count can be seen by the OPC data collected on Aug 11 in figure 4. This figure shows that a somewhat higher percentage of smaller sized dust particles was observed to penetrate the loader cab. Never the less, the loader cab appeared to provide effective protection throughout the particle size range, with less than 5 % of the 1 ìm or larger particles penetrating the loader cab enclosure. The average shift cab protection factor and the average shift percentage of cab penetration of respirable dust measured with the personal samplers during this particular day was 24.2 and 4.1%, showing reasonably good agreement with the OPC data.

Although the original cab provided negligible control of respirable dust, the original cab enclosure kept a notable amount of the larger sized dust particles from entering the cab. The average mass median diameter (MMD) of the outside dust particles and the inside dust particles for the original cab was 27.3 ìm and 11.5 ìm, respectively. This indicates that the CAT 980B front-end loader had a fairly good enveloped cab structure for resealing and retrofitting with a filtered air conditioning system. Finally, the silica percentage of the respirable dust for the CAT 980B front-end loader was found to be very low, commonly below 5%, both inside and outside the

TABLE I - DUST LEVEL SUMMARY OF CAB STUDY

PARAMETERS	CAT 980B FRONT-END LOADER		DAVEY M8B ROTARY DRILL	
	BASELINE 3 Shifts Average [*Range*]	MODIFIED CAB 6 Shifts Average [*Range*]	BASELINE 4 Shifts Average [*Range*]	MODIFIED CAB 4 Shifts Average [*Range*]
Outside Cab Respirable Dust Level, mg/m^3	0.63 [*0.41, 0.74*]	0.30 [*0.09, 0.47*]	0.72 [*0.10, 1.13*]	0.23 [*0.12, 0.46*]
Inside Cab Respirable Dust Level, mg/m^3	0.55 [*0.32, 0.75*]	0.03 [*0.01, 0.07*]	0.13 [*0.09, 0.19*]	0.08 [*0.02, 0.17*]
†*p*-value ($t_{statistic} \leq t_{critical}$, one-tail test)	0.328	0.006	0.042	0.078
††Cab Protection Factor, (Out/In)	1.1 [*1.0, 1.3*]	10.1 [*2.1, 50.1*]	5.4 [*0.5, 13.2*]	2.9 [*2.0, 7.9*]
††Percentage of Cab Penetration, (In/Out) ×100	87 [*77, 103*]	10 [*2, 48*]	19 [*8, 182*]	34 [*13, 49*]
††Percentage of Dust Reduction, ((In − Out)/Out) ×100	-13 [*-23, +3*]	-90 [*-98, -52*]	-81 [*-92, +82*]	-66 [*-87, -51*]
‡Mass Median Diameter--Outside Cab, ìm	27.3 [*25.1, 30.6*]	25.6 [*19.9, 36.9*]	31.3 [*24.9, 36.6*]	32.5 [*24.2, 48.6*]
‡Mass Median Diameter--Inside Cab, ìm	11.5 [*9.2, 15.4*]	8.1 [*1.7, 21.7*]	28.7 [*18.3, 46.2*]	18.3 [*13.1, 25.4*]
‡‡Silica Percentage of Respirable Dust--Outside Cab	3.5 [*3.0, 4.1*]	2.0 [*1.6, 3.1*]	35.4 [*28.0, 39.9*]	35.4 [*18.2, 46.6*]
‡‡Silica Percentage of Respirable Dust--Inside Cab	3.9 [*1.8, 5.6*]	N.E.S.	22.1 [*15.2, 31.6*]	29.3 [*N.E.S., 29.3*]

† Null Hypothesis (H_o): (Average Inside Cab Dust Level - Average Outside Cab Dust Level) = 0
Alternative Hypothesis (H_a): (Average Inside Cab Dust Level - Average Outside Cab Dust Level) < 0

†† The average cab protection factor, average percentage of cab penetration, and average percentage of dust reduction are based on the average dust level measured outside and inside the cab. The range is based on individual shift measurements.

‡ The mass medium diameter is the dust particle size where half of the airborne dust mass is above and half below this size (measured with Sierra personal impactors).

‡‡ Silica analysis of respirable personal samplers by MSHA Standard Method No. P-7, with infrared determination of quartz in respirable coal mine dust. Analysis usually performed on sample composites to obtain enough mass. N.E.S. - Not Enough Sample.

cab during all the baseline testing and modified cab testing.

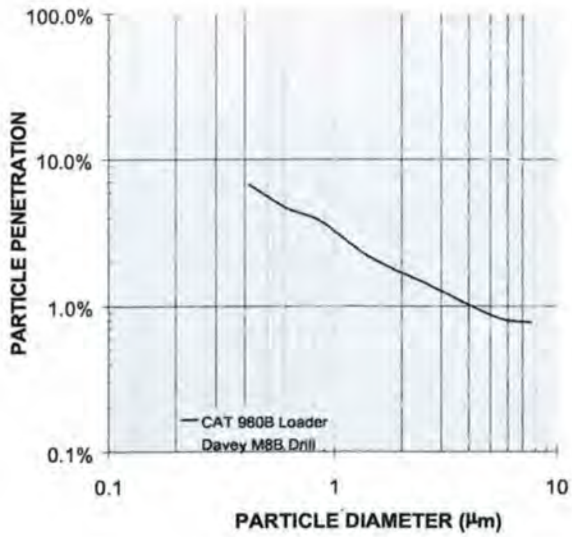


Figure 4 - Percentage of aerosol penetrating into the cabs.

***Davey M8B Rotary Rock Drill*:** Figure 5 shows the Davey M8B rotary drill with the Red Dot and Clean Air Filter[7] units operating on top of the cab enclosure during the highwall drilling operation. The drill operated throughout most of the shift, except for a morning break and short non-production time periods needed for minor drill maintenance. This drill operation utilized two employees working as a team. One employee operated the drill from within the cab (drill operator) while the other employee worked outside the cab (drill helper), changing drill steels and clearing the cuttings from the hole. Throughout the shift the drill operator and helper switched work details (positions). During the baseline testing, the two cab doors were constantly left open all shift so the employees could visually and verbally communicate with each other. During the modified cab testing, the two cab doors were typically closed during most of the drilling activities. The bifold door facing the drill table was opened for drill steel changes and both doors were opened for drill placement during the modified cab sampling shifts. The employees open these cab doors at these particular times so that they can observe and communicate (visually and verbally) to each other during the manual changing of drill steels and drill machine placement on the bench.

Figure 5 - Davey M8B drill studied.

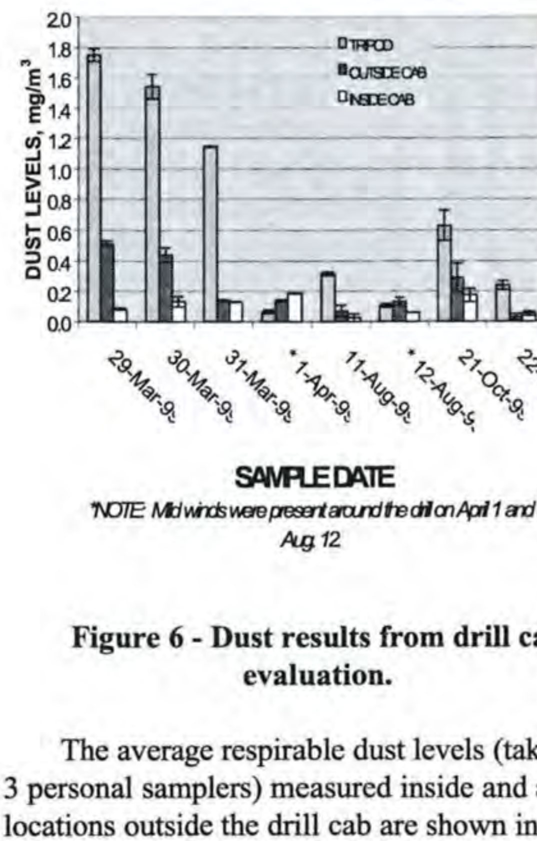


Figure 6 - Dust results from drill cab evaluation.

The average respirable dust levels (taken by 3 personal samplers) measured inside and at two locations outside the drill cab are shown in figure 6, with their respective standard error bars for the samplers. The inside and outside cab dust samplers were at fixed positions on the drill, while the mobile tripod dust samplers were placed on the downwind side of the drill hole shroud (see figure 5). The dust levels measured inside the operator cab were commonly lower and noticeably more consistent than those levels measured at the tripod and outside of the cab during the study. The tripod dust levels were more variable and typically higher than the outside cab dust levels, during both the baseline and modified cab testing. The tripod dust levels were also significantly higher during 3 of the baseline sampling shifts as compared to the modified cab sampling shifts.

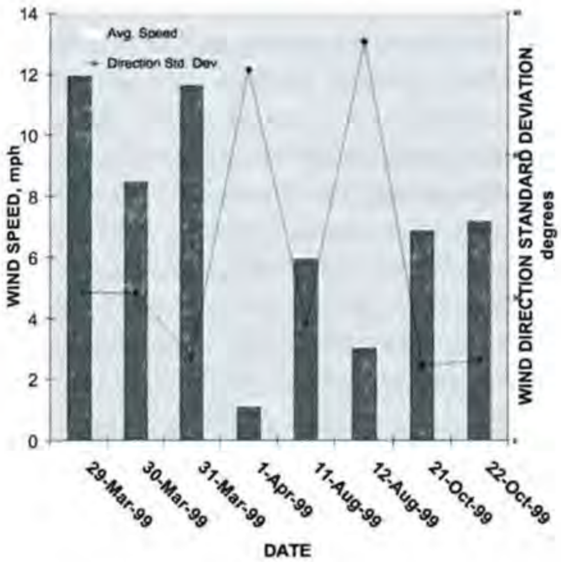


Figure 7 - Summary of daily wind speed and direction measurements around the drill.

The key factors influencing these day-to-day dust level variations were wind speed and direction. Figure 7 shows the average wind speed and the standard deviation of the wind direction around the drill for the sampling shifts, while figure 8 shows the typical wind direction histories observed during a strong windy day (March 31) versus a calm mild day (August 12). As evidenced by these data, on the strong windy days the wind direction deviations were notably less than for the calmer days. In comparison tripod dust levels were notably higher than the outside cab dust levels for the strong windy days, while they were more comparable on the calm days (see figure 6). This most likely occurred because the dust plume for the windy days was more directional towards the downwind tripod sampling location, while it was more dispersed among the tripod and outside cab sampling locations for the calm days (see figure 8). Figure 9 also shows the strong positive relationship between the tripod dust level and wind speed. The wind speed irrespective of directional variation was also believe to be a key factor in this tripod dust and wind speed relationship, since notably more dust entrainment around the drill was visually observed on the extremely windy days during the baseline sampling in March.

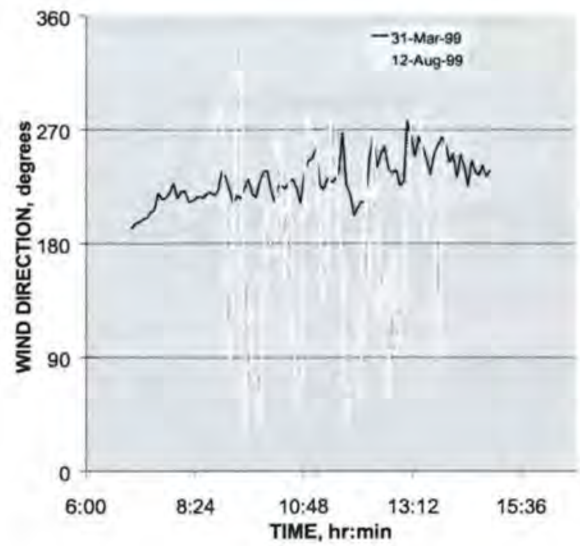


Figure 8 - Strong and mild wind direction histories around the drill.

Table I shows the average dust levels and cab protection factors, with daily ranges for the baseline and modified cab on the Davey M8B drill. The drill=s outside cab respirable dust levels reported in table I are inclusive averages of both the tripod and outside cab sampling locations. A negligible change in operator cab dust control effectiveness was measured by adding the Red Dot and Clean Air Filter[7] units to the cab enclosure. The enclosed cab dust protection factor was decreased on average from 5.4 to 2.9. Similarly, the percentage of cab penetration of dust was increased from 19% to 34% and the percentage of dust reduction decreased from -81% to -66% with the cab improvements.

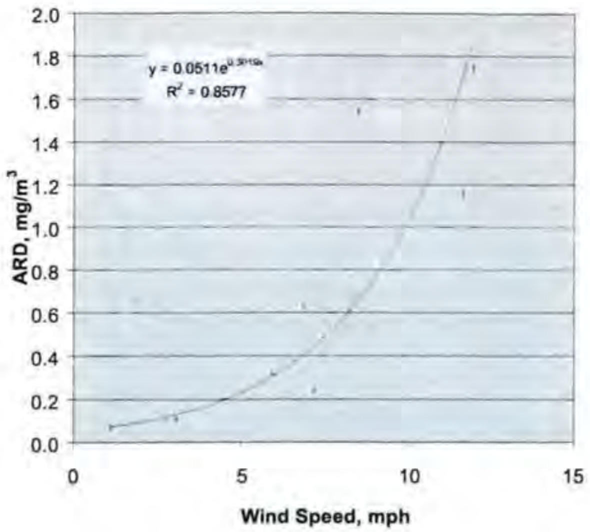


Figure 9 - Tripod dust level and wind speed relationship around the drill.

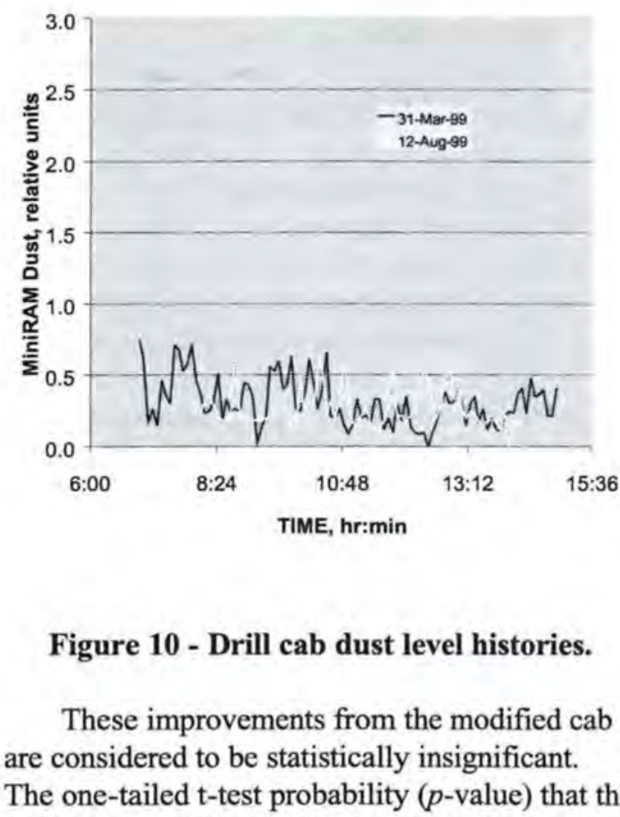


Figure 10 - Drill cab dust level histories.

These improvements from the modified cab are considered to be statistically insignificant. The one-tailed t-test probability (*p*-value) that the inside and outside cab dust levels are the same increased from 0.042 to 0.078 with the cab modification. Typical instantaneous dust level histories (MINIRAM) recorded inside the drill cab are shown in figure 10 for the March 31st baseline shift and the Aug. 12th modified shift. These dust level histories illustrate that no notable inside cab dust reductions were achieved from the drill cab modifications.

Problems encountered with the drill cab enclosure were large openings in the cab structure for the mechanical control linkages and a loosely fitting bi-folding door facing the drill table. Positive cab pressure was not achieved on the drill because of these enclosure sealing problems. Also, the operator usually opened the cab doors to communicate with the helper, during drill steel changes and drill moves. Furthermore, the wind direction played a very important role in the dust measurements made during these field studies, especially for the baseline conditions. These variations can be seen in the shift ranges of the cab protection factors, the percentage of cab penetration, and the percentage of dust reductions measured (see table I). The baseline cab protection factors ranged from 0.5 to 13.2 (percentage of cab penetration from 8 to 182 and percentage of dust reductions from -92% to + 82). The modified cab provided less variation in protection factors, ranging between 2.0 and 7.9 (percentage of cab penetration from 13 to 49 and percentage of dust reductions from -87% to - 57%). Although the drill cab=s clean air system did not show an average improvement in its effectiveness, the variation caused by wind effects were somewhat reduced.

The particle size percentage of dust penetration (percentage of particle count inside the cab as compared to outside the cab) into the drill cab by particle size count is demonstrated by the OPC data collected on Aug 12 in figure 4. As can be seen in this figure, the drill had a notably higher percentage of dust penetrating the cab as compared to the loader. The drill cab dust penetration was one order of magnitude higher as compared to the front-end loader. Ten to 30% of the 7 to 1 ìm dust particles, respectively, penetrated the drill cab enclosure. The average shift protection factor and the average shift percentage of cab penetration of respirable dust measured with the personal samplers during this particular day were 2.0 and 49.3%, showing reasonably good agreement with the OPC data.

The drill cab=s air cleaning system did provide some improvement in the median dust size that entered the cab. A negligible difference was observed in the mass median diameter (MMD) of dust outside the cab as compared to inside the cab during the baseline tests (31.3 ì m outside and 28.7 ì m inside). However, the MMDs of the outside dust and the inside dust for the improved cab were 32.5 ì m and 18.3 ì m, respectively. This indicates that the filtered air made some improvement within the cab, but the effect was diluted by outside air infiltration into the cab by gaps in the structure (no positive cab pressure) or by the door being opened frequently. Finally, the silica percentage of the respirable dust for the Davey M8B drill was found to be notably higher than that of the front-end loader, commonly above 20%, both inside and outside the cab during all the baseline testing and modified cab testing.

CONCLUSIONS

These field studies show that two key elements are needed to control dust levels in enclosed operator cabs. First, the cab needs to have a high quality of re-circulating and incoming filtered airflow; secondly, a cab structure needs to be adequately sealed to achieve positive static pressure with the incoming clean air flow. Both of these key elements were accomplished with the CAT 980B front-end loader, providing on average a 10:1 cab protection factor for the operator. The cab structure on the Davey M8B was not adequately sealed, diminishing the overall effectiveness of the cab air filtration system. By not achieving positive pressure inside the drill cab, the outside dust was able to penetrate the cab structure.

Relative cab performance measures determined in the field were noticeably affected by the wind and outside dust levels. The cab protection factor, percentage of cab penetration, and percentage of dust reduction measures were observed to change noticeably during day-to-day operations, while the respirable dust levels remained consistently low inside the cab. Exterior cab dust levels affected by weather (wind and precipitation) were found to considerably change the relative cab performance measures, especially if the exterior cab dust levels were very low. However, the primary goal of enclosed cab performance should focus on consistently achieving inside cab dust levels below worker compliance levels, while ensuring adequate protection from high dust levels outside the cab.

MSHA=s dust enforcement data show that enclosed cabs on drills, bulldozers, refuse/backfill trucks, and high lifts (front-end loaders) continue to be suspect in providing adequate operator protection from silica dust at mining operations. Therefore, some of the enclosed cabs used on mining equipment need to be updated, reconditioned, or better maintained. To resolve enclosed cab performance problems and improve mine worker health, MSHA is currently pursuing enclosed cab seminars around the U.S. to build partnerships between health specialists, labor, mining companies, mining equipment manufacturers, heating & air-conditioning equipment manufacturers and filter media companies [MSHA2000]. NIOSH is currently studying field measurement quality control procedures for prompt determination of an enclosed cab=s dust protection capabilities.

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