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IN-DEPTH SURVEY REPORT

CONTROL TECHNOLOGY COMPARATIVE EVALUATION OF ROCK-DRILLING RIGS

at

Trimont Quarry
Hopkinton, Massachusetts

REPORT WRITTEN BY
Anthony T Zimmer

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Cincinnati, Ohio 45226

SITE SURVEYED	Trimont Quarry 12090 West 50th Place Hopkinton, Massachusetts 01748
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SURVEY CONDUCTED BY	Anthony Zimmer Ronald Hall Paul Jensen Phillip Froehlich
EMPLOYER REPRESENTATIVES CONTACTED	Merril MacInnis, Instructor Joseph DeLaney, Instructor James Merloni, Jr , Administrator New England Laborers' Training Academy
EMPLOYEE REPRESENTATIVE CONTACTED	No Union
MANUSCRIPT PREPARED BY.	Deanna L Elfers

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ABSTRACT

A field study was conducted to comparatively evaluate the dust control technologies on three, track-mounted, rock-drilling rigs This equipment is used in a wide variety of industrial applications including mining, transportation, and construction activities Uncontrolled rock drilling is notorious for generating high concentrations of respirable dusts, including crystalline silica Silicosis, a progressive, disabling, and sometimes fatal lung disease, has been recognized in the rock-drilling workforce (NIOSH Alert, DHHS Publication No 92-107) The respirable dusts are generated because compressed air is used to flush the rock cuttings up from the drill hole Three rigs were evaluated. The first rig used water to suppress dust emissions The second rig used water and a dust collection system to suppress emissions The third rig was equipped with the preceding controls and an enclosed, ventilated operator cab Video-exposure monitoring, using handheld aerosol monitors, was the primary technique used to identify and evaluate exposure variations from rig to rig The monitoring results demonstrated that as the level of engineering control increased, the exposures decreased The exposure reduction of the second rig was 61 to 70 percent when compared to the first rig, and the exposure reduction of the third rig was 61 to 87 percent when compared to the first rig Several work activities notably increased exposures such as "collaring the hole" at the beginning of the operation and "blowing out the hole" at the end of the operation The driller reduced his exposures by staying upwind of the dust plume when not making adjustments at the drill controls

INTRODUCTION

A field study was conducted to comparatively evaluate the dust control technologies on three, track-mounted, rock-drilling rigs. This equipment is used in a wide variety of industrial applications, including mining, transportation, and construction activities. These rigs operate on the principle of percussion drilling, using either compressed air or fluid to power the rig. Uncontrolled rock-drilling is notorious for generating high concentrations of respirable dusts, including crystalline silica. Silicosis, a progressive, disabling, and sometimes fatal lung disease has been recognized in the rock-drilling workforce.[1] Respirable dust is primarily generated from these rigs by compressed air which flushes rock cuttings up from the drill hole.

With the assistance of drilling instructors from the New England Laborers' Training Institute, three rock-drilling rigs were evaluated during drilling operations at a rock quarry located near Hopkinton, Massachusetts. Each rig was equipped with progressively more sophisticated control technologies. The first rig used water to suppress dust emissions. The second rig used water and a dust collection system to suppress emissions. The third rig was equipped with the preceding controls and an enclosed, ventilated operator cab. Video-exposure monitoring, using handheld aerosol monitors (HAMs), was the primary assessment tool used to identify exposure variations from rig to rig and to determine what drilling activities contributed to or reduced exposures.

PROCESS DESCRIPTION

The rock-drilling rigs evaluated are mobile, track-mounted units that use air (pneumatic) and/or fluid (hydraulic) pressure to power the drill These rigs are highly rugged and mobile Prior to drilling, the operator marks locations on the ground to be drilled The rock-drilling rig is moved into position, and the drill platform is positioned over the marked location

These rigs operate on the principle of percussion drilling. A pneumatic or hydraulic hammer, located on the drill mast, provides the power to the drill bit Hollow steel drill rods are added to the drill platform (12' lengths) as the depth of the hole increases The steel bit is simultaneously rotated using a constant feed force to maintain contact with the rock The diameter of the steel bits vary from 2 5 to 5 inches The rock cuttings are flushed up the drill hole by compressed air via radial exit ports located on the drill bit On rigs equipped with a dust collection system, the rock cuttings are exhausted through a movable suction head takeoff that encloses the opening of the hole (see Figure 1)

Effective rock-drilling requires a highly skilled and experienced operator A driller starts by positioning the drill controls upwind of the dust plume With the exception of the rig having an enclosed cab, the drill controls are located less than 4 ft from the opening of the hole While drilling, the driller visually checks the hammer cage located on the drill mast to determine the drilling rate and listens to the drill impactions to determine the hardness and

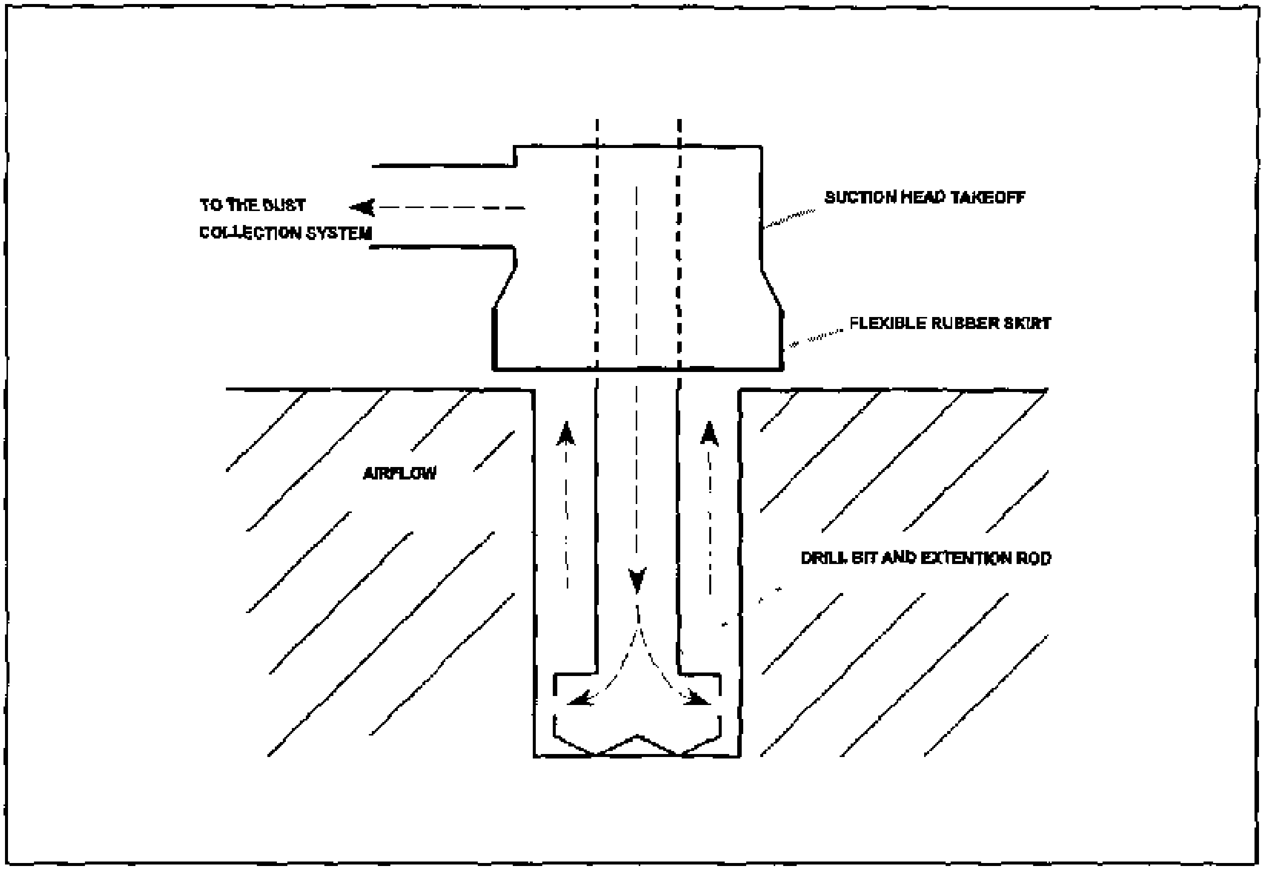


Figure 1 General Drilling Schematic

fracturing of the rock being drilled Miscalculation by the driller could easily damage the drill rig and entrap the extension rods, drill collars, and bit

METHODOLOGY

The three track-mounted, rock-drilling rigs were comparatively evaluated during the field study Each rig was equipped with progressively more sophisticated engineering controls to reduce dust emissions The first rig was an Ingersoll-Rand Crawlair CM350 that used water to suppress dust emissions The second rig was a Tamrock Zoomtrak DHH850 that used water and a dust collection system to suppress dust emissions The third rig was a Fuwakawa 150 that used the same type of engineering controls as the Tamrock, but in addition was equipped with an enclosed, ventilated operator cab

Video exposure monitoring using handheld aerosol monitors was the primary tool for evaluating the real-time dust exposures resulting from these rigs [2] A HAM is a light-scattering device in which small particles are detected and related to mass concentration Relative response for the HAM is greatest for particle sizes from 0 3 to 2 μm The HAM responds primarily to respirable dust and does not differentiate between crystalline silica and other dusts The analog output of the HAM was connected to a data logger (Rustrak Ranger) The video camera was equipped with an on-screen clock synchronized with that of the data acquisition system When the data collection was completed, the data from the data logger were downloaded to a portable computer (Dell 320n) using application software (Pronto), and were later imported into a spreadsheet program for detailed analysis (Microsoft Excel) To assist in the discernment of how and when exposures occurred, the HAM-generated exposure data was overlaid onto the video recording of the workers' activities [3] The video overlays were provided to the New England Laborers Training Institute to be used as a training tool

Several other exposure assessment tools were used in the evaluation Respirable dust (NIOSH Method 0600) samples were collected to coincide with the video exposure monitoring of a drilling operation [4] These samples were collected on tared, 37 mm diameter, 5-μm pore-size polyvinyl chloride membrane filters mounted in series with Higgins-Dewell cyclones Air was drawn through the filter at a flowrate of 2 2 liters per minute (lpm) using battery-operated sampling pumps (Air Check Sampler) Ventilation measurements were taken with a hot-wire anemometer (TSI Velometer, model 8357) Temperature, wind speed, and direction measurements were taken with a Young Weather Station (model ER 100)

Area and personal samples were collected during several drilling operations for each rig by the methods stated above A personal sample was taken on the rock driller Area samples were taken adjacent to and downwind of the drill rig controls to simulate a "worst case" exposure On those rigs equipped with dust collection systems, an area sample was placed adjacent to the cartridge filtration system dump

RESULTS AND DISCUSSION

During the five-day survey, several sample runs were conducted with the drilling rigs One sample run was used for an in-depth analysis and comparison to the other rock-drilling rigs According to the drill instructors, these operations represented a "typical operation " Comparisons were based upon the personal samples on the driller and the area sample placed adjacent to the drill controls

THE CRAWLAIR DRILLING RIG

The Crawlair drill rig is a pneumatic rig that is considered an industry "workhorse" (see Figure 2) According to the instructors, the pneumatic rigs are slower in drilling holes (compared to the hydraulic rigs), but drill better through the overburden material Water is slowly fed to the compressed air via a small water tank (30 gal) located on the rig The water is used to agglomerate the small particles into larger particles Judicious use of water is imperative in the operation of this rig Too much water will create a mud slurry at the bottom of the hole that could possibly entrap the bit, couplings, and steel extensions Too little water will not effectively control visible emissions

Figure 2. Crawlair rock drilling rig.

The Crawlair drilling operation had the highest exposures with average HAM monitoring results of 0 28 and 0 86 mg/m^3 for the personal and area samples, respectively   Several factors appear to explain why the personal samples were lower than the area samples   First, the driller positioned the rig to insure that the drill controls were upwind of the dust plume created by the operation   Also, when the driller was not adjusting the rig, he moved to a location upwind of the drilling operation, further reducing his exposures   An analysis of the video monitoring information revealed that the driller spent approximately 47 percent of his time at the drill controls   Figure 3 shows an overlay comparison of the area versus the personal sample during a 15-min portion of the operation

Visible emissions were noted throughout the 58-min operation involving the drilling of a 3 in diameter, 44 ft hole (see Figure 4)   The average wind speed and direction during this operation were relatively constant (4 mph from the southwest)   Exposures increased after the addition of the second steel extension (Figure 4, label A @ ~16 min) and decreased after the driller increased the water flowrate (Figure 4, label B @ ~21 min)   The addition of each steel extension resulted in an exposure decrease   An activity that resulted in an exposure increase was noted at the end of the operation when the driller "blew out the hole" (Figure 4, label C @ 52 min)   This activity ensured that loose rock cuttings did not fall back down into the freshly drilled hole

Figure 3. Overlay Comparison of Area Versus Personal Sampling During a Fifteen Minute Portion of the Crawlair Drilling Operation

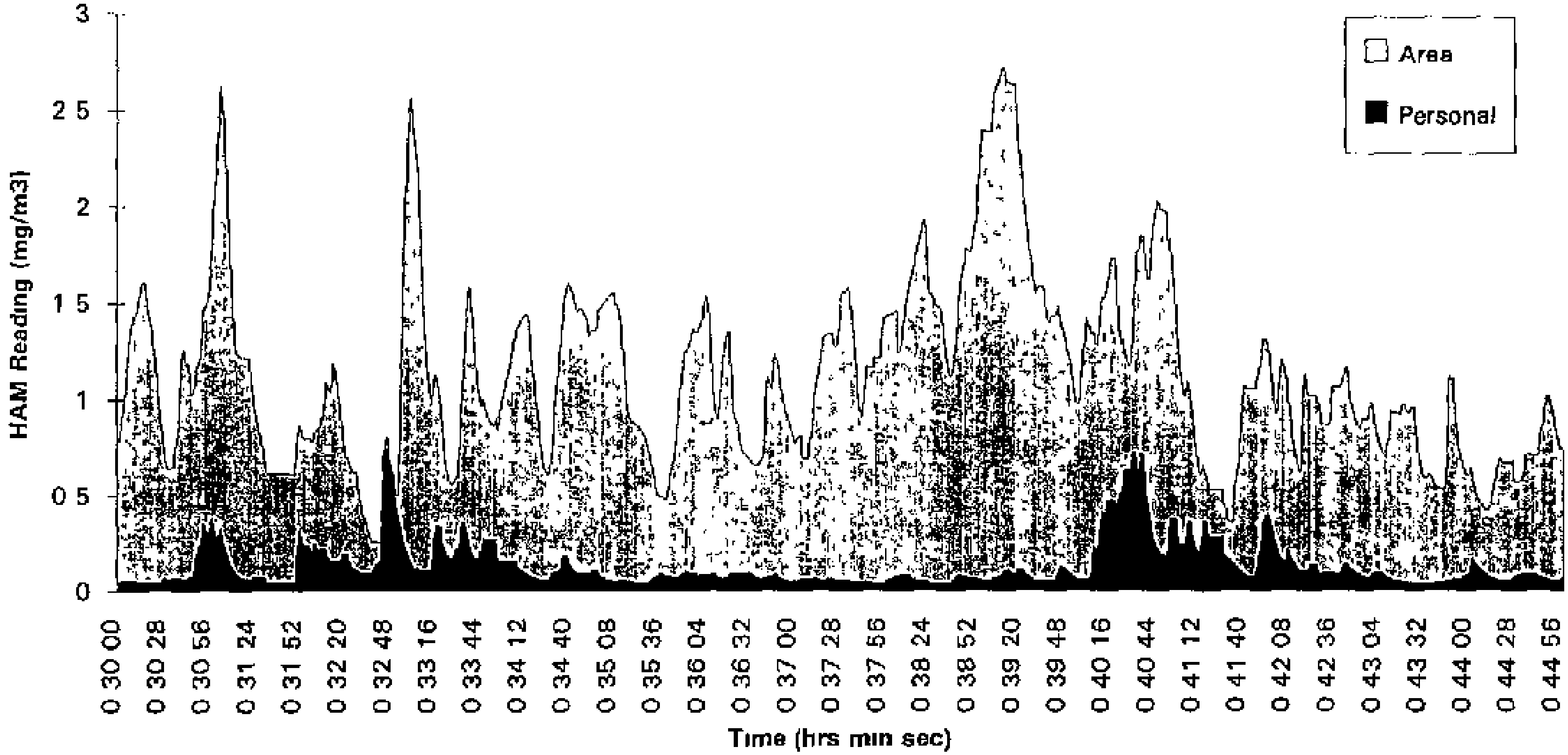
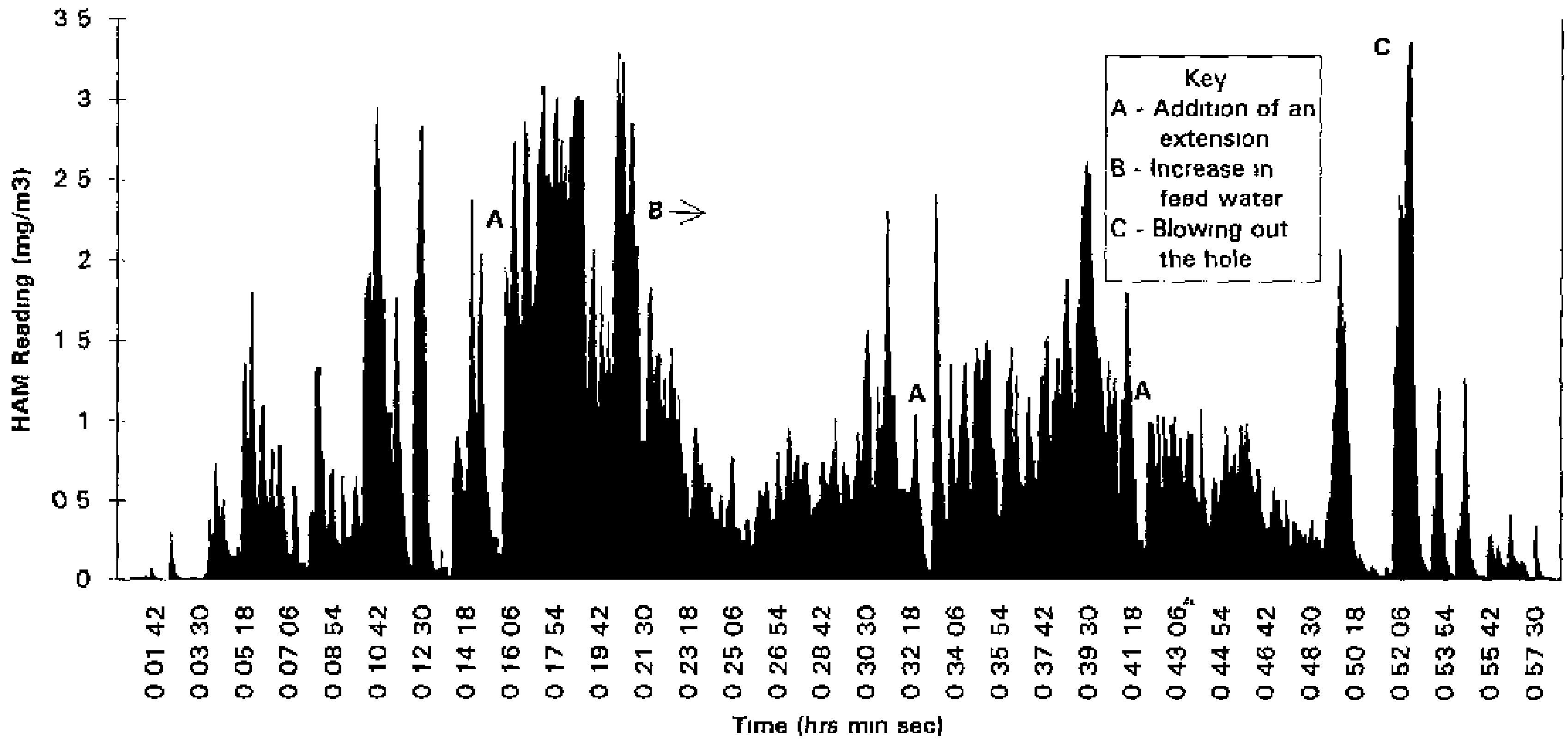


Figure 4 Crawlair Drilling Operation Area Sample Adjacent Drill Controls.



THE TAMROCK-DRILLING RIG

The Tamrock is a self-contained, fully hydraulic unit having two methods to control emissions. water suppression (as previously discussed with the Crawlair), and a dust collection system (see Figure 5) The collection system consists of a cyclone precollector and a cartridge filtration system Ventilation measurements taken at the exhaust to the cartridge filtration system showed a volumetric flowrate of 700 to 800 cfm A movable suction head take-off with a flexible rubber skirt encloses the opening of the hole to improve dust capture efficiencies (see Figure 1)

Figure 5. Tamrock rock drilling rig.

Judicious use of water is imperative to effectively operate this rig Too much water can cause the conditions previously described with the Crawlair Additionally, a wet rock slurry can plug the collection system The latter situation actually occurred during an earlier sample run Another problem reported by the instructors occur when a subsurface spring is encountered If a driller is not paying attention, the water from the spring can easily entrap the drill bit and plug the dust collection system According to the drill instructors, the rubber skirt at the ground interface can sometimes be a hinderance because the driller is not receiving a visual cue regarding how well the rock cuttings are being exhausted from the hole

The Tamrock-drilling operation had average HAM monitoring results of 0 11 and 0 26 mg/m^3 for the personal and area samples, respectively As discussed with the Crawlair rig, a similar finding was noted in that the personal samples results were less than the area sample results An analysis of the video monitoring information revealed that the driller spent approximately 48 percent of his time at the drill controls Figure 6 shows an overlay comparison of the area versus the personal sample during a 15 min portion of the drilling operation

When the area and personal HAM results were compared to the respective Crawlair operation, the Tamrock-drilling operation had a 70 percent exposure reduction for the area sample and a 61 percent exposure reduction for the personal sample This 33-min operation also involved drilling a 3 in diameter, 44 ft hole (see Figure 7) The average wind speed and direction during this operation were relatively constant (2 mph from the southeast)

Figure 6. Overlay Comparison of Area Versus Personal Sampling During a Fifteen Minute Portion of the Tamrock Drilling Operation.

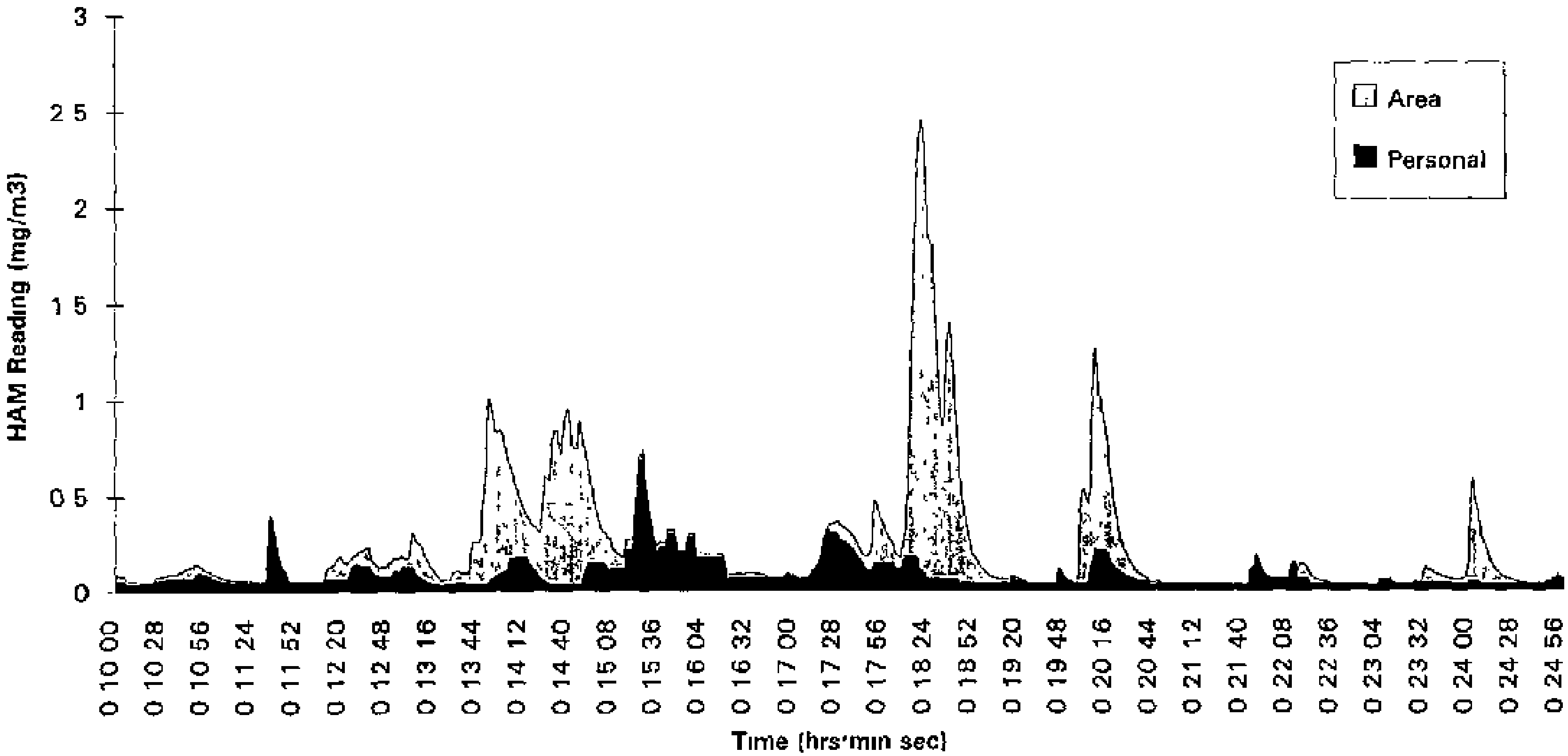
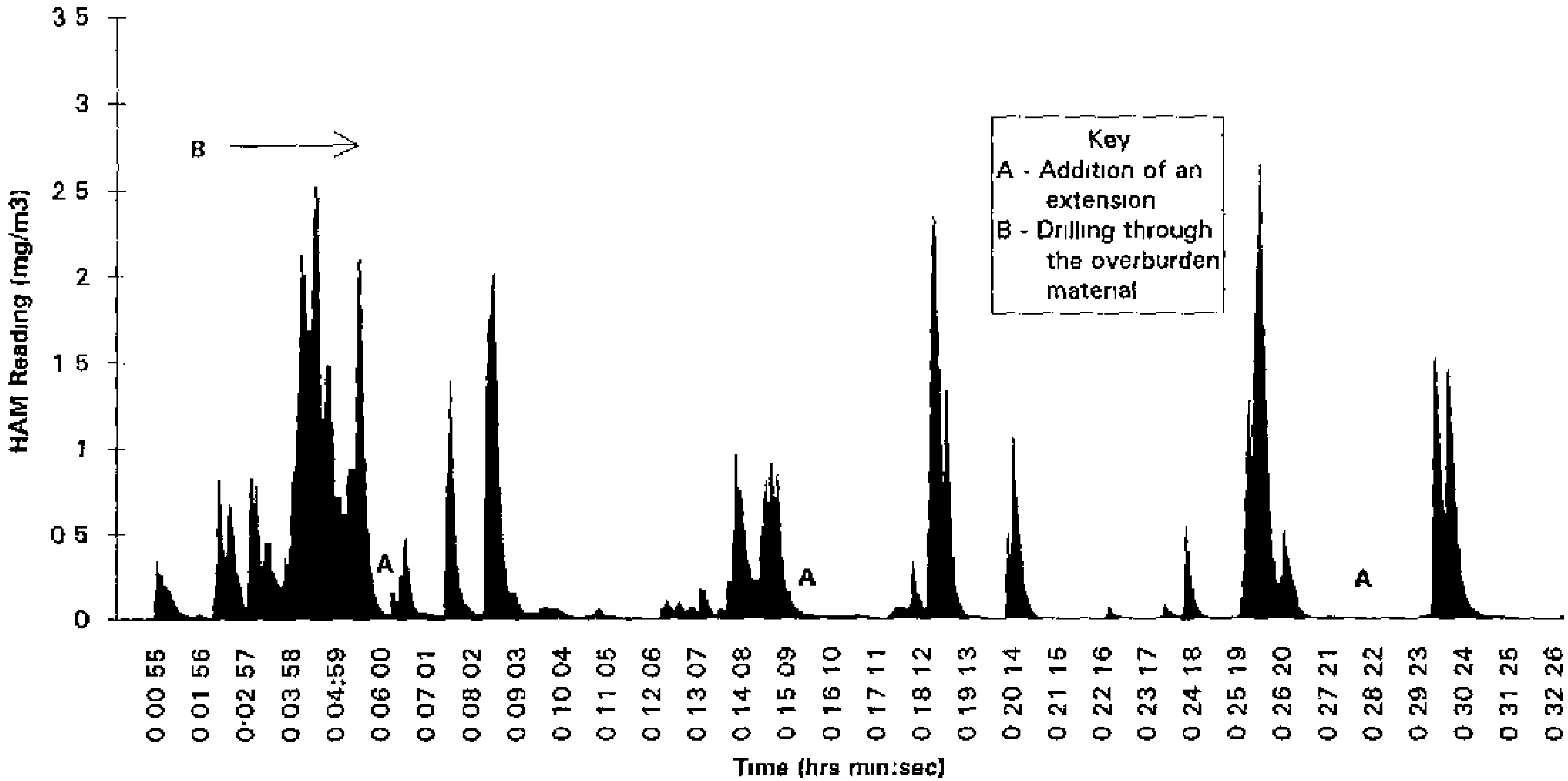


Figure 7. Tamrock Drilling Operation Area Sample Adjacent the Drill Controls.



The initial "collaring" of the hole (Figure 7, label B @ ~3-6 mins) resulted in increased emissions that were not suppressed by water or captured by the dust collection system Collaring is necessary to prevent loose material in the overburden from falling back into the hole This activity involves forcing drilled rock cuttings (or suitable material) onto the loose sidewalls of the hole As material is impacted to the sidewall, a constant diameter sleeve is created through the overburden material Visible emissions were noted on several occasions when the rock cuttings exhausted from the bottom of the hole were not adequately controlled by the dust collection system, or when the driller lifted the rubber skirt surrounding the hole to check on how well the rock cuttings were being exhausted from the hole These activities resulted in periodic exposures throughout the sample run

Another potential dust source was the cartridge filtration system dump A reverse pulse of air is used to knock off the filter cake buildup from the cartridge filtration system to the ground via a rubber boot A visible plume of dust was noted every time the filter cake was dumped to the ground The distance from the bottom of the rubber boot to the ground was approximately 2 ft The average HAM readings taken at this location were 1 17 mg/m^3 during the dump cycle (0 28 during the entire operation) According to the Tamrock technical manual, a dust collection bag can be purchased to fit over the bottom of the dust collector This addition could prevent the resuspension of fine particulate and reduce the potential for inhalation by the driller

The Fuwakawa Drilling Rig

The Fuwakawa drilling rig is a fully contained hydraulic drilling rig that uses the same engineering controls as the Tamrock unit plus one additional control, a fully enclosed, ventilated cab (see Figure 8) From the cab, the drilling operator can perform all drilling operations including the addition/ subtraction of steel extensions Ventilation measurements taken at the inlet to the dust collection system showed a volumetric flowrate of 300-400 cfm

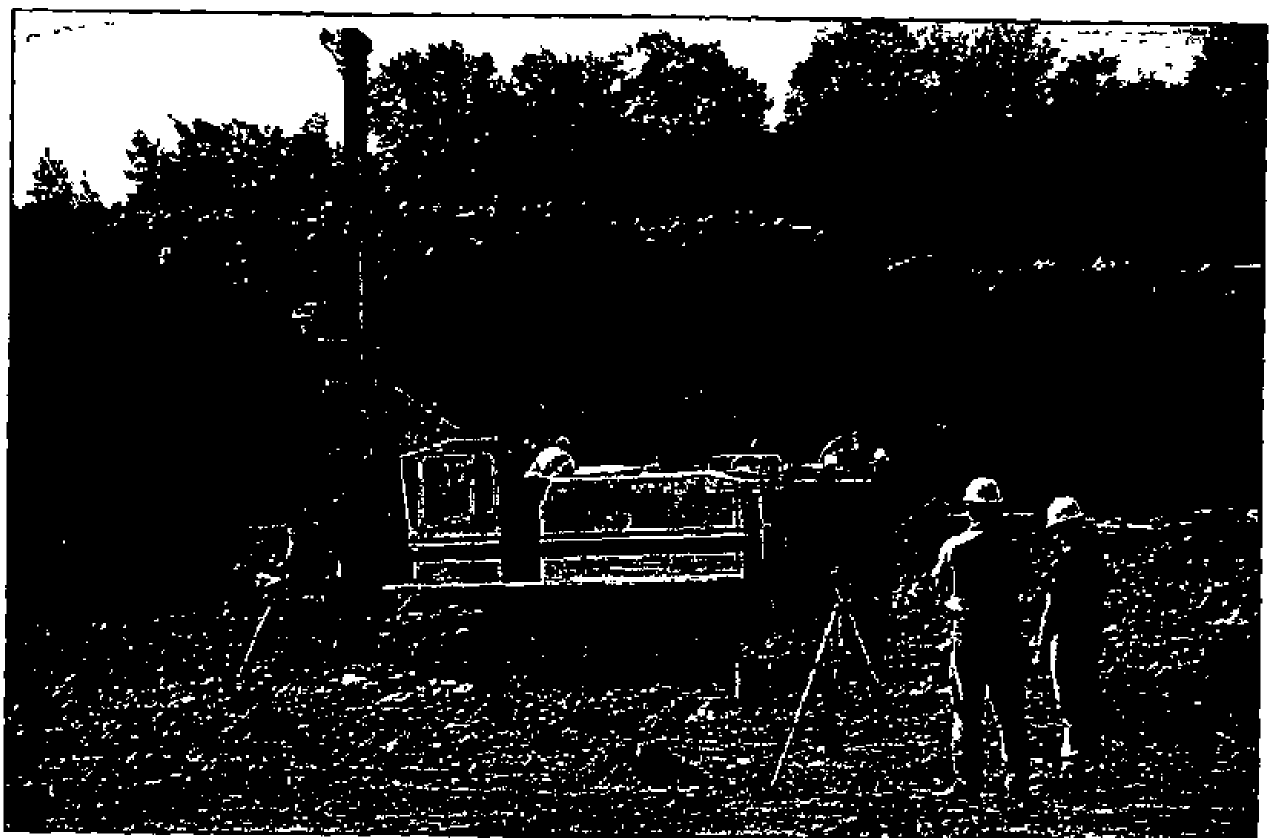


Figure 8 Fuwakawa rock drilling rig

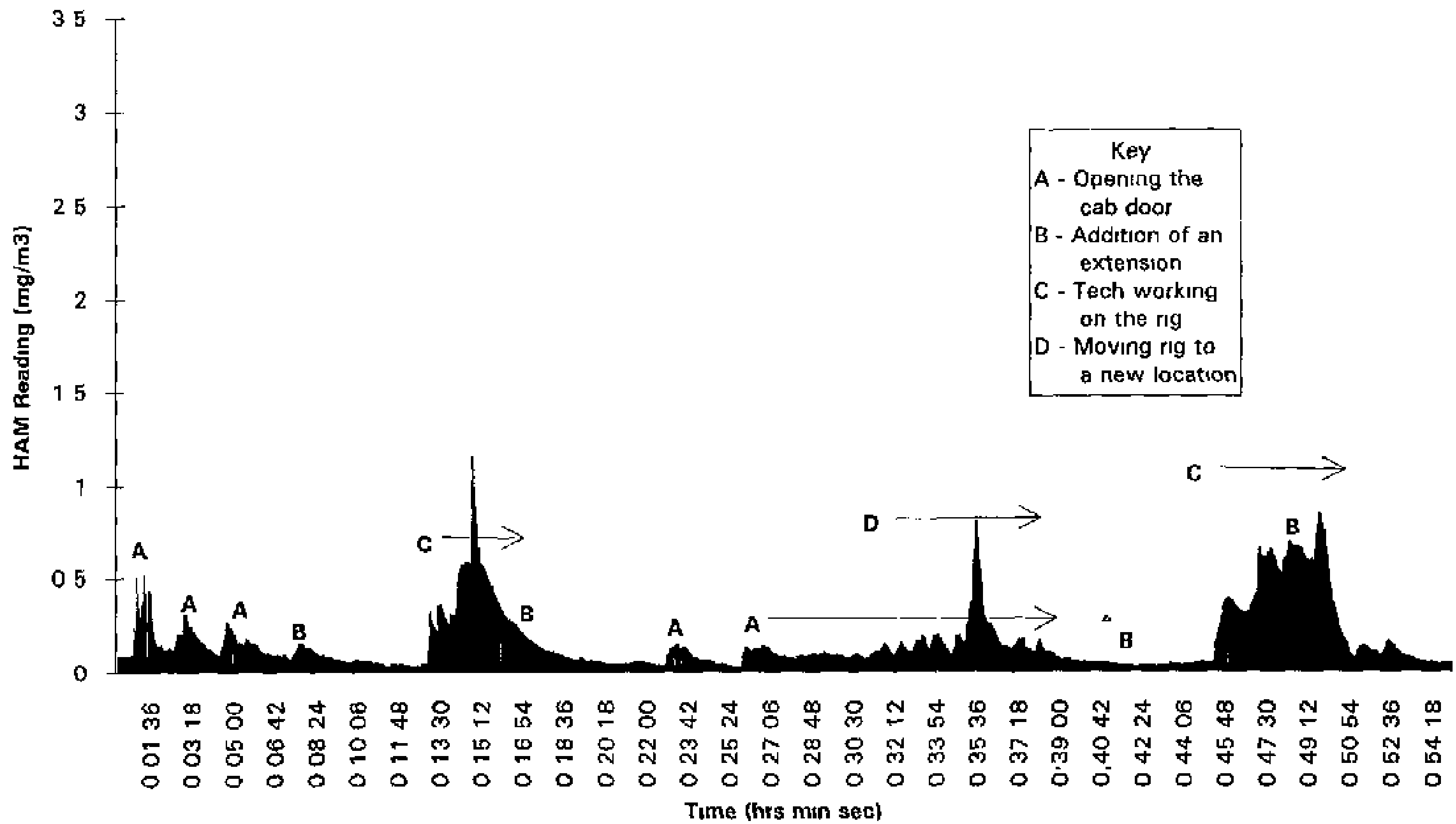
This drilling operation had average HAM monitoring results of 0.11 mg/m^3 for the personal sample of the driller located within the ventilated cab. When this result was compared to the respective area and personal HAM results on the Crawlair, the Fuwakawa drilling operation had an 87 percent exposure reduction for the area sample and a 61 percent exposure reduction for the personal sample (see Figure 9). The 55-min operation involved the drilling of two 3 in diameter, 33 ft holes. The average wind speed and direction during this operation were relatively constant (4 mph from the west-southwest).

The average HAM monitoring results of 0.11 mg/m^3 were adjusted from a gross result of 0.17 mg/m^3 to allow for a nonroutine exposure source. Two exposure peaks (Figure 9, label C @ 13.5 & 46 mins) were noted when an equipment technician was working on the rig. These peaks were integrated and subtracted from the rest of the run.

With the exception of that nonroutine exposure source, the opening of the cab door resulted in the main exposure source (Figure 9, label A). This was especially apparent when the driller moved to a new drill site while leaving the door open (Figure 9, label D @ 30.5 min). An analysis of the video-monitoring information revealed that the driller spent approximately 36 percent of his time with the cab door open.

As previously described in the Tamrock operation, a slight plume of dust was noted during the dump cycle on the cartridge filtration system. The average HAM readings taken at this

Figure 9 Fuwakawa Drilling Operation Area Sample in the Operator Cab



location were 0 51 mg/m^3 during the dump cycle (0 14 during the entire operation)   The reverse pulse of air, used to knock off the filter cake buildup, did not appear as forceful as that of the Tamrock   In addition, the rubber boot extended from the bottom of the filtration unit to the ground   These observations would tend to explain the lower HAM reading when compared to the Tamrock   A dust collection bag, similar to the one recommended for the Tamrock, could be fitted over the bottom of the dust collector to prevent the resuspension of fine particulate, and thus avert unnecessary exposures

COMPARISON OF HAM MONITORING RESULTS TO RESPIRABLE DUST SAMPLING

Respirable dust (NIOSH Method 0600) samples were taken along with the HAM monitoring as a secondary source of respirable dust information for both the area samples and the personal samples (see Tables 1 and 2)   When comparing the personal samples and the area samples taken at the drill controls of each rig, the respirable dust and real-time HAM results for the Crawlair were correspondingly higher than those of the Tamrock   Similarly, the respirable dust and real-time HAM results for the Tamrock were correspondingly higher than those of the Furukawa drilling rig   In all cases, the respirable dust samples showed exposure reductions equal to or greater than those of the HAM monitoring results

Table 1 Area Sample Comparison of Respirable Dust Sampling to the Average HAM Indicated Results (mg/m^3)^A

Drilling Rig	Description	Sample Time (min)	Respirable Dust	Average HAM
Crawlair I	Drill Controls	50	5.05	0.77
Crawlair I	Background	48	<0.06	NS
Crawlair II	Drill Controls	59	4.67	0.86
Crawlair II	Background	59	0.43	NS
Tamrock I	Drill Controls	46	0.26	0.26
Tamrock I	Filter Unit	45	0.87	0.28
Tamrock I	Background	44	0.27	NS
Tamrock II	Drill Controls	48	0.34	TD
Tamrock II	Filter Unit	48	0.34	0.21
Tamrock II	Background	39	0.42	NS
Fuwakawa I	Drill Controls	59	<0.12	0.13
Fuwakawa I	Filter Unit	59	0.20	0.14
Fuwakawa I	Background	48	<0.06	NS

Note ^{A}Crawlair II, Tamrock I, and Fuwakawa I represented the "typical operation" that was analyzed in the results and discussion section.

<# Indicates that the filter weight was below the limit of detection for the analytical method (<0.02 mg)

NS Indicates not sampled

TD Indicates technical difficulties with the equipment

Table 2 Personal Sample Comparison of Respirable Dust Sampling to the Average HAM Indicated Results (mg/m^3)[A]

Drilling Rig	Description	Sample Time (min)	Respirable Dust	Average HAM
Crawlair I	Driller	53	0.48	0.33
Crawlair II	Driller	58	0.99	0.28
Tamrock I	Driller	48	0.34	0.11
Tamrock II	Driller	50	0.51	0.18
Fuwakawa I	Driller	67	0.18	0.11

Note [A]Crawlair II, Tamrock I, and Fuwakawa I represented the "typical operation" that was analyzed in the results and discussion section

The two sampling techniques represent completely different methods of detecting dust concentrations. A HAM is a light-scattering device in which small particles are detected a elated to mass concentration. Relative response for the HAM is greatest for particle sizes from 0.3-2 μm. Therefore, the HAM readings give a relative indication of respirable dust exposures. In contrast, respirable dust sampling is a quantitative technique giving an average exposure concentration over a designated sample time. A cyclone is used as a particle size-selective device, allowing particles through to the collecting filter, based upon such factors as the dimensions of the cyclone and the centrifugal force exerted on the particles.

When the respirable dust results were compared to the HAM monitoring results, a correlation coefficient of 0.97 was calculated. The correlation coefficient from these sample observations (eleven) tend to show that the respirable dust results and the average HAM results tracked one another during the evaluation

CONCLUSIONS

This study demonstrated several notable findings As the level of engineering control increased, the worker exposures decreased According to the drill instructors, the cost for a new Crawlair rig ranges from $70,000 to $80,000 Based on the evaluation, this is the slowest (length drilled per unit time) rig, and results in the highest exposures The cost for a new Tamrock rig ranges from $190,000 to $200,000 This rig is roughly 30 to 40 percent faster than the Crawlair, and results in decreased exposures The cost for a new Furukawa rig ranges from $400,000 to $450,000 Although this rig is the most expensive, the Furukawa rig is roughly 40 to 50 percent faster than the Crawlair and results in the lowest exposures Currently available technology is expensive but effective in controlling exposure to dust created by rock-drilling operations

Video-exposure monitoring demonstrated that some brief worker activities (i e , collaring or blowing out the hole) increased exposures It also showed that small particles were resuspended at the cartridge filtration dump This exposure source might be effectively controlled with a dust collection bag Finally, the driller reduced his exposures by positioning the rig such that the drill controls were upwind of the dust plume and by staying upwind of the dust plume when not making adjustments at the drill controls

This field study demonstrates the utility of the video-exposure monitoring technique in comparatively evaluating the control technologies incorporated on several rock-drilling rigs This assessment tool was useful in the determination of how the driller work activities contributed or reduced his exposures This technique serves as a good qualitative tool to assess occupational exposures, rather than as a quantitative tool given the limitations of direct-reading instrumentation In addition, the video-exposure overlay technique served as an informative training tool The video overlays are currently being used by the instructors from the New England Laborers' Training Institute as a training aid for rock-drilling apprentices

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