Retrofit Options for Better Dust Control

Cab filtration, pressurization systems prove effective in reducing silica dust exposures in older trucks.

By Gregory J. Chekan and Jay F. Colinet

Enclosed cabs that protect operators are common on mining equipment, such as drills, wheel loaders, and haul trucks. As equipment ages, however, many of the original components on the cab enclosure deteriorate through normal operation in harsh mine environments. As a result, the effectiveness of the air-filtration system and cab seals is lessened and the protection initially afforded to an operator is compromised, possibly exposing them to elevated levels of respirable silica dust.

In an effort to improve protection of equipment operators, the National Institute for Occupational Safety and Health (NIOSH) entered into a number of cooperative research efforts with the mining industry and companies that manufacture and install cab enclosure units. Several studies regarding the effectiveness of these systems have been published for surface coal and noncoal operations. In these studies, units were installed on front-end loaders and overburden drills to reduce respirable coal and silica dust in the operator's cab. The units feature air-conditioning, heating, filtration, and pressurization systems that recirculate and filter a majority of the inside cab air combined with a smaller portion of outside makeup air. Outside air is cleaned with high-efficiency filters before it enters the cab, and the cab enclosure is maintained under a positive pressure.

In this current study, NIOSH and Sigma Air Conditioning Inc. entered into a cooperative cost-sharing agreement to evaluate the impact of retrofitting a haul truck at an underground limestone mine with a new filtration/pressurization system to reduce the operator's exposure to silica dust. After the new unit was installed and seals on the cab upgraded, measured levels of respirable quartz dust in the cab decreased 63 percent.

TABLE 1

Summary of Gravimetric Dust Concentrations

Truck	Respirable Dust Concentrations (mg/m^3) Outside	Inside	Reduction	Respirable Quartz Concentrations (mg/m^3) Outside	Inside	Reduction
A. Pre-installation						
Truck 1	0.425	0.279	34%	0.035	0.023	34%
Truck 2	0.402	0.272	32%	0.031	0.016	48%
B. Post-installation						
Truck 1	1.01	0.317	69%	0.071	0.017	76%
Truck 2	0.652	0.428	34%	0.063	0.033	48%
Komatsu	0.707	0.215	70%	0.036	0.009	75%

Sampling procedures

Two types of dust-sampling instruments were used. The primary dust-measuring instrument was the gravimetric sampler operated at 1.7 l/min. to follow Mine Safety and Health Administration (MSHA) requirements for sampling in metal/nonmetal mines. A 10-mm Dorr-Oliver cyclone collected the respirable fraction of the airborne dust (smaller than 10 microns) and deposited it onto a 37-mm polyvinyl chloride (PVC) filter with a nominal pore size of 5.0 µm. The filters were weighed before and after sampling to calculate overall respirable dust concentrations based on the sampling rate and time. The filters were then analyzed for silica content with X-Ray Diffraction (XRD) using the NIOSH 7500 Method.

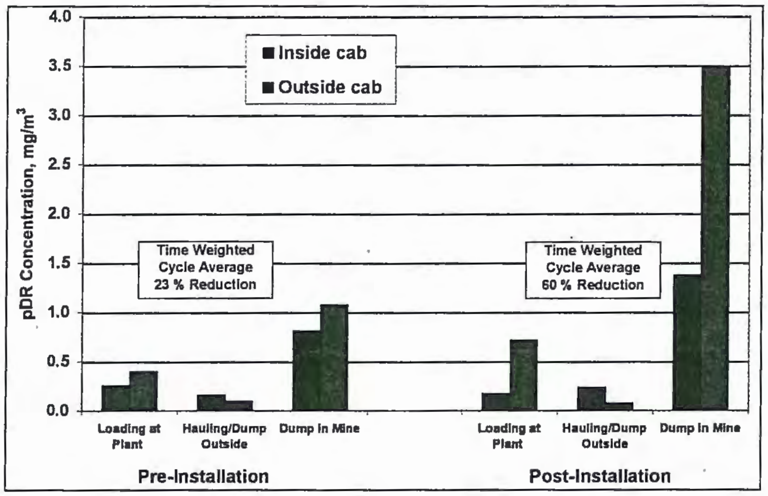
Figure 1: Two gravimetric samplers and a pDR were positioned outside the cab below the front window of Truck 1.

The second sampling instrument was the MIE personal DataRAM (pDR). The pDR is a real-time aerosol monitor that measures and records the concentration of respirable airborne dust using a light-scattering technique. Light-scattering instruments offer only a relative measure of concentrations, but provide a continuous record of dust levels so that concentrations can be evaluated over any time interval during the sampling period.

Gravimetric and pDR samplers were used to measure dust concentrations outside and inside the truck cab. Their locations were selected so as not to interfere with the operator's vision or operation of the truck. Two gravimetric samplers and a pDR were positioned outside of the cab below the front window (Figure 1). Two gravimetric samplers and one pDR were also hung inside the cab to the right of the operator, at the same height as his breathing zone. Outside dust levels were compared to dust levels in the cab to calculate the percent reduction in dust afforded by the enclosed cab.

FIGURE 2

pDR Dust Concentrations During Haulage Cycles



At this particular mine, two trucks were candidates for installation of the new filtration system. Both trucks — identified as Truck 1 and Truck 2 — were Euclid R-50s, manufactured in 1975. Truck 1 was used to load fines from the processing plant, transport these fines to different locations, dump the fines, and then return to the plant for the next load. The operator dumped the fines at outside locations on the property, or hauled the fines into the mine and dumped them for backfill.

Truck 2 was used to haul larger-sized product from the processing plant and dump the product at different locations on the mine property. When needed, Truck 2 would also be used to haul stone from the faces in the mine and dump them at the outside crushing facility.

Both trucks were originally fitted with a heating and air-conditioning unit that had minimal dust-filtering capabilities for intake air and neither was equipped with a pressurizer to positively ventilate the cab. Both units were functional, but outdated and in need of replacement.

Baseline sampling was conducted for three days on Truck 1 and for two days on Truck 2 (it was idled the second day of sampling for maintenance). Sampling time was approximately 6 hours per shift. During sampling, a time study was conducted on truck activity and general dust conditions were noted for each day.

Table 1-A shows the average gravimetric concentrations from the samplers located on Trucks 1 and 2. Truck 1 had respirable dust and respirable quartz dust reductions of 34 percent and 34 percent, respectively. Truck 2 had 32 percent and 48 percent reductions. The reductions in dust for both trucks are comparable, indicating that the truck cabs and their air conditioning and heating systems were in similar operating condition.

To further quantify the respirable dust and evaluate dust reduction in the truck cabs, the pDRs were used to monitor dust levels for the trucks during the haulage cycle. The pDRs were set to log the concentrations at 10-second intervals providing approximately 2,200 data points for 6 hours of sampling. From the time studies conducted on the trucks, the dust concentrations during each operation were determined by correlating the loading, hauling, and dumping times with the times and concentrations recorded on the pDRs.

As shown in Figure 2, for pre-installation, the shift cycle was separated into three distinct operations. On the first two days of sampling, Truck 1 loaded at the plant and dumped the fines either outside or in the mine as backfill. The graph shows that the highest concentration for Truck 1 occured when the truck was dumping in the mine. While in the mine, the pDR sampler may also be exposed to diesel exhaust and fog, which may impact the relative concentrations recorded by the sampler.

Loading at the plant is the second highest dust source, while hauling/dumping outside is the lowest pDR concentration. It should also be noted that the dust concentrations inside the cab are higher than the outside. This may be due to the sampling location selected for the outside samplers at the front of the truck cab. Any dust generated by tramming would flow toward the rear of the truck and away from the front of the truck. Similar cycle trends were also observed for Truck 2.

These sampling results show that the cabs on the two trucks were similar in performance and dust exposure, with similar dust concentrations observed entering the cab during a typical shift. After presenting this information to mine management and discussing the pros and cons of retrofitting each truck, Truck 1 was selected for several reasons. First, it had slightly more quartz dust entering the cab. Second, because it was used exclusively to load fines, normally a much dustier operation, it would benefit more from the new system. Third, maintenance records showed that Truck 1 was in better mechanical condition and would most likely have a longer service life.

Installing a new air system

For this study, the original air conditioning system on the Euclid R-50 was replaced with a Sigma Model EC5BX3C rooftop-mounted unit. The cost of the unit was approximately $6,000 plus the cost of installation. The new system included heating, cooling, and pressurization, with high-efficiency filter media for

Figure 3: A Sigma unit installed on Truck 1 (left) required a raised, protective box welded to the cab protector (right) to shield the air-conditioning unit.

both the pressurizer filter and the return air filters. The pressurizer filter is a pleated cartridge-style filter using a spun polyester washable media rated at 99 percent efficiency for particles greater than 0.5 μm. The pressurizer has a separate blower, which introduces outside fresh air to positively pressurize the cab. The return air has a two-stage filter design. The first stage uses a Farr 30/30 filter, which is designed to remove the larger particles and reduce loading of the second and final stage filter. The final stage filter, which also has a 99 percent efficiency rating, again uses the pleated spun polyester washable media in a 2-in. flat panel design.

Mounting rooftop systems on older model haul trucks may require special installation because there may not be sufficient space for the unit to fit between the top of the cab and cab protector on the truck bed, as can be seen in Figure 1. In these situations, the cab protector must be modified and a raised steel box welded into place for clearance. However, NIOSH recommends that mine operators adopting this technology contact the original equipment manufacturer and MSHA prior to making equipment modifications.

Installation of the unit required two workers approximately two 8-hour shifts to complete. Another shift was utilized for resealing the cab with foam weather stripping around the doors and service panels and caulking to seal smaller cracks. A positive static pressure of 0.01 in. of water gauge was achieved after resealing. Figure 3 shows the unit installed on top of the truck cab and the protective box (constructed from 0.5-in. steel plate) welded to the top of the cab protector on the truck bed for clearance of the unit.

Post-installation results

Table 1 shows the average concentrations for Truck 1 from the gravimetric samplers for the three days of sampling pre-and post-installation

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Keys to Success

Studies show that two key components for successful installation and operation are effective filtration and cab integrity. Outside air and inside recirculated air should be filtered through a high-quality and high-efficiency filter and the cab should be sealed to attain a positive pressure.

It is also highly recommended that makeup air be positively pressurized after being filtered to eliminate any possibility of dust-laden air being drawn into the system. Additionally, the makeup air intake should optimally be located on the cab at the furthest practical distance from dust sources. This reduces the amount of loading on the filters and increases the time between cleaning or replacement.

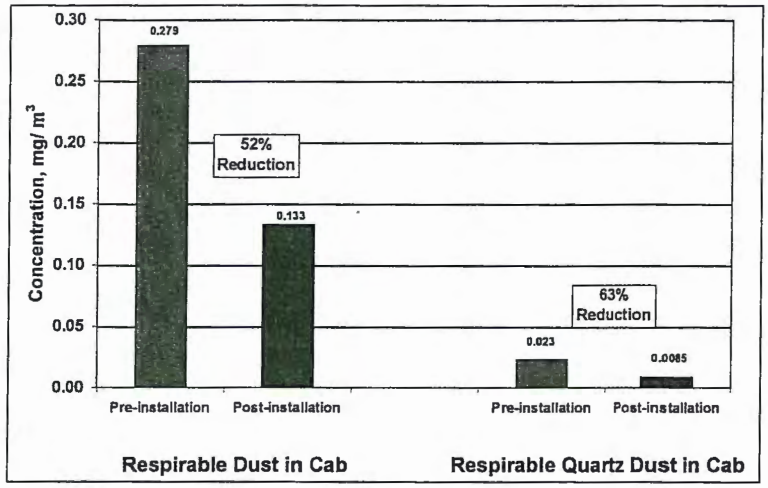
Finally, the discharge for makeup air into an enclosed cab should be located high in the enclosure, preferably at the roof. This allows the clean air to be blown down over the equipment operator's breathing zone without becoming contaminated by any in-cab dust sources. The Sigma filtration and pressurization system met each of these design criteria.

The second factor for dust control effectiveness — cab integrity — is necessary in order to achieve some level of pressurization. Field testing shows that installing new door gaskets and plugging and sealing cracks and holes in the shell of the cab have a major impact on increasing cab pressurization. To prevent dust-laden air from infiltrating into the cab, the cab's static pressure must be greater than the wind's velocity pressure.

Higher static pressure requirements help overcome outside wind speeds, but this necessitates more air being delivered by the outside air unit, causing more loading on the filters. Higher airflows also create more air-conditioning (heating and cooling) requirements for operator comfort, which may increase the size and cost of the system. ■

FIGURE 4

Dust Reductions Normalized to Baseline Levels



of the Sigma system. The reduction of respirable dust and respirable quartz dust was 34 percent and 34 percent respectively, before the new system was installed. After installation of the new system, the reduction improved to 69 percent and 76 percent, respectively. Figure 2 shows the inside and outside dust concentration data from the pDRs for the different operations of the haulage cycle. The pattern is similar to the pre-installation pDR concentrations, but the reductions in dust concentration are greater for "loading at plant" and "dumping in mine". The reduction in respirable dust from outside to inside the cab, based on the time-weighted cycle average, is 60 percent, compared to 23 percent before installation.

It should be noted that the outside dust levels for all three days of post-installation sampling were much higher than during pre-installation. This was visually noted during sampling and supported by the measured dust concentration in Table 1. The respirable dust and the quartz dust concentrations outside the cab during post-installation sampling were double the values found during baseline sampling. These higher concentrations obviously influence the amount of dust penetrating the cab, which needs to be taken into account to determine the actual reduction in cab dust before and after installation of the unit.

Figure 4 accounts for these higher outside concentrations by normalizing the average concentration values during post-installation to the baseline values during pre-installation inside the cab. Using this analysis, a 52- percent reduction in respirable dust and a 63-percent reduction in respirable quartz dust was achieved in the cab after the new system was installed. This is a measure of the actual improvement in the cab working environment if outside dust levels during post-installation sampling were equivalent to baseline levels.

As a final measure to evaluate the new system installed on Truck 1, dust surveys were conducted on other trucks for comparison. As a control, the original Euclid R50 (Truck 2) was re-sampled for one day during the post-installation survey. In addition, a five-year-old 100-ton Komatsu truck, used to haul stone from the mine, was also sampled for one day to determine the effectiveness of the factory-installed pressurization and filtration system supplied on this newer truck. The number of samplers (gravimetric and pDRs) and their positioning on the outside and inside of the cabs was kept consistent with the previous sampling.

Table 1-B shows the one-day gravimetric sampling results for each truck. As a control, Truck 2 shows no change from the pre-installation survey reductions. The Komatsu truck reductions are similar to the Euclid R-50 after retrofit with the new system (Truck 1). This indicates that older model trucks can be successfully upgraded to protect operators from silica dust. ■

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