# CURRENT NIOSH DUST CONTROL RESEARCH FOR NONCOAL SURFACE MINES

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## SUMMARY

Miners at noncoal surface mining operations are often exposed to high levels of respirable dust. In an effort to lower the respirable dust exposure of these surface miners, the National Institute for Occupational Safety and Health (NIOSH) has been conducting research to address this problem in a practical and economically viable manner.

One successful effort deals with lowering the dust exposure of equipment operators in enclosed cabs. Many types of surface mining equipment utilize enclosed cabs to protect equipment operators from dust exposure. Normally when the equipment is new, the cabs are fairly airtight. These tightly sealed cabs, combined with good filtration systems, generally provide the operator with good dust protection. However, most mining equipment is older, and as aging occurs, many components of the enclosure deteriorate. The structural integrity of the cab diminishes and the effectiveness of the air filtration system fails. NIOSH has been successfully researching cost-effective methods to improve both filtration effectiveness and cab integrity of these older cabs in order to provide a healthier work environment for equipment operators.

Dust sampling records indicate that drill operators and helpers have the highest dust exposure of all workers at surface mining operations. Since much of the overburden contains a high percentage of silica, the health hazard associated with this dust can be even more serious. NIOSH research is addressing techniques to lower respirable dust levels at surface drilling operations.

## INTRODUCTION

NIOSH's mission is to assure a safe and healthy work environment for the working men and women of this nation. The primary emphasis of NIOSH's Pittsburgh Research Laboratory (PRL) is mining health and safety research. This report focuses on two areas of research

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performed at PRL to lower miners' exposure to respirable dust at surface operations. The first area deals with enclosed cabs. A significant number of miners work in enclosed cabs at surface operations, including drill, dozer, loader, and scraper operators, as well as a vast array of different haulage vehicles and trucks. Secondly, this report discusses methods to lower dust levels at surface drills. The dust generated during surface drilling exposes the drill operator, drill helper, explosive crew, as well as any other individuals working in and around the drill to high respirable dust levels. Figure 1 shows the relevance of this research based upon the Mine Safety and Health Administration's dust compliance sampling records for the metal/nonmetal mining industry. This chart indicates that the highest exposure categories at surface operations involve these job classifications. The intent of this report is to provide mine operators with a number of techniques to help lower the dust exposure of workers at surface operations.

## DUST CONTROL RESEARCH

### *Enclosed Cab Dust Control Research*

Many types of heavy equipment used in the mining and construction industries use enclosed cabs to protect equipment operators from dust and noise exposure. If enclosed cabs are not properly designed or fabricated, or if components on the cab, such as gaskets and seals, significantly deteriorate over time, the protection afforded to the cab operator can be seriously jeopardized, causing the worker to be overexposed to respirable dust. In addition, the enclosed cab must provide the operator with conditioned air (heating or cooling) so that windows and doors are kept closed.

There has been a significant amount of recent research investigating how to improve the protection to miners working in enclosed cabs. This has included a number of cooperative efforts with mining companies, heating and air conditioning companies, and cab filtration manufacturers. Many of these studies have investigated retrofitting older cabs at surface operations with new filtration and pressurization systems. These studies have encompassed a full spectrum of different types and conditions of equipment and have included evaluating enclosed cabs that were not structurally sound, as well as ones that were very sound. From this research, we have identified a number of significant factors that determine how effective an enclosed cab will be at protecting a worker. A term called "protection factor" is commonly used for comparing the cab effectiveness and measures the ratio of outside versus inside respirable dust levels. The higher the protection factor value, the more protection afforded to the machine operator, or the lower the worker's personal dust exposure.

A brief summary of some of these studies highlights the importance of these significant factors. One cab evaluated was a very old Davey M8B surface drill, in which it was not physically possible to seal the cab.[6] This cab had large holes in the enclosure where control linkages entered the cab, as well as a loose fitting bifold door that was on the drill table side of the drill. A new air-conditioning/heater pressurization and filtration unit was installed on the roof of the cab but because of the numerous gaps and holes in the cab enclosure, positive pressure was not achievable. The discharge of the new filtration system was directed down over the drill operator in an attempt to provide him with a clean-air zone within the cab. Dust measurements

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

taken before and after the implementation of the new unit indicated very minor changes to the drill operator's respirable dust exposure.[7] Because of this, we do not believe it is cost-effective to install an air cleaning unit on surface mining equipment that is not capable of being sealed to some minor level of pressurization.

If even a very minimal amount of pressurization is attainable inside these cabs, totally different results can be achieved. At this same operation, a substantial reduction to an enclosed cab operator's respirable dust exposure was achieved with very minimal pressurization. A CAT980B front-end loader was equipped with a Red Dot Corporation and Clean Air Filter unit located on top of the cab. Both of the companies cost-shared this research effort with NIOSH. In addition to the installation of the new filtration unit, visible cab enclosure cracks were sealed with silicon and the door jams were sealed with dense foam weather stripping. Because of these sealing efforts, a positive static pressure of 0.01 to 0.015" w.g. was achieved inside the enclosed cab. The front-end loader operator's protection factor went from 1:1.1 during baseline testing to 1:10.1 with the new dust filtration system and other improvements to the cab integrity, allowing pressurization to be achieved. The cost for the Red Dot Corporation unit was $2,300, but this did not include the cost for the compressor for the air conditioning unit. The Clean Air Filter pressurization and filtration component was an additional $1,600.

A similar study was performed on an Ingersol Rand DM45E drill at a different surface mining operation. Three days of baseline testing was performed, followed by the installation of a new Air International Transit/Sigma Air Conditioning Company filtration and pressurization unit. After determining that the unit was working properly, three additional days of post-testing was performed. Sigma Air Conditioning Company cost-shared this research effort. Their unit was comprised of three different components: a filter/heater/air conditioning main unit, a condenser unit for air conditioning, and a pressurizer unit. This unit delivered up to a maximum of 450 cfm and pressurization inside the cab ranged from approximately 0.20 to 0.40"of w.g.. The cost for this unit was approximately $10,000 plus the cost for installation. Respirable dust concentrations inside the cab went from 0.64 $mg/m^3$ during pre-testing to 0.05 $mg/m^3$ during post-testing with the new system, representing a 92 pct. reduction in respirable dust levels in the drill cab. The average protection factor measured with the new system was 1:52.

In addition to the above research, another study is currently being performed at a surface mine evaluating the performance of a new pressurization system on a DrilTech D40KII rotary percussion drill. Baseline measurements were taken when outside temperatures ranged from 60 to 70 degree F. A new Clean Air Filter Company cab filtration and pressurization system was installed to an existing and older Red Dot AC unit. Immediately after the installation, the static pressure inside the cab was 0.01"w.g.. Time was spent improving cab integrity by installing new door gaskets and plugging and sealing cracks and holes in the shell of the cab. This increased the cab pressure to approximately 0.1" w.g. Since the post-testing on this cab was performed in the winter months when outside air temperatures were low, a floor heater in

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[7]JA Organiscak, AB Cecala, WA Heitbrink, ED Thimons, M Schmitz, and E Ahrenholtz. Field Assessment of Retrofitting Surface Coal Mine Equipment Cabs with Air Filtration Systems. Proceedings of Blacksburg Mine Conference, 2000.

the cab was being used. The results from this study showed that this radiator type floor heater inside the cab actually caused dust levels to be approximately 17 times higher during post-testing than for pre-testing, (Figure 2).[8] It was believed that baseline measurements were assisted by the air-conditioning unit being used during pre-testing, which lowered dust levels as the re-circulated air in the cab traveled through the condenser unit. Testing the drill in the shop area using optical particle counters verified that the floor heater increased dust levels in the cab as a result of dust from the drill operator's clothing and work boots, and from product that had accumulated on the floor. To combat this floor heater problem, a floor sweeping compound was field tested to suppress this in-cab dust. Test results indicated roughly an 80 pct. reduction in respirable concentrations with the floor sweeping compound.[9] If a company chooses to use a sweeping compound, it is highly recommended to use a natural-based type to reduce any possible operator irritation or allergic reactions to odors from petroleum-based oils and wax compounds. Before using any sweeping compound, review its MSDS for hazardous ingredients and precautions.

Because of the significant increase in dust levels with the floor heater, NIOSH recommends that they not be used. Heaters should be positioned high in the cab where they are less prone to pick up dust from the floor and operator's clothing.

Red Dot Corporation agreed to donate a new prototype unit (Red Dot R-9777- cost $2,300) heating and air-conditioning unit that was recently installed on the DrilTech D40KII drill. Clean Air Filter Company is working with Red Dot Corporation. This new unit includes a outside air filtration and pressurization system which was also donated by Clean Air Company (unit cost - $1,600). This system has an external three stage contiguous filter cartridge connected to the inlet side of an external cab pressurization fan; an external electrostatic backup filter on the outlet side of the pressurizing fan; and an internal re-circulation filter on the inlet side of the HVAC fans. The external cab pressurizing fan is designed to deliver approximately 70 cfm of make-up air with the HVAC system recirculating approximately 400 cfm of cab air. The analysis is currently being evaluated on this drill but it appears that inside cab respirable dust levels are at extremely low levels.

For an enclosed cab to be effective from a dust control standpoint, there are two key components that are necessary: 1) effective filtration, and 2) cab integrity. From the various field evaluations, it was obvious that both of these components are important and must be properly addressed for the system to be effective. There are a number of aspects that must be addressed for effective cab filtration. An effective filtration system should be composed of both a re-circulation and clean outside-air system. The majority of air inside an enclosed cab should be re-circulated through a good respirator dust grade filter. We believe that 70 to 80 pct. of the cab air should be re-circulated. This allows air to be conditioned to the cab operator's comfort (heating or air conditioning) without major air changes that would significantly affect the size

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[8]Cecala, AB., JA. Organiscak, & WA Heitbrink. Dust Underfoot - Enclosed Cab-Floor Heaters Can Significantly Increase Operator's Respirable Dust Exposure. Rock Products. Vol. 104, No. 4, April 2001, pp. 39-44.

[9]Technology News 487. Sweeping Compound Application Reduces Dust From Soiled Floors Within Enclosed Operator Cabs. March 2001.

and capability requirements, and ultimately the cost for conditioning the cab air. Another consideration is to have separate fans for makeup and recirculating air. A major component in an effective system is to have the makeup air positively pressurize the enclosed cab. This results in any system leakage to be from the inside the cab to outside, avoiding dusty air from entering the cab. It is also highly recommended that the makeup air be positively pressurized after being filtered to eliminate any possibility of dust laden air being drawn into the system. Also, the inlet for the makeup air should be located on the cab the furthest distance from the dust sources (where practical).[10] This reduces the amount of loading on the filters and increases the time between cleaning and/or replacement. The discharge for clean air into an enclosed cab should be 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. Many systems have the intake and discharge for the re-circulation air located in the roof unit. Although this is acceptable, the most beneficial design would be to draw the re-circulated air from the bottom of the cab. This would provide a one directional flow of clean air from the top to the bottom of the cab. We do not recommend the discharge of clean air low in the cab because as we observed, this can entrain a significant amount of dust from soiled work clothes, boots, and a dirty floor. Figure 3 is the ideal schematic for an effective filtration and pressurization system on an enclosure drill cab.

The second factor for dust control effectiveness in enclosed cabs is cab integrity. Cab integrity is necessary in order to achieve some level of pressurization. Field testing has shown installing new door gaskets and plugging and sealing cracks and holes in the shell of the cab has a major impact on increasing cab pressurization. To prevent dust laden air from infiltrating into the cab, the cab's static pressure must be higher than the wind's velocity pressure.[11] Figure 4 is a graph of the leakage or penetration into the cab of contaminants in various wind velocities (miles/hr) during a controlled test. Although higher static pressure requirements have an advantage for overcoming wind speeds, a major drawback is that this necessitates that more air must be delivered by the outside air unit, and this causes more loading on the filters. Another drawback is that it creates more air conditioning (heat & cooling) requirements for operator comfort which increase the size and cost for this component. We have a number of field studies that provided very good protection to the cab operator with minimum cab pressurization.

We also recommend the use of some type of pressure gauge inside the enclosed cab to inform the operator when pressurization is marginal. Loss of pressure indicates either a filter loading problem or a cab integrity failure. Filter maintenance work could be performed when a predetermined pressure loss occurs over time. A sudden increase in pressure would normally indicate a major filter failure and this problem should be immediately corrected.

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[10]Technology New 485, Improved Cab Air Inlet Location Reduces Dust Levels and Air Filter Loading Rates. February 2001.

[11]Heitbrink, WA, ED Thimons, JA Organiscak, AB Cecala, M Schmitz, and E Ahrenholtz. Static Pressure Requirement for Ventilated Enclosures. Progress in Modern Ventilation, Vol. 2, Proceedings of the Ventilation - 2000. 6th International Symposium on Ventilation for Contaminant Control. June 4-7, 2000, Helsinki, Finland.

*Surface Drill Dust Control Research*

The following section provides control technology that has been effective in reducing the dust exposure of drill operators, drill helpers, and other personnel working in and around the drilling process. Surface mine drills typically have three major dust sources. These are 1) dust generated from dust collectors, 2) dust from drill skirt leakage, and 3) dust from leakage around the drill stem and drill table. Effective control technology will be presented for all three of these dust sources on drills. Dust collection equipment on surface drills are either dry-dust collectors or wet-suppression. From NIOSH experience, the U.S. mining/drilling industry is roughly split between dry dust collection and wet dust suppression, although dry dust collection is somewhat more prevalent. This article will discuss both techniques to control dust generated from drilling.

*Controlling dust generated from the dust collector dump cycle:*

This technique was developed by the Bureau of Mines and is composed of a barrier or shroud placed round the hopper discharge doors extending to the ground.[12] This shroud confines the dust collector fines during dumping to an enclosed space, thus reducing airborne dust entrainment into the surrounding work environment. Although this dust control technique was developed for surface mine drills, it can be applied to any mobile rock drill.

During testing of this technique, a temporary shroud was installed around the hopper doors to measure respirable dust reductions. The shroud was made of a brattice material and mounted by large magnets for easy installation and removal during testing. Two flaps were cut in the shroud to allow the operator access to open and close the hopper doors. Average airborne respirable dust concentrations at the hopper discharge during dumping were reduced from 25.4 $mg/m^3$ to 4.9 $mg/m^3$ when using the shroud, being a 81 pct reduction. Any dust present while using the shroud was primarily attributed to leakage at the open vertical seam in the shroud. A more permanent installation would have a sealed seam and would be expected to provide even better dust suppression. Considering the very minimal cost associated with the material, supplies, and manpower required to install this brattice shrouding around the hopper discharge doors on the dust collector, it should be implemented on all drills in which this technique is applicable.

*Controlling drill skirt dust leakage:*

The use of an exhaust ventilation collector system to capture dust at the drill site is a common control technique. This is normally accomplished by enclosing the area where the drill stem enters the ground by hanging a rubber or cloth "skirt" or "shroud" from the underside of the drill deck. The dust is removed by the collector filtering media and the clean air is exhausted to the environment.

The integrity of the drill stem shroud, including how well it seals to the ground, is probably the single most important factor contributing to the effectiveness of a dry collection system.[13,14]

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[12]Technology News 447, Dust Collector Discharge Shroud Reduces Dust Exposure to Drill Operators at Surface Coal Mines. March 1995.

[13]Technology News 286, Optimizing Dust Control on Surface Coal Mine Drills. September 1987.

Generally, the shroud volume should be 1.8 times the volume of the hole and there should be at least 0.2" w.g. of negative pressure inside the shroud. The length and width of the shroud should be 2.5 times its height. The air is ducted out of the drill stem shroud either from the top of the shroud near the outside edge or from the side of the shroud near the top. Ducts can be constructed either of rigid steel or of a flexible elastomeric material. Varying the open area of the shroud will change the shroud's dust capture efficiency. As the open area is reduced, the velocity in the open area will increase, thus improving capture efficiency. The most common open area is the gap between the bottom of the shroud and the ground, which is called the shroud height.

During field tests the dust reductions varied from 31 to 99 pct. over a height range of 27 inches down to 0 inches. With a shroud height of 6 to 9 inches or lower, it was apparent that the dust control system worked very well. However, as the height increased, the control efficiencies decreased. During drilling, it is sometimes necessary to raise the drill shroud. This is done to prevent the large cuttings from falling back into the hole, and so the operator can observe when the seam has been reached to stop drilling. As a result, there are times when a broken seal between the shroud and the ground during cutting cannot be avoided. Therefore, it is important for the driller to keep the open area to a minimum. Also, raising the drill in incremental steps during drilling will minimize the shroud height.

Most decks shrouds were rectangular and constructed of four separate pieces of rubber belting attached to the drill deck. Because of this design, there was a measurable amount of dust escaping from the open seams as well as the open area between the shroud and the ground. In additional testing[15], this technique was further optimized. This work showed that circular and slightly conical shroud design, without any seams, was superior to the previous design. Steel banding was used to attach the shroud to the bottom of the drill deck. The shroud is capable of being hydraulically raised to nearly flush with the drill deck and lowered to make contact with the ground after leveling the drill. A steel band is attached to the bottom of the shroud to maintain shape as well as to provide weight for lowering. Sheet rubber material, which is thinner than material typically used for deck shrouds, is used for flexibility. Operation is accomplished by guide wires attached to the bottom steel bands and a hydraulic cylinder. This is controlled by the drill operator using a hand valve located with his other drill controls. The shroud has a small trap door which can be manually raised/lowered so that the cuttings can be shoveled from inside the shroud without losing the dust capture efficiency.

Testing on this technique consisted of comparisons with the shroud in fully operable condition and with the shroud partially raised to simulate a leakage condition. Respirable dust concentrations were less than 0.5 mg/m$^3$ with the shroud lowered and 52 mg/m$^3$ with the shroud raised. Dust reduction efficiencies greater than 99 pct were achieved. This compares to

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[14]Technology News 447, Dust Collector Discharge Shroud Reduces Dust Exposure to Drill Operators at Surface Coal Mines. March 1995.

[15] NIOSH Hazard Control 27. New Shroud Design Controls Silica Dust from Surface Mine and Construction Blast Hole Drills. November 1998. DHHS Publication No. 98-150.

typical efficiencies for square shrouds in the 95 pct range. For the minor changes to the shroud arrangement, it only makes sense to use the improved circular design.

*Controlling dust leakage around the drill stem and drill table:*
Another significant sources of dust on a drill rig is the dust leakage around the drill stem and drill table. The best technique found to control this dust leakage is a device called the Air Ring Seal (AIRRS), which has been designed and tested by NIOSH.

Leakage around the drill stem most likely occurs because of excessive wear in the mechanical donut-type rubber seal which is used on many drills. This rubber seal is normally a high maintenance area because the drill stem is constantly rotating against it. The AIRRS was designed specifically to reduce respirable dust emissions coming from the drill stem but a secondary benefit is the elimination of a high-wear item on the drill.

The AIRRS is a donut-shaped compressed air ring with closely spaced holes along the inside perimeter of the ring, (Figure 5). High velocity air jets are produced as this compressed air exits through these drill holes in the donut-shaped ring. This AIRRS is located immediately below the drill table with the air jets directed downward around the drill steel to impede movement of dust particles flowing up through this opening. The AIRRS was fabricated for field testing and was made of 2-in. schedule 40 pipe to form a donut-shaped manifold with a 18-in ID. The large size of the header was necessary to accommodate movement of the drill pipe when fully raised and the deck bushing moves free of the deck. One sixteenth inch holes were drilled on the inside perimeter of the AIRRS at a 45 degree down angle and on ½ inch spacing. Although 10 $lb/in^2$ was the best header pressure determined for laboratory tests, it was necessary to use higher pressures in the field tests because of the much larger gap deck bushing accommodation. In a hole-by-hole comparison, the AIRRS averaged a respirable dust reduction of 55 pct. Further improvements by enlarging the air jets and hard-mounting under the drill deck virtually eliminated the dust leakage.

In addition to the reduction in respirable dust concentrations, there were also a number of other benefits with the AIRRS. The new system visually eliminated all the large cuttings on this drill from depositing on the drill table. Second, it eliminated the use of a rubber bushing underneath the deck that was frequently damaged and required a lot time and money to keep operating. The AIRRS is a virtually maintenance-free, non-mechanical seal. It was determined through testing that using the AIRRS at a lower bailing velocity should also improve its performance.

The AIRRS was successfully field tested and shown to be a low maintenance nonmechanical seal to reduce dust emissions from the drill pipe and deck bushing gap. The low cost and simplicity of the device provides a viable means to drill operators to reduce dust emissions as well as reduce housekeeping requirements on drills.

*Controlling dust by wet suppression:*
Previous tests conducted in the field at U.S. surface coal mines showed that wet suppression systems can significantly control respirable dust. The critical factor affecting the efficiency of the wet systems is the amount of water pumped into the bail air. Since no data were available on optimal water flow rates for wet suppression systems, a field study was designed to examine the relationship of respirable dust emission rate versus water flow rate. The testing was

performed over a two-week period on a BE45R drill at a mine in northwestern Colorado. Various water flow rates were tested for a number of holes. Each hole was drilled at a specific and constant water flow rate. A flow meter equipped with a needle valve was mounted in the cab of the drill. Flows were controlled and recorded by one of the test team members from inside the cab. A recording flow meter was mounted in the water line near the control system pump. Uncontrolled emission rates ranged from 3.8 to 9.3 g/ft and control efficiencies ranged from 9 percent at a flow of 0.2 gpm to 96 percent at a flow of 1.2 gpm.

Very practical and simple operational guidelines can be provided to all mine operators who perform wet drilling and which automatically accounts for various operating conditions such as different drills, changes in bit size, and different strata. In order to operate at close to the optimum water flow rate, the operator should slowly increase the amount of water just to the point where visible dust emissions are abated. Due to the initial sharp increase of dust control effectiveness, the visible dust abatement point will be easy to identify. Addition of more water beyond this point will not provide any significant improvement in dust control, but will most likely create operational problems mentioned earlier. It is important that the water be increased slowly to account for the lag time, as the air/water/dust mixture travels from the bottom to the top of the hole.

## ACKNOWLEDGMENT
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## CONCLUSION
This report provides operators with a number of methods and techniques to lower respirable dust levels to workers at surface operations. Many different types of surface equipment use enclosed cabs to house the equipment operators. These enclosures have many advantages to protect workers from various health and safety concerns at mine sites. Various field studies have shown that operator's respirable dust exposure inside these enclosed cabs can be significantly reduced through improved air pressurization and filtering systems, along with having a competent cab structure with integrity to achieve some level of pressurization. A number of different commercial systems have been shown to significantly lower respirable dust levels inside these enclosed cabs in a very economical manner. In addition to the enclosed cab research, a number of other dust control techniques were discussed to help lower dust levels around drilling machines. This would impact lowering the drill operators, drill helper, explosive crew, and any other personnel working in and around this area. Research is continuing in a number of different areas to further improve designs and control technology in this area to reduce worker exposure to the lowest levels in a cost-effective manner.

Figure 1. Job Classification for Surface Mining Exceeding MSHA's Dust Compliance Permission Exposure Limit (PEL) for 10 Year Period (1991-2001).

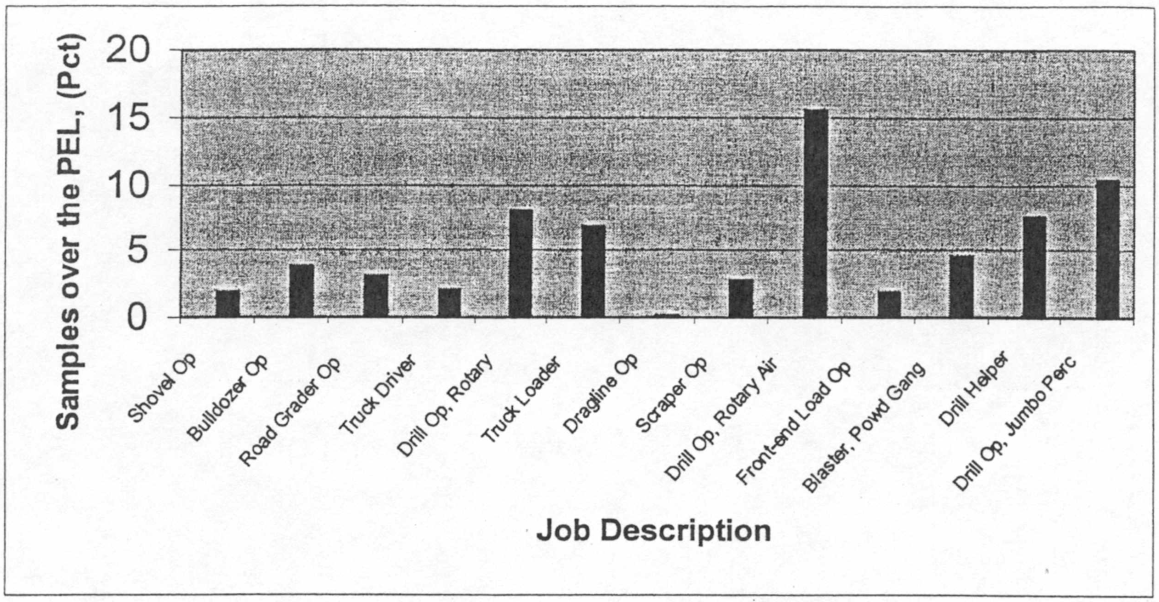


Figure 2. Location of floor heater inside enclosed cab of drill.

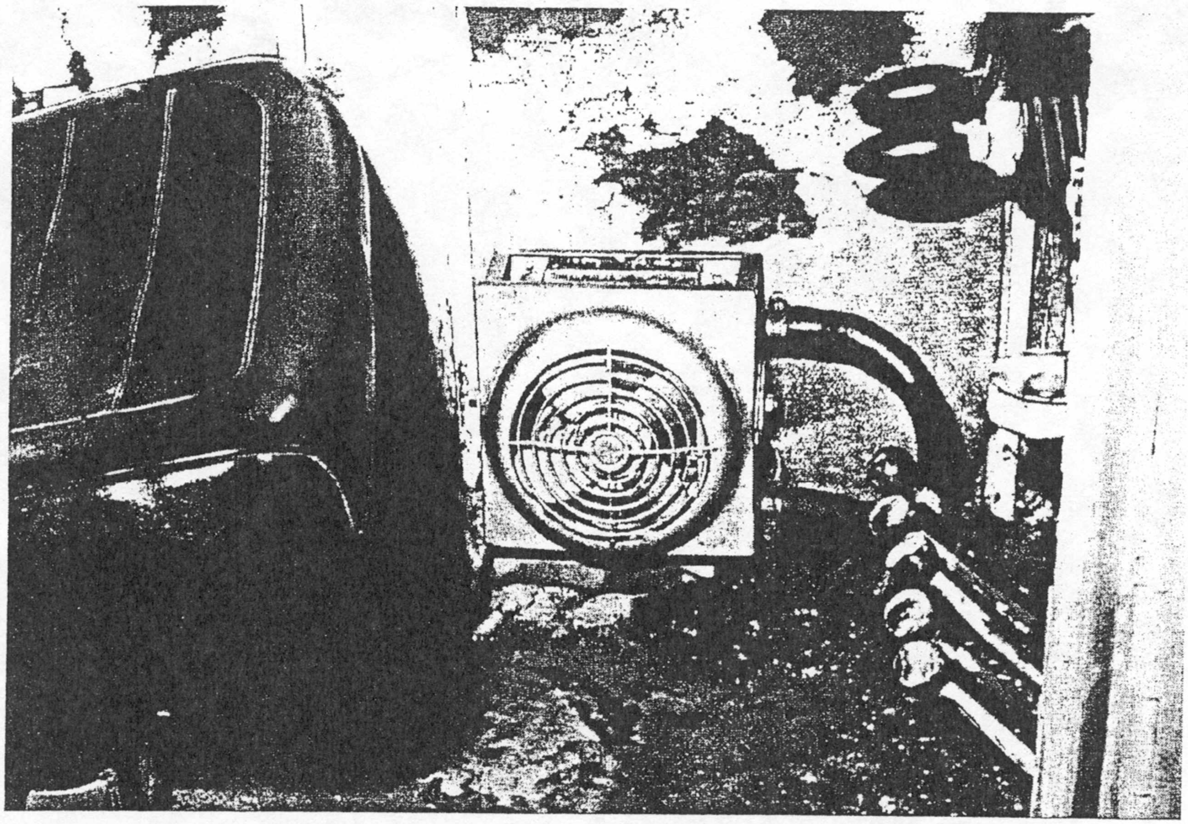


Figure 3. Ideal schematic for an effective filtration and pressurization system on an enclosed cab.

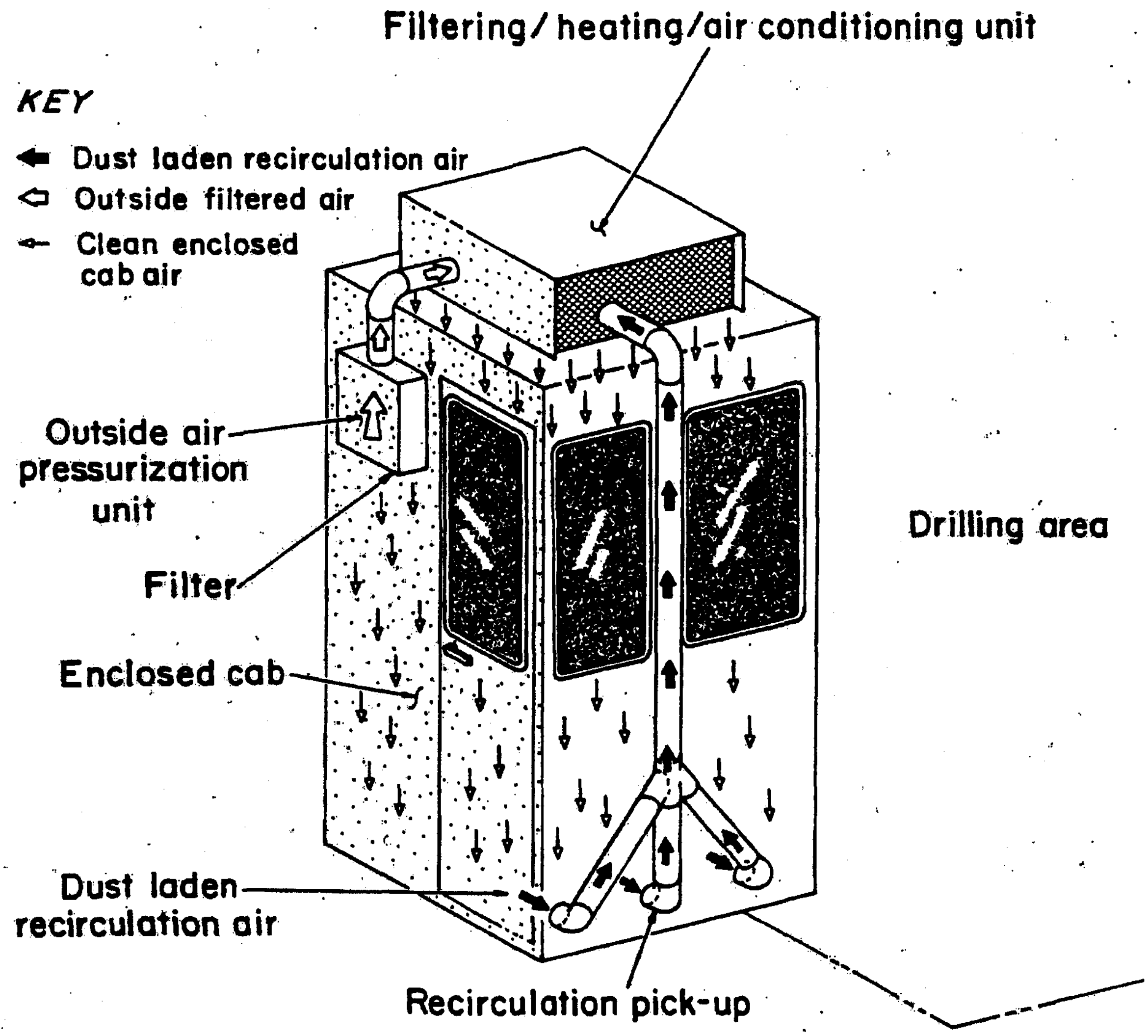


Figure 4. Penetration/Leakage into Enclosed Cab at Increasing Wind Velocities.

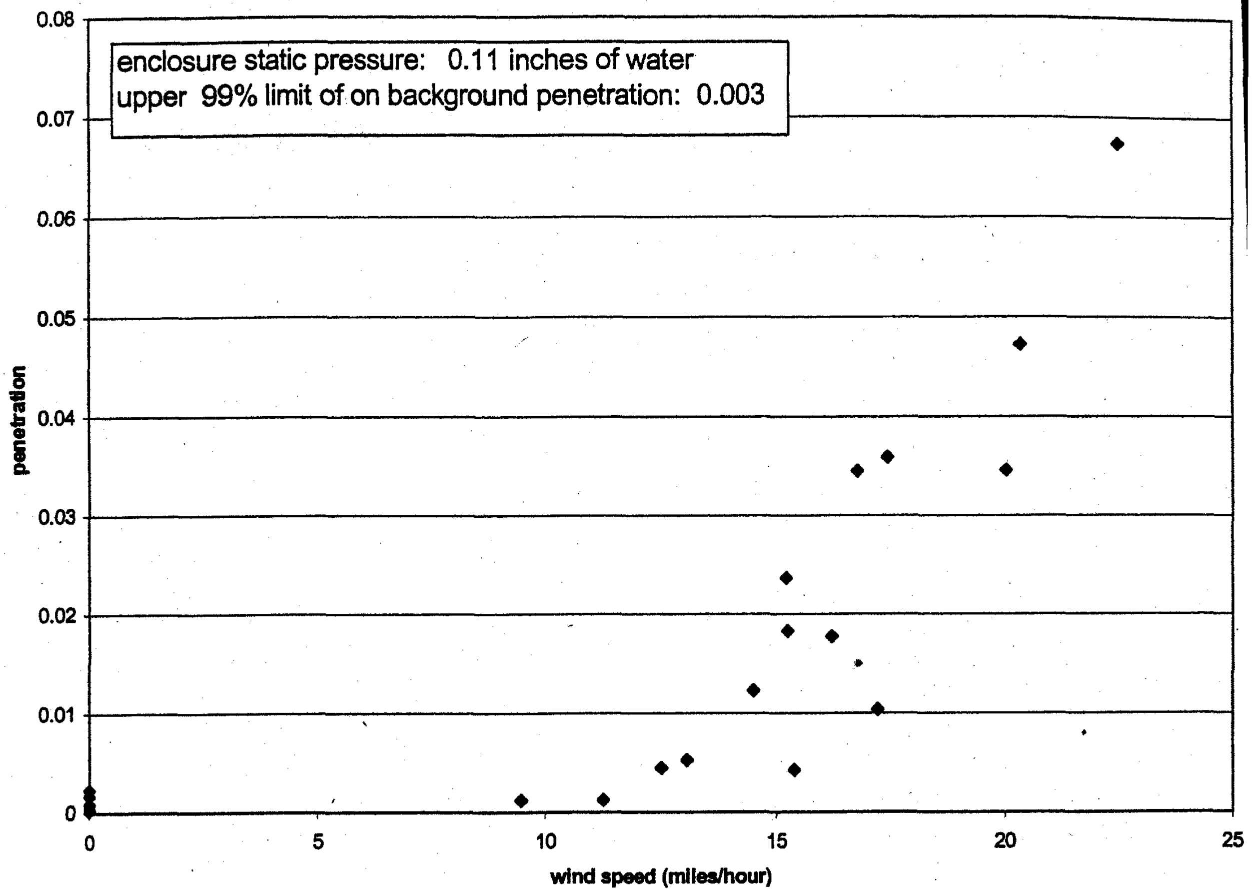
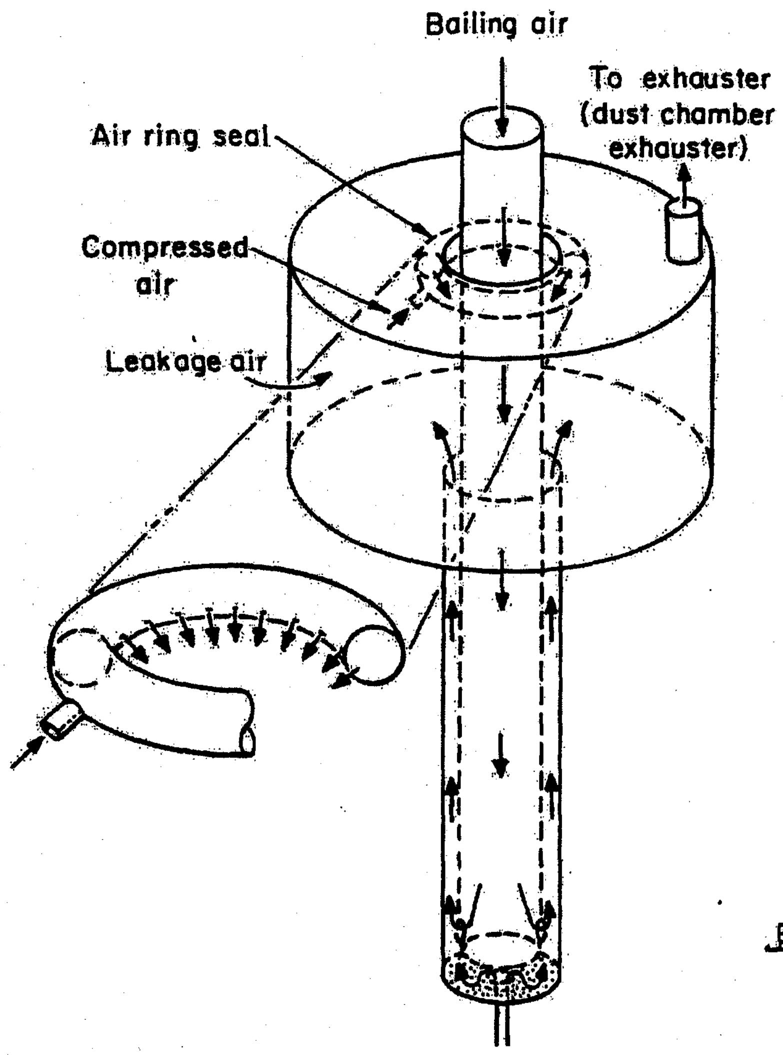


Figure 5. Air Ring Seal (AIRRS) location and operation using compressed air to produce high velocity jets along donut shaped ring.

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