## In-Depth Survey Report

# CONTROL TECHNOLOGY FOR DOWEL DRILLING IN CONCRETE

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**DEPARTMENT OF HEALTH AND HUMAN SERVICES**
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**National Institute for Occupational Safety and Health**

## Site Surveyed:

Hartsfield-Jackson Atlanta International Airport
6000 North Terminal Parkway Suite 4000
Atlanta, GA 30320

## NAICS Code:

237310 Highway, Street, and Bridge Construction

## Survey Dates:

April 16-20, 2012

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# Abstract

## Background

Workplace exposure to respirable crystalline silica can cause silicosis, a progressive lung disease marked by scarring and thickening of the lung tissue. Quartz is the most common form of crystalline silica. Crystalline silica is found in several construction materials, such as brick, block, mortar and concrete. Construction tasks that cut, break, grind, abrade, or drill those materials have been associated with overexposure to dust containing respirable crystalline silica. Highway construction tasks that can result in respirable crystalline silica exposures include breaking pavement with jackhammers, concrete sawing, milling pavement, clean-up using compressed air, and dowel drilling. Dowel drilling machines are used to drill horizontal holes in concrete pavement so that dowels can be inserted to transfer loads across pavement joints. NIOSH scientists are conducting a study to assess the effectiveness of dust control systems sold by dowel drill manufactures by measuring exposures to workers operating dowel drills with and without dust controls installed. This site visit was part of that study.

## Assessment

NIOSH staff visited the Archer Western Contractors site at the Hartsfield-Jackson Atlanta International Airport on April 16-20, 2012, and performed industrial hygiene sampling on April 17, 19, and 20, 2012. The sampling measured exposures to respirable dust and crystalline silica among two workers that operated four-gang dowel drills to drill holes in a new concrete runway. The NIOSH scientists who visited the site also monitored the temperature, relative humidity, wind speed and direction, and collected data (e.g., air flow, design) about the dust controls and observed the work process in order to understand the conditions that led to the measured exposures.

## Results

The quartz content of bulk dust samples collected at this site ranged from 35 to 48 percent by weight, with an arithmetic mean quartz content of 41 percent. Time weighted average respirable dust concentrations at this site ranged from 0.17 to 1.9 mg/m$^3$, with a geometric mean of 0.68 mg/m$^3$. Time weighted average respirable quartz exposures ranged from 0.024 to 0.42 mg/m$^3$, with a geometric mean of 0.13 mg/m$^3$.

## Conclusions and Recommendations

The geometric mean respirable dust exposure at this site was almost 80% lower when compared to two previous sites visited during this study. In addition to the use of the dust control, the difference may have been due to better maintenance of the dust control system at this site.

Despite the lower exposures when compared to two previous sites, the respirable dust exposures of one employee exceeded the OSHA construction industry PEL for

respirable dust containing >1% quartz on two days. At this site, the 10-hour TWA quartz exposure of one employee exceeded the NIOSH REL on two days and approached the NIOSH REL on the third day, even though the sampling time was only two hours in duration on that day. Employees should continue to wear half-facepiece air-purifying respirators with n-95 filters for protection against the respirable dust and respirable quartz exposures they encounter while dowel drilling. The respirators should be used as part of a comprehensive respiratory protection program with elements that include training, fit-testing, and medical qualification of the users.

Video exposure monitoring highlighted some sources of the workers' exposures. For example, the filters from the dust collection system were cleaned with compressed air. The use of compressed air to clean those filters should be prohibited. In addition to creating a potential source of dust exposure, cleaning the filters with compressed air may also damage the filter media and shorten the service life of the filters. The drill operators also dumped buckets of concrete dust collected by the dust collection system on the ground between the runway slabs. This practice increased the likelihood that the dust became airborne again, which created a potential exposure hazard. Alternative work practices include providing a covered receptacle nearby, or providing extra buckets and the lids to cover them. The covered receptacle or the covered buckets could be collected at the end of the day for disposal (check local regulations) or perhaps returned to the batch plant for recycling

# Introduction

## Background for Control Technology Studies

The National Institute for Occupational Safety and Health (NIOSH) is the primary Federal agency engaged in occupational safety and health research. Located in the Department of Health and Human Services, it was established by the Occupational Safety and Health Act of 1970. This legislation mandated NIOSH to conduct a number of research and education programs separate from the standard setting and enforcement functions carried out by the Occupational Safety and Health Administration (OSHA) in the Department of Labor. An important area of NIOSH research deals with methods for controlling occupational exposure to potential chemical and physical hazards. The Engineering and Physical Hazards Branch (EPHB) of the Division of Applied Research and Technology has been given the lead within NIOSH to study the engineering aspects of health hazard prevention and control.

Since 1976, EPHB has conducted a number of assessments of health hazard control technology on the basis of industry, common industrial process, or specific control techniques. Examples of these completed studies include the foundry industry; various chemical manufacturing or processing operations; spray painting; and the recirculation of exhaust air. The objective of each of these studies has been to document and evaluate effective control techniques for potential health hazards in the industry or process of interest, and to create a more general awareness of the need for or availability of an effective system of hazard control measures.

These studies involve a number of steps or phases. Initially, a series of walk-through surveys is conducted to select plants or processes with effective and potentially transferable control concept techniques. Next, in-depth surveys are conducted to determine both the control parameters and the effectiveness of these controls. The reports from these in-depth surveys are then used as a basis for preparing technical reports and journal articles on effective hazard control measures. Ultimately, the information from these research activities builds the data base of publicly available information on hazard control techniques for use by health professionals who are responsible for preventing occupational illness and injury.

## Background for this Study

Crystalline silica refers to a group of minerals composed of silicon and oxygen; a crystalline structure is one in which the atoms are arranged in a repeating three-dimensional pattern [Bureau of Mines 1992]. The three major forms of crystalline silica are quartz, cristobalite, and tridymite; quartz is the most common form [Bureau of Mines 1992]. Respirable crystalline silica refers to that portion of airborne crystalline silica dust that is capable of entering the gas-exchange regions of the lungs if inhaled; this includes particles with aerodynamic diameters less than approximately 10 micrometers (µm) [NIOSH 2002]. Silicosis, a fibrotic disease of the lungs, is an occupational respiratory disease caused by the inhalation and deposition of respirable crystalline silica dust [NIOSH 1986]. Silicosis is irreversible, often progressive (even after exposure has ceased), and potentially fatal. Because no effective treatment exists for silicosis, prevention through exposure control is essential. Silicosis is associated with a higher risk of tuberculosis and other lung disease [Parks et al. 1999]. Silica has been classified as a known human carcinogen by the International Agency for Research on Cancer [IARC 1997]. Occupational exposure to respirable crystalline silica has been associated with autoimmune diseases, such as rheumatoid arthritis, and kidney disease [Parks et al. 1999, Stratta et al. 2001].

Crystalline silica is a constituent of several materials commonly used in construction, including brick, block, and concrete. Many construction tasks have been associated with overexposure to dust containing crystalline silica [Chisholm 1999, Flanagan et al. 2003, Rappaport et al. 2003, Woskie et al. 2002]. Among these tasks are tuckpointing, concrete cutting, concrete grinding, abrasive blasting, and road milling [Nash and Williams 2000, Thorpe et al. 1999, Akbar-Kanzadeh and Brillhart 2002, Glindmeyer and Hammad 1988, Linch 2002, Rappaport et al. 2003]. Highway construction tasks that have been associated with silica exposures include jackhammer use, concrete sawing, milling asphalt and concrete pavement, clean-up using compressed air, and dowel drilling [Valiante et al. 2004]. Linch [2002] also identified dowel drills as sources of dust emissions on highway construction sites.

Dowel drilling machines (also known as gang drills or dowel drills) are used to drill horizontal holes in concrete pavement. Steel dowels transfer loads between adjacent concrete pavement slabs [Park et al. 2008]. They are typically used in "transverse joints in rigid airport and highway pavement to transfer shear from a heavily loaded slab to an adjacent less heavily loaded slab" [Bush and Mannava 2000]. Typical dowel drilling machines have one or more drills held parallel in a frame that aligns the drills and controls wandering [FHWA 2006]. The dowel drilling machine may be self-propelled or boom mounted, and may ride on the slab or on the grade [FHWA 2006]. After drilling to a typical depth of 23 cm (9 inches (in)) the anchoring material is placed, and the dowel is installed. The diameter of the hole is determined by the dowel diameter and whether cement-based grout or an epoxy compound is used to anchor the dowels [FHWA 2006]. Compressed air may be used to clean the hole prior to placing the anchoring material.

The study by Valiante et al. [2004] reported that dowel drilling respirable quartz exposures ranged from 0.05 milligrams per cubic meter ($mg/m^3$) to 0.16 $mg/m^3$, 8-hour (hr) time weighted average (TWA). Linch [2002] also documented quartz exposures during dowel drilling. The Linch [2002] study reported 8-hr TWA respirable quartz exposures for operators and laborers using boom-mounted 3-gang dowel drilling machines. The operators' 8-hr TWA exposures ranged from less than the minimally detectable concentration[1] of 0.029 mg/m$^3$ to 0.11 mg/m$^3$, with a geometric mean respirable quartz exposure of 0.037 mg/m$^3$ for eight samples. The highest result was 2.2 times the NIOSH Recommended Exposure Limit (REL) for quartz (and all forms of crystalline silica) of 50 micrograms per cubic meter (µg/m$^3$). The laborers' 8-hr TWA respirable quartz exposures ranged from 0.12 -1.3 mg/m$^3$ (2.4 – 26 times the NIOSH REL), with a geometric mean of 0.24 mg/m$^3$ (4.8 times the NIOSH REL) for 8 samples. Linch [2002] concluded his study of dowel drilling exposures with this statement:

> "Means of controlling the respirable dust generated from concrete drilling during all operations needs to be developed, tested, and employed. Pneumatic drilling is the common method of drilling concrete pavement. Methods of using small amounts of water through the drill stem should be developed for these specific applications. High-velocity dust collection systems that effectively control respirable dust should be tested and made available."

There are only two American manufacturers of dowel drills, E-Z Drill, Inc. and Minnich Manufacturing. Both manufacturers offer optional dust control systems for their machines. The manufacturers both make local exhaust ventilation (LEV) dust control systems to capture the dust generated by the dowel drilling process. In addition, they both sell water kits to suppress the dust that results from drilling holes for dowels. One manufacturer's water kit supplies water through the drill steel, while the other manufacturer's water kit sprays water on the surface to be drilled. NIOSH research aims to evaluate the effectiveness of current dust controls for dowel drilling machines, work with manufacturers to improve dust controls if necessary, and promote the use of tools with dust controls.

Three approaches were planned to evaluate the effectiveness of current dust controls on dowel drilling machines. The first measured respirable dust emissions from dowel drilling machines in a controlled setting, isolated from the effects of wind, weather, and other sources of particulate, assessing the effectiveness of the controls in reducing emissions. Emissions with and without the use of controls were compared. The second approach collected current data on respirable dust and crystalline silica exposures associated with dowel drilling without dust controls because the most recent dowel drilling exposure studies were published more than five years ago [Linch 2002, Valiante et al. 2004]. The third approach, including this survey, will assess personal respirable dust and respirable crystalline silica exposures of workers operating dowel drilling machines with dust controls in place in a real-world setting to determine the ability of the dust controls to limit exposures.

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[1] The minimally detectable concentration is the analytical limit of detection divided by the sample volume [Hewett and Ganser 2007]. Linch [2002] reported an LOD for quartz on filters of 0.01 mg/sample and a sample volume of 350.2 L for an operator's sample.

### Background for this Survey

In order to assess the effectiveness of the dust controls, it was necessary to evaluate exposures at a site where dust controls were used during dowel drilling. This survey was performed on April 16-20 at Hartsfield-Jackson International Airport in Atlanta, GA. An opening meeting and site walkthrough were performed on April 16, 2012. Sampling was conducted on April 17, 19 and 20, 2012, to assess the extent of respirable dust and crystalline silica exposure while workers used dowel drills equipped with dust controls to drill holes in concrete pavement. The drilling was done as part of the expansion of the airport's runway 27R.

The Federal Aviation Administration [FAA 2009] requires dowel drilling during runway construction, either using rotary-type core drills or rotary-type percussion drills. Contractors reportedly do not use core drills for this task because: 1) they leave a core that must be extracted from a blind hole (one that doesn't pass completely through the concrete); 2) the core may break in the hole, requiring the eventual use of a percussion drill to remove it; 3) core drills are slower, and; 4) core drills utilize water as a coolant, which mixes with concrete dust to create a slurry that must be collected, and water wets the hole, which interferes with the epoxy used to anchor the dowel rods.

## Plant and Process Description

### Introduction

Archer Western Contractors was founded in 1983. The company's headquarters are in Atlanta, GA, with seven regional offices nationwide. Archer Western is a subsidiary of The Walsh Group, a large general contractor, design-build, and construction management company. Archer Western Contractors works in civil, transportation, and building construction.

### Process Description

Dowel drilling was performed by two construction workers employed by Archer Western Contractors. Each worker operated an identical 4-gang slab-riding dowel drill (model A4SC, Minnich Manufacturing Company, Inc., Mansfield, OH). Both drills were equipped with the drill manufacturer's dust collection system.

The drills used H-thread steels and bits to drill horizontal holes 31cm (12 in) on center, 44.5 mm (1¾ in) in diameter and 38 cm (15 in) deep into the side of the new concrete runway slab. The work cycle consisted of moving the drill and compressor, positioning the drill, drilling the holes, moving the drill into position for the next set of holes, checking the depth of the previously-drilled holes, and using an air lance (a valve and length of rigid metal tubing attached to the compressor with a flexible air hose) to remove dust from the holes. Maintenance practices included cleaning the filters (first by rolling and tapping them on the grade between the new slabs, and then by using the air lance to clean them), emptying the plastic dust-collection buckets, and occasionally using the air lance to clean the dust collection system.

The workers wore hardhats, safety vests, safety glasses, ear plugs, work gloves, and work boots (Figure 1). They also wore 3M half-facepiece, air-purifying respirators with model 2091 P-100 filters (3M Occupational Health and Environmental Safety, St. Paul, MN). Medical clearance for the workers was provided by an outside clinic as part of the company's respiratory protection program.


**Figure 1 - Worker Operating Dowel Drill**

## Occupational Exposure Limits and Health Effects

As a guide to the evaluation of the hazards posed by workplace exposures, NIOSH investigators use mandatory and recommended Occupational Exposure Limits (OELs) when evaluating chemical, physical, and biological agents in the workplace. Generally, OELs suggest levels of exposure to which most workers may be exposed up to 10 hours per day, 40 hours per week for a working lifetime without experiencing adverse health effects. It is, however, important to note that not all workers will be protected from adverse health effects even though their exposures are maintained below these levels. A small percentage may experience adverse health effects because of individual susceptibility, a pre-existing medical condition, and/or hypersensitivity (allergy). In addition, some hazardous substances may act in combination with other workplace exposures, the general environment, or with medications or personal habits of the worker to produce health effects even if the occupational exposures are controlled at the level set by the exposure limit. Combined effects are often not considered in the OEL. Also, some substances are absorbed by direct contact with the skin and mucous membranes, and thus can increase the overall exposure. Finally, OELs may change over the years as new information on the toxic effects of an agent become available.

Most OELs are expressed as a TWA exposure. A TWA exposure refers to the average airborne concentration of a substance during a normal 8- to 10-hour workday. Some substances have a recommended Short Term Exposure Limit (STEL) or ceiling values which are intended to supplement the TWA where there are recognized toxic effects from higher exposures over the short-term.

In the U.S., OELs have been established by Federal agencies, professional organizations, state and local governments, and other entities. The U.S. Department of Labor OSHA Permissible Exposure Limits (PELs) [29 CFR[2] 1910.1000 2003a] are occupational exposure limits that are legally enforceable in covered workplaces under the Occupational Safety and Health Act. NIOSH recommendations are based on a critical review of the scientific and technical information available on the prevalence of health effects, the existence of safety and health risks, and the adequacy of methods to identify and control hazards [NIOSH 1992a]. They have been developed using a weight of evidence approach and formal peer review process. Other OELs that are commonly used and cited in the U.S. include the Threshold Limit Values (TLVs®) recommended by American Conference of Governmental Industrial Hygienists (ACGIH®), a professional organization [ACGIH® 2010a]. ACGIH® TLVs® are considered voluntary guidelines for use by industrial hygienists and others trained in this discipline "to assist in the control of health hazards." Workplace Environmental Exposure Levels™ (WEELs) are recommended OELs developed by the American Industrial Hygiene Association® (AIHA®), another professional organization. WEELs have been established for some chemicals "when no other legal or authoritative limits exist" [AIHA® 2007].

OSHA requires an employer to furnish employees a place of employment that is free from recognized hazards that are causing or are likely to cause death or serious physical harm [Occupational Safety and Health Act of 1970, Public Law 91–596, sec. 5(a)(1)]. Thus, employers are required to comply with OSHA PELs. Some hazardous agents do not have PELs, however, and for others, the PELs do not reflect the most current health-based information. Thus, NIOSH investigators encourage employers to consider other OELs in making risk assessment and risk management decisions to best protect the health of their employees. NIOSH investigators also encourage the use of the traditional hierarchy of controls approach to eliminating or minimizing identified workplace hazards. This includes, in preferential order, the use of: (1) substitution or elimination of the hazardous agent, (2) engineering controls (e.g., local exhaust ventilation, process enclosure, dilution ventilation) (3) administrative controls (e.g., limiting time of exposure, employee training, work practice changes, medical surveillance), and (4) personal protective equipment (e.g., respiratory protection, gloves, eye protection, hearing protection).

[2] *Code of Federal Regulations. See CFR in references.

### Crystalline Silica Exposure Limits

When dust controls are not used or maintained or proper practices are not followed, respirable crystalline silica exposures can exceed the NIOSH REL, the OSHA PEL, or the ACGIH® TLV®. NIOSH recommends an exposure limit for respirable crystalline silica of 0.05 mg/m$^3$ as a TWA determined during a full-shift sample for up to a 10-hr workday during a 40-hr workweek to reduce the risk of developing silicosis, lung cancer, and other adverse health effects [NIOSH 2002]. When source controls cannot keep exposures below the NIOSH REL, NIOSH also recommends minimizing the risk of illness that remains for workers exposed at the REL by substituting less hazardous materials for crystalline silica when feasible, by using appropriate respiratory protection, and by making medical examinations available to exposed workers [NIOSH 2002]. In cases of simultaneous exposure to more than one form of crystalline silica, the concentration of free silica in air can be expressed as micrograms of free silica per cubic meter of air sampled (μg/m$^3$) [NIOSH 1975].

$$\mu\text{g SiO}_2/\text{m}^3 = \frac{\mu\text{g Q} + \mu\text{g C} + \mu\text{g T} + \mu\text{gP}}{\text{V}}$$

Where Q is quartz, C is cristobalite, and T is tridymite, and P is "other polymorphs."

The current OSHA PEL for respirable dust containing crystalline silica for the construction industry is measured by impinger sampling. In the construction industry, the PELs for cristobalite and quartz are the same. The PELs are expressed in millions of particles per cubic foot (mppcf) and calculated using the following formula [29 CFR 1926.55 2003b]:

$$Respirable\ PEL = \frac{250\ mppcf}{\%\ Silica + 5}$$

Since the PELs were adopted, the impinger sampling method has been rendered obsolete by gravimetric sampling [OSHA 1996]. OSHA currently instructs its compliance officers to apply a conversion factor of 0.1 mg/m$^3$ per mppcf when converting between gravimetric sampling and the particle count standard when characterizing construction operation exposures [OSHA 2008].

The ACGIH® TLV® for α-quartz and cristobalite (respirable fraction) is 0.025 mg/m$^3$ [ACGIH® 2010a].

## Methodology

### Sampling Strategy

This evaluation focused on task-based sampling, in order to quantify the exposure associated with the dowel drilling task. The total sampling times reflect the period sampled while the workers were dowel drilling, including cleaning the holes with compressed air and drill maintenance (e.g., cleaning filters, dumping buckets).

They may not reflect the length of the workers' daily shift. Partial-period consecutive samples were collected to avoid the potential for sample loss due to overloading or equipment failure associated with the use of full-period single samples [NIOSH 1977].

## Sampling Procedures

### *Air Sampling*

Personal breathing zone air samples for respirable particulate were collected at a flow rate of 2.2 liters/minute (L/min) using battery-operated sampling pumps (Aircheck Sampler model 224, SKC, Inc., Eighty Four, PA) calibrated before and after each day's use. A sampling pump was clipped to each sampled employee's belt worn at their waist (Figure 2). The pump was connected via Tygon® tubing and a tapered Leur-type fitting to a pre-weighed, 37-mm diameter, 5-micron (µm) pore-size polyvinyl chloride (PVC) filter supported by a backup pad in a three-piece filter cassette sealed with a cellulose shrink band (in accordance with NIOSH Methods 0600 and 7500) [NIOSH 1998, NIOSH 2003]. The front portion of the cassette was removed and the cassette was attached to a Higgins-Dewell type respirable dust cyclone (model BGI4L, BGI Inc., Waltham, MA). At a flow rate of 2.2 L/min, the BGI4L cyclone has a 50% cut point ($D_{50}$) of 4.37 µm [BGI 2003]. $D_{50}$ is the aerodynamic diameter of the particle at which penetration into the cyclone declines to 50% [Vincent 2007]. The cyclone was clipped to the sampled employee's vest near their head and neck (Figure 3). Bulk samples of dust were also collected in accordance with NIOSH Method 7500 [NIOSH 2003].


**Figure 2 - Worker Wearing Pump and Cyclone (Circled)**

The filter samples were analyzed for respirable particulates according to NIOSH Method 0600 [NIOSH 1998]. The filters were allowed to equilibrate for a minimum of two hours before weighing. A static neutralizer was placed in front of the balance and each filter was passed over this device before weighing. The filters were weighed on an analytical balance (model AT201, Mettler-Toledo, LLC, Columbus, OH). The limit of detection (LOD) was 60 µg/sample. The limit of quantitation (LOQ) was 190 µg/sample.

In addition to the personal samples, area samples for respirable particulate were collected using the method described above. The samplers were clipped to a tripod at breathing-zone height (approximately 1.5 m (60 in) above grade). The tripod was placed to the south of the runway construction area (for convenience in relocating the tripod each day, it was located near a pipe sticking out of the ground at 33 38.050 N 84 24.505 W)

Crystalline silica analysis of the respirable particulate samples was performed using X-ray diffraction according to NIOSH Method 7500 [NIOSH 2003] with modifications. Each filter was removed from the sampling cassette and placed in a 15-mL vial. Next, 10 mL of tetrahydrofuran (THF) was added to each sample vial, which dissolved the PVC filter. Each sample was mixed by vortex. The sample vials were then placed in an ultrasonic bath for ten minutes. A silver-membrane filter was placed in the vacuum filtration unit to accept the sample suspension from each vial. First, 2 mL of THF solvent was added to the filter. The sample suspension was vortexed and immediately placed upon the silver membrane filter. The sample vial was rinsed three times, using with 2 mL THF for each rinse. Each rinse was added to the sample on the silver membrane filter. Finally, vacuum was applied to deposit the sample suspension onto the filter. The silver-membrane filter was then transferred to an aluminum sample plate and placed in the automated sample changer for analysis by X-ray diffraction. The LOD for quartz on a 37-mm PVC 5 µm filter was 6 µg/sample. The LOQ was 19 µg/sample.

Bulk samples were analyzed in accordance with NIOSH Method 7500. Approximately 2.0 g of sample was ground to a fine powder using a mortar and pestle. The powder was screened with a 10-µm sieve using 2-propanol and an ultrasonic bath. The powder was placed in a drying oven for two hours to evaporate the alcohol. The dried samples were stored in a desiccator. Approximately 2.0 mg of each sample was then weighed into a 50-mL beaker. About 10 mL of 2-propanol was added to the beaker, which was covered with a watch glass. Each covered beaker was placed in an ultrasonic bath for approximately 3 minutes, until agglomerated particles were separated. A 25-mm silver membrane filter was placed in the vacuum filtration unit. Two mL of 2-propanol was added to the filter, followed by the sample suspension and beaker rinsing. Finally, vacuum was applied to deposit the suspension onto the filter. The silver membrane filter was transferred to an aluminum sample plate and placed in the auto sample changer for analysis by X-ray diffraction. The LOD for quartz was 0.3% by weight. The LOQ was 1.0%.

### Video Exposure Monitoring

Respirable dust exposures in real-time were assessed using a Personal Dataram (Model pDR-1000AN, Thermo Electron Corp., Franklin, MA). The pDR is a nephelometer that uses light scattering to produce a measure of dust over a size range of 0.1-10 μm and a concentration range of 0.001 to 400 mg/m$^3$ (Figure 3). These readings are relative to a gravimetric calibration performed by the manufacturer in mg/m$^3$ using standard SAE fine (ISO fine) test dust. For this survey, the pDR was programmed to record the average dust concentration once every second.

**Figure 3 - Worker Wearing pDR**

A video camera was paired with the direct reading instrument, and video exposure monitoring techniques were used to characterize exposure [NIOSH 1992b]. In the laboratory, the data collected with the pDR were overlaid onto the video recording to observe the effects of factors such as the performance of different tasks and work practices on exposure.

### Measurement of Dust Control Flow Rate

Exhaust air flow rates were measured using a Sierra Instruments, Inc. (Monterey, CA) model 730-N5-1 fast response in-line mass flow meter (range 0-2.83 m$^3$/min (0-100 cfm)). A Sierra Instruments, Inc. Model 954 Flo-Box was used to read the signal from the meter.

Air flow measurements required an extended straight inlet into the dust collector (Figure 4). A 5-cm (2-in) to 5-cm (2-in) flexible coupling (Model RC 50, American Valve, Greensboro, NC) was used to attach a 30-cm (12-in) long piece of Schedule 40 plastic pipe to the dust collector inlet. A threaded 5-cm (2-in) to 5-cm (2-in) adapter connected the pipe to the outlet of the mass flow meter. A second threaded

5-cm (2-in) to 5-cm (2-in) adapter was connected to the inlet of the mass flow meter. This adaptor was attached to a 27-cm (10½-in) long piece of Schedule 40 plastic pipe. The other end of that pipe was open to the atmosphere.

**Figure 4 - Measuring Air Flow**

### *Weather Monitoring Methods*

The NIOSH researchers used a data-logging weather station (Kestrel 4500, Nielsen-Kellerman, Boothwyn, PA) mounted on top of a tripod to assess weather conditions at the site. The weather meter was approximately 1.5 m (60 in) off the ground; about breathing zone height [NIOSH 2010]. The location of the tripod was described in the area sample method, above. The weather meter was programmed to record data every 10 minutes. Airport weather observations were gathered from the Internet as a back-up. Average wind direction was calculated from the logged data [EPA 2000].

### *Measuring Productivity*

Productivity was measured by counting the number of holes drilled during each sampling period on each work day.

## Control Technology

Each of the drill bits was surrounded by a close-capture hood at the work surface. Each hood take-off was attached to 5-cm (2-in) diameter corrugated flexible hose (the interior surface is corrugated as well). The other end of the hose was attached to a dust collector at the back of the dowel drill unit. There were four hoods and two dust collectors on each of the units used at the Hartsfield-Jackson Atlanta International Airport. Two hoods were connected via flexible hose to each dust collector. Suction was provided by a pneumatic transfer pump (an eductor). There were two eductors on each dust collector. A 5-cm (2-in) deep pleated Minimum Efficiency Reporting Value (MERV) 13 cartridge filter (P/N P148646-016-340, Donaldson Company, Inc., Bloomington, MN) in each dust collector captured the dust. The dust build-up collected on the filter fell into a five-gallon plastic bucket attached to the bottom of each dust collector. A timed reverse pulse system was used to remove the dust build up. The workers can also activate the reverse pulse system manually. The workers dumped the plastic buckets when they noticed a decrement in the system's performance (e.g., a noticeable increase in visible airborne dust around the drills).

# Results

Table 1 presents the bulk sampling results. The air sampling results are reported in Tables 2 through 7. This evaluation focused on task-based sampling in order to quantify the respirable dust and silica exposures associated with the dowel drilling task. The total sampling times in Tables 3 and 7 may not reflect the length of the workers' daily shift.

## Crystalline Silica Content in Bulk Samples

One bulk sample was collected for every air sample collected on both workers. The bulk samples were collected from settled dust near the holes drilled by the workers during the corresponding air sampling period. On April 17, worker 1 only drilled 6 holes during the first sampling period, and no bulk sample was collected. The crystalline silica content of the bulk samples is reported in Table 1, below. The quartz content in the bulk samples ranged from 35 to 48 percent by weight, with an arithmetic mean quartz content of 41 percent. No other forms of crystalline silica were detected in the bulk samples.

Table 1 –Crystalline Silica Content of Bulk Dust Samples

| Date | Worker | Sample Period | Quartz % |
|---|---|---|---|
| 4/17/2012 | 1 | 2 | 39 |
| 4/17/2012 | 1 | 3 | 43 |
| 4/17/2012 | 1 | 4 | 48 |
| 4/19/2012 | 1 | 1 | 35 |
| 4/19/2012 | 1 | 2 | 39 |
| 4/19/2012 | 2 | 1 | 40 |
| 4/20/2012 | 1 | 1 | 37 |
| 4/20/2012 | 2 | 1 | 44 |

## Air Sampling Results

### Respirable dust results

No respirable dust was detected on any of the area samples. Table 2 reports the respirable dust results for all of the personal breathing zone air samples. Table 3 presents the TWA respirable dust results. Eight-hour TWAs were calculated assuming that no further exposure occurred during the unsampled portion of the workday [OSHA 2008].

Respirable dust exposures ranged from 0.038 to 0.49 mg/m$^3$, 8-hr TWA. Worker 1 drilled for 503 minutes on April 17. An eight hour TWA was not calculated for that worker on that day. For the actual sampling times, TWA respirable dust exposures ranged from 0.17 to 1.9 mg/m$^3$. Those actual TWA respirable dust data were assumed to follow a log-normal distribution, with a geometric mean of 0.68 mg/m$^3$, and a geometric standard deviation of 2.5.

Table 2 – Respirable Dust Sampling Results

| Date | Worker | Sample Period | Sampling Time (minutes) | Respirable Dust Concentration (mg/m$^3$) |
|---|---|---|---|---|
| 4/17/2012 | 1 | 1 | 60 | 9.1 |
| 4/17/2012 | 1 | 2 | 102 | 1.5 |
| 4/17/2012 | 1 | 3 | 179 | 0.53 |
| 4/17/2012 | 1 | 4 | 162 | 1.1 |
| 4/19/2012 | 1 | 1 | 217 | 1.0 |
| 4/19/2012 | 1 | 2 | 82 | <0.17 |
| 4/19/2012 | 2 | 1 | 133 | (0.52) |
| 4/20/2012 | 1 | 1 | `120 | 1.1 |
| 4/20/2012 | 2 | 1 | 106 | (0.17) |

Notes: mg/m$^3$ means milligrams per cubic meter. < means that the sample mass was less than the LOD of 60 µg/respirable dust per sample and a value of LOD/√2 was used to calculate the concentration. () means that the sample mass was between the LOD and the LOQ of 190 µg/sample. Values in parenthesis should be regarded as trace values with limited confidence in their accuracy.

Table 3 – Respirable Dust TWA Results

| Date | Worker | Sampling Time (minutes) | Respirable Dust TWA Concentration (mg/m$^3$) | Respirable Dust 8-Hour TWA Concentration (mg/m$^3$) |
|---|---|---|---|---|
| 4/17/2012 | 1 | 503 | 1.9 | na |
| 4/19/2012 | 1 | 299 | *0.79 | *0.49 |
| 4/19/2012 | 2 | 133 | (0.52) | (0.14) |
| 4/20/2012 | 1 | 120 | 1.1 | 0.29 |
| 4/20/2012 | 2 | 106 | (0.17) | (0.038) |

Notes: mg/m$^3$ means milligrams per cubic meter. na means not applicable: an 8-hr TWA was not calculated because the sample time (and task duration) exceeded 8 hours. 8 hour TWAs were calculated assuming no dust exposure occurred during the remainder of the day. * means that the sample mass of one of the samples used to calculate the TWA was less than the LOD of 60 µg/respirable dust per sample and a value of LOD/√2 was used to calculate the concentration. () means that the sample mass was between the LOD and the LOQ of 190 µg/sample. Values in parenthesis should be regarded as trace values with limited confidence in their accuracy.

### *Calculating the PEL*

For each worker, the sum of the respirable crystalline silica masses for each sample included in each day's TWA is divided by the sum of the respirable dust masses for those samples and multiplied by 100 to calculate the percent silica over the workday using the equation below. The resulting % silica value is used to calculate the OSHA PEL [OSHA 2008].

$$\%\ \text{Silica} = \frac{\text{Sample}_1\ \text{Silica Mass }(\mu\text{g}) + \cdots + \text{Sample}_n\ \text{Silica Mass }(\mu\text{g})}{\text{Sample}_1\ \text{Dust Mass }(\mu\text{g}) + \cdots + \text{Sample}_n\ \text{Dust Mass }(\mu\text{g})}\ \text{x}\ 100$$

Thus, the PEL for worker 1 may be different from the PEL for worker 2, and the PEL for worker 1 or worker 2 may be different every day.

Table 4 reports the respirable dust masses and quartz masses reported for each sample, the percent quartz, and by worker and day. The analytical method for quartz uses X-ray diffraction and is more sensitive than the gravimetric method used to analyze respirable dust samples. That makes it possible to report a result for quartz in a sample and report a respirable dust result less than the LOD for the same sample. In those cases, a PEL was not calculated using that sample.

Table 4 - Respirable Quartz and Dust Masses and Percent Quartz

| Date | Worker | Sample Period | Respirable Quartz (µg/sample) | Respirable Dust (µg/sample) | Percent Quartz (%) |
|---|---|---|---|---|---|
| 4/17/2012 | 1 | 1 | 276.5 | 1200 | 23.0 |
| 4/17/2012 | 1 | 2 | 66.5 | 330 | 20.2 |
| 4/17/2012 | 1 | 3 | 53.5 | 210 | 25.5 |
| 4/17/2012 | 1 | 4 | 73.5 | 330 | 17.9 |
| 4/19/2012 | 1 | 1 | 120 | 490 | 24.5 |
| 4/19/2012 | 1 | 2 | (8.6) | ND | - |
| 4/19/2012 | 2 | 1 | 21 | (150) | 14.0 |
| 4/20/2012 | 1 | 1 | 59.6 | 300 | 19.9 |
| 4/20/2012 | 2 | 1 | (5.6) | ND | - |

Overall, there was 22% quartz in worker 1's samples on April 17, 2012, resulting in a PEL of 9.3 mppcf or 0.93 mg/m$^3$. The PEL for worker 1 also has to take into account the fact that he drilled for 503 minutes, and be reduced accordingly, using the equation below [Brief and Scala 1975].

$$\mathrm{RF} = \frac{8}{\mathrm{h}} \times \frac{24 - \mathrm{h}}{16}$$

Where $h$ is the number of hours in the day. The reduction factor is 0.93 for a 503 minute day, resulting in a PEL of 0.86 mg/m$^3$ for worker 1 on April 17.

The PEL for worker 1 on April 19 was 8.3 mppcf, or 0.83 mg/m$^3$, based on 25% quartz in one of his samples. The PEL for worker 2 on April 19 was 13 mppcf, or 1.3 mg/m$^3$, based on 14% quartz in his sample.

On April 20, the PEL for worker 1 was 10 mppcf, or 1.0 mg/m$^3$, based on 20% quartz in his sample. The PEL for worker 2 could not be determined because the blank-corrected respirable dust result was less than the LOD.

## *Comparing the Respirable Dust Exposures to the PELs*

Table 5 provides the TWA and 8-hour TWA exposures and the calculated PELs for both workers for the three sampling days. The respirable dust exposure of worker 1 exceeded the PEL on April 17 by a factor of 2.2. His exposure was well within the assigned protection factor of 10 associated with the half-facepiece air purifying respirator he wore. While the results on April 17 and 19 reflect all of the time the workers drilled on that day, the results on April 20 account for only the first two hours of the work day. For example, the single sample for worker 1 was 1.1 mg/m$^3$ for the 120-minute sampling period. Those results should be interpreted with caution because the exposure for the rest of the day was not assessed.

Table 5 - TWA and 8-Hour TWA Exposures and Calculated PELs

| Date | Worker | Respirable Dust TWA Concentration (mg/m$^3$) | Respirable Dust 8-Hour TWA Concentration (mg/m$^3$) | Respirable Dust PEL (mg/m$^3$) |
|---|---|---|---|---|
| 4/17/2012 | 1 | 1.9 | na | 0.86 |
| 4/19/2012 | 1 | 0.79 | <0.49 | 0.83 |
| 4/19/2012 | 2 | (0.52) | (0.14) | 1.3 |
| 4/20/2012 | 1 | 1.1 | 0.29 | 1.0 |
| 4/20/2012 | 2 | (0.17) | (0.038) | na |

### *Respirable Quartz Sampling Results*

Table 6 presents the results of the respirable quartz samples collected in the breathing zones of both workers over all three days. Table 7 reports the TWA and 10-hour TWA results and compares them with the NIOSH REL. TWA respirable quartz exposures ranged from 0.024 to 0.42 mg/m$^3$. The results were assumed to follow a log normal distribution, with a geometric mean of 0.13 mg/m$^3$ and a geometric standard deviation of 3.1. Comparing the 10-hour TWA exposures with the NIOSH REL indicated that the quartz exposure of worker 1 exceeded the NIOSH REL on days 1 and 2 and approached the REL on day 3, even though a single sample was collected that day during two hours of drilling. The highest TWA quartz exposure encountered by worker 1, 0.42 mg/m$^3$ did not exceed the assigned protection factor of 10 associated with the half-facepiece air purifying respirator he used during his work day.

Table 6 – Respirable Quartz Sampling Results

| Date | Worker | Sample Period | Sampling Time (minutes) | Respirable Quartz Concentration (mg/m$^3$) |
|---|---|---|---|---|
| 4/17/2012 | 1 | 1 | 60 | 2.1 |
| 4/17/2012 | 1 | 2 | 102 | 0.30 |
| 4/17/2012 | 1 | 3 | 179 | 0.14 |
| 4/17/2012 | 1 | 4 | 162 | 0.21 |
| 4/19/2012 | 1 | 1 | 217 | 0.25 |
| 4/19/2012 | 1 | 2 | 82 | (0.048) |
| 4/19/2012 | 2 | 1 | 133 | 0.073 |
| 4/20/2012 | 1 | 1 | `120 | 0.23 |
| 4/20/2012 | 2 | 1 | 106 | (0.024) |

Notes: mg/m$^3$ means milligrams per cubic meter. () means that the one of the sample masses included in the TWA calculation was between the quartz LOD of 6 µg/sample of and the LOQ of 19 µg/sample. Values in parentheses should be regarded as trace values with limited confidence in their accuracy.

Table 7 – Respirable Quartz TWA Results

| Date | Worker | Sampling Time (minutes) | Respirable Quartz TWA Concentration ($mg/m^3$) | Respirable Quartz 10-Hour TWA Concentration ($mg/m^3$) | NIOSH REL ($mg/m^3$) |
|---|---|---|---|---|---|
| 4/17/2012 | 1 | 503 | 0.42 | 0.35 | 0.05 |
| 4/19/2012 | 1 | 299 | (0.20) | (0.098) | 0.05 |
| 4/19/2012 | 2 | 133 | 0.073 | 0.016 | 0.05 |
| 4/20/2012 | 1 | 120 | 0.23 | 0.046 | 0.05 |
| 4/20/2012 | 2 | 106 | (0.024) | (0.0042) | 0.05 |

Notes: $mg/m^3$ means milligrams per cubic meter. REL means recommended exposure limit. 10 hour TWAs were calculated assuming no quartz exposure occurred during the remainder of the day. () means that the one of the sample masses included in the TWA calculation was between the quartz LOD of 6 µg/sample of and the LOQ of 19 µg/sample. Values in parenthesis should be regarded as trace values with limited confidence in their accuracy.

## Video Exposure Monitoring Results

The pDR and video camera were used to evaluate exposures associated with seven activities that are part of the dowel drilling task: removing dust from drilled holes with compressed air, drilling, moving the drill, dumping the dust collection buckets, removing the filters from the dust collectors at the back of the drill and cleaning them by rolling and tapping them on the ground, using compressed air to flush settled dust from the flexible dust-collection ducts, and using compressed air to clean the filters after they were removed from the dust collectors. When reviewing these results, bear in mind that the pDR is calibrated using a standard dust, and these results are best viewed as relative measures of dust exposure.

Two different intervals of video exposure monitoring were performed during the task of removing dust from drilled holes using compressed air. During the first interval, 2 minutes and 46 seconds of the task were analyzed (Figure 5). The worker stepped down from the slab, put on his faceshield (it fit over his hardhat), and walked to where he left the air lance in the last hole he cleaned. He then turned on the valve and began to clean holes as he walked back to the drill. He slid the lance in and out of each hole one or more times to blow out the dust. After cleaning 47 holes, he closed the valve, placed the air lance on the grade near the drill, stepped onto the slab, and turned off the air supply to the lance at the compressor. Respirable dust concentrations ranged from 0.32 to 1.0 $mg/m^3$ during the recorded task, with a geometric mean of 0.37 $mg/m^3$. The highest exposure occurred when the worker raised his arm over his head to put on his faceshield, probably from dust shaken from his clothing.


**Figure 5 - Using Air Lance to Clean Holes**

The second interval of removing dust from drilled holes collected exposure data for 1 minute and 16 seconds. During that time, the worker cleaned approximately 30 holes with compressed air (the camera was on the opposite side of the slab). That sampling interval included only the work of cleaning the holes with the air lance. The worker's respirable dust exposure ranged from 0.062 mg/m$^3$ to 19 mg/m$^3$, but the geometric mean exposure was less than that of the first interval, 0.36 mg/m$^3$.

Video exposure monitoring was also collected during drilling, for 4 minutes and 6 seconds. The activities included purging the filters in their dust collectors by briefly and rapidly manually pulsing the controls to reverse the airflow through the system for a total of about 15 seconds. The worker also ran the drill, stood on the slab between the compressor and the drill, stepped off the slab and walked on the grade to inspect the drill and check its progress. The worker then stepped onto the slab, and when the set of four holes was complete, moved the drill into position to drill four more holes. After starting the drill, he stepped off the slab to check the drill, and then used a tape measure and dowel rod to check the depth of the four holes he had just drilled. The respirable dust concentration during this period ranged from 0.084 to 20 mg/m$^3$; the geometric mean concentration was 0.32 mg/m$^3$. The peak exposure occurred when the worker stood on the grade, adjacent to the slab and leaned over the drill to check its progress.

Moving the drill included 2 minutes and 54 seconds of activity. The worker moved the drill while standing on the slab, started the drill, and then stepped off the slab onto the grade. He then walked around the front of the drill to mark its position; walked back to use a dowel rod to check the depth of the holes just drilled, and stepped back onto the slab. The worker then stood next to the drill or between the drill and compressor while drilling progressed, occasionally leaning over the front of the drill to observe its operation (Figure 6). Finally, this monitoring sequence was completed when those four holes were completed, and the worker rolled the drill into position to drill four more holes. The respirable dust concentration ranged from 0.29 to 6.4 mg/m$^3$, with a geometric mean of 0.45 mg/m$^3$. The highest value, 6.4 mg/m$^3$, occurred when the worker was standing on the grade, leaning over and checking the depth of a hole with a dowel rod, approximately 1.2 m (4 ft) away from the drill while it was in operation.


**Figure 6 - Operating the Drill**

When the worker dumped the dust collection buckets, he knelt behind the drill and removed the buckets from beneath the dust collectors, picked the buckets up, carried them to the edge of the slab next to the front of the drill, and put them down. He then carried each bucket in turn to the grade in the space between the slabs, dumped the concrete dust (adding their contents to an existing pile of dust) and carried each bucket back to the edge of the slab. He then stepped onto the slab and carried the buckets to the rear of the drill. This sequence of actions was completed in 35 seconds. The respirable dust concentrations ranged from 0.13 to 1.4 mg/m$^3$, with a geometric mean of 0.21 mg/m$^3$. The peak exposure took place when the worker was out of view behind the drill. The highest measurement with the worker in view, 0.52 mg/m$^3$, happened when the worker placed an empty bucket on the edge of the slab and picked up a full bucket.


**Figure 7 - Worker Dumping Bucket**

The next VEM sequence recorded involved removing the filter from each dust collector and cleaning them by rolling and tapping them on the ground (Figure 8). The sequence began with the worker kneeling behind the drill and removing the filters one at a time from both dust collectors (the buckets had already been removed). He then carried the filters across the slab and stepped down onto the grade. He then bent over and grasped the first filter between his hands. Next, he rolled the filter between his hands (on its long axis) and bounced it on the ground (and sometimes shook it), next to the pile where he had dumped the contents of the dust-collection buckets. He repeated the process with the second filter and then carried both filters as he walked and stepped up onto the slab. Respirable dust measurements ranged from 0.12 to 2.9 mg/m$^3$, with a geometric mean of 0.27 mg/m$^3$. The maximum concentration recorded during this sequence occurred as the worker bounced and rolled the second filter.


**Figure 8 - Cleaning the Filter by Tapping and Rolling**

In order to use compressed air to remove settled dust from the dust collection hoses and hoods, the worker first removed the hoses from the dust collector inlets. The VEM sequence begins with the worker standing between the drill and compressor, near the back of the drill, holding the air lance in his hands. He then squats down and picks up the end of a dust collection hose in one hand and inserts the air lance in the hose, moving it back and forth in the hose. He repeats this process for all four hoses and dust streams out of each dust collection hood in turn at the opposite end of the drill as he performs the task (the drill array was raised to the vertical position for this task). The sequence ends as the worker is walking back to the compressor, carrying the air lance. Respirable dust measurements during this task ranged from 0.11 to 24 $mg/m^3$, with a geometric mean of 0.19 $mg/m^3$. The peak exposure was measured when he first stuck the air lance in the first hose. His station behind the drill and the wind direction during this task removed him from the dust escaping from the collection hoods (Figure 9).


**Figure 9 - Flushing Hoses and Hoods**

The final task evaluated with video exposure monitoring was cleaning the dust collection filters with compressed air (Figure 10). The worker stood near the back of the drill, between the drill and the compressor. The worker held a filter in one hand and the air lance in the other and cleaned the filter with the air lance. Next, he placed the filter on the slab and held it in place with his foot while cleaning it. He then picked the filter up in one hand and cleaned it again, before depositing the filter in an empty dust collection bucket. He next repeated the process with the second filter. Respirable dust measurement during this task ranged from 0.18 to 407 mg/m$^3$, with a geometric mean of 12 mg/m$^3$. The maximum value occurred as the worker bent over, with the filter in one hand and the air lance in the other.


**Figure 10 - Cleaning Filter with Compressed Air**

## Dust Control Flow Rate Results

Air flow measurements were obtained from the number 2 and number 4 dust collector inlets on both drills. On the drill with Archer Western equipment number 192x5085, the air flow at the number 2 inlet was 13 liters/second (L/sec)(28 cfm). At the number 4 inlet, it was 41 L/sec (87 cfm). On drill 192x5090, the air flow at the number 2 inlet was 25 L/sec (52 cfm). It was 9.9 L/sec (21 cfm) at the number 4 inlet on that drill. The condition and loading of the filters inside the dust collectors were not evaluated before the measurements were made.

## Weather Monitoring Results

Table 8 presents the wind speed and direction, temperature and relative humidity for both workers' for all three drilling days (i.e., averaged over their total sampling periods). The average temperature on April 17 was 24 °C (76 °F), with a range from 19 °C (66 °F) to 28 °C (82 °F). The average relative humidity was 61% on April 17, with a range from 46% to 88%.

The average temperature on April 19 was 15 °C (59 °F) during worker 1's sampling period (range 13 °C (56 °F) to 18 °C (64 °F)) and 14 °C (57 °F) during worker 2's sampling period (range 13 °C (56 °F) to 16 °C (60 °F)). The average relative humidity was 80% for worker 1 (range 74% to 87%) and 83% (range 75% to 97%) for worker 2 on April 19.

On April 20, the average temperature was 15 °C (59 °F) (range 15 °C (59 °F) to 16 °C (60 °F)), with a relative humidity of 96% (range 90% to 98%) during the sampling periods for both workers. A light rain fell during the sampling periods on April 20.

The average wind speed was 6 kilometers/hour (kph)(4 miles/hour (mph)) on April 17. The average wind speed was 10 kph (6 mph) for worker 1 on April 19 and 11 kph (7 mph) for worker 2 on that day. On April 20, the average wind speed was 8 kph (5 mph) for both workers.

The average wind direction on April 17, 225 degrees, corresponds to a wind from the southwest. The average wind direction on April 19 was from the east northeast. On April 20, the wind was from the east.

There are too few samples to attempt to derive a correlation between wind speed, direction, temperature, and or relative humidity and the workers' exposures. At other runway construction sites visited during this project, the drill operators stood next to their drills for large parts of their work day. At this site, the need to use an air lance to blow out the holes and the work practice of marking holes well ahead of the drill meant that the workers moved around a lot during the day. That movement makes it impossible to relate their positions relative to the wind direction and their exposures.

Table 8 – Wind Speed and Direction, Temperature, and Relative Humidity by Worker and Drilling Day

| Date | Worker | Average Wind Speed kph (mph) | Average Wind Direction degrees | Average Temperature °C (°F) | Average Relative Humidity % |
|---|---|---|---|---|---|
| 4/17/2012 | 1 | 6 (4) | 221 | 24 (76) | 61 |
| 4/19/2012 | 1 | 10 (6) | 67 | 15 (59) | 80 |
| 4/19/2012 | 2 | 11 (7) | 63 | 14 (57) | 83 |
| 4/20/2012 | 1 | 8 (5) | 92 | 15 (59) | 96 |
| 4/20/2012 | 2 | 8 (5) | 92 | 15 (59) | 96 |

Notes: kph is kilometers/hour, mph is miles/hour

## Productivity Results

Worker 1 drilled 406 holes April 17, 229 holes on April 19, and 102 holes on April 20. On April 19, worker 2 drilled 156 holes. He drilled 106 holes on April 20. Table 9 provides the number of holes drilled for each sampling period on all three sampling days, when those data were recorded. The first sampling period for worker 1 reflected an hour spent setting up the drill (dumping buckets, cleaning filters, marking pavement, and moving the drill). There was downtime associated with drill maintenance, fueling the compressor, and turning the drills around (i.e., to cross the runway).

Table 9 – Number of Holes Drilled by Date, Worker, and Sample Period

| Date | Worker | Sample Period | Holes Drilled |
|---|---|---|---|
| 4/17/2012 | 1 | 1 | 6 |
| 4/17/2012 | 1 | 2 | 92 |
| 4/17/2012 | 1 | 3 | 116 |
| 4/17/2012 | 1 | 4 | 192 |
| 4/19/2012 | 1 | 1 | 189 |
| 4/19/2012 | 1 | 2 | 40 |
| 4/19/2012 | 2 | 1 | 156 |
| 4/20/2012 | 1 | 1 | 102 |
| 4/20/2012 | 2 | 1 | 106 |

# Conclusions and Recommendations

Bulk samples of the concrete used in the runway slabs had an average quartz content of 41%. Two previous runway construction sites visited during this dowel drilling study averaged 9.1 % (Indiana) and 6.4% (Missouri) [Echt et al. 2011a, Echt et al. 2011b]. This range in quartz content may be due to the aggregates used, the specifications of the mix, or other factors.

TWA respirable dust concentrations ranged from 0.17 to 1.9 mg/m$^3$, with a geometric mean of 0.68 mg/m$^3$. At one previous airport construction site, where two four-gang drills were used without dust controls, the respirable dust TWAs ranged from 0.445 mg/m$^3$ to 21.2 mg/m$^3$ , with a geometric mean of 3.25 mg/m$^3$ [Echt et al. 2011a]. At an airport construction site where two five-gang drills were used with dust controls, TWA respirable dust concentrations ranged from 1.7 mg/m$^3$ to 6.0 mg/m$^3$, with a geometric mean of 3.0 mg/m$^3$ [Echt et al. 2011b]. The geometric mean respirable dust exposure at this site was almost 80% lower compared to those sites. In addition to the use of the dust control, the difference may have been due to better maintenance of the dust control system at the current site.

TWA respirable quartz exposures ranged from 0.024 to 0.42 mg/m$^3$, with a geometric mean of 0.13 mg/m$^3$. The TWA respirable quartz concentration at the previous site where two four-gang drills were used without controls ranged from 0.0221mg/m$^3$ to 0.675 mg/m$^3$, with a geometric mean of 0.12 mg/m$^3$ [Echt et al. 2011a] (quartz was not measured in air samples at the two five-gang drill site due to a laboratory error). The average quartz content in air samples at the current site was 21%, compared to 3.8% at the previous site [Echt et al. 2011a]. That difference may account for the reduction in respirable dust exposures and the lack of reduction in respirable quartz exposures observed between the two sites.

At this site, the 10-hour TWA quartz exposure of worker 1 exceeded the NIOSH REL on two days and approached the NIOSH REL on the third day, even though the sampling time was only two hours in duration. Fortunately, the exposures were within the assigned protection factor of the respirators used by the workers. This would not be the case if the exposures were compared to the more stringent ACGIH TLV for quartz.

Video exposure monitoring highlighted some sources of the workers' exposures. The geometric mean respirable dust exposures associated with most activities ranged from 0.19 to 0.52 $mg/m^3$, with the exception of using compressed air to clean the dust collector filters. The geometric mean respirable dust exposure associated with that task was 12 $mg/m^3$. Using compressed air to clean the filters should be prohibited to eliminate it as a source of exposure. Cleaning the filters with compressed air may also damage the filter media and shorten the service life of the filters. Removing the filters and cleaning them with compressed air may also result in dust being deposited on the clean side of the filter. The reverse pulse feature of the dust collector should preclude the need to remove the filters for cleaning. While some dust will remain on the filter after pulsing, the presence of the dust on the filter will increase filtration efficiency. Consult with the manufacturer to determine how often the filters should be replaced.

Dumping the collected dust on the ground between the slabs also increases the chances that the dust will become airborne again. Alternative work practices include providing a covered receptacle nearby, or providing extra buckets and the lids to cover them. The covered receptacle or the covered buckets could be collected at the end of the day for disposal (check local regulations) or perhaps returned to the batch plant for recycling.

The other tasks that utilized compressed air for cleaning, such as removing dust from drilled holes and purging the dust collection hoses with the air lance may result in higher exposures if the worker happened to be downwind (and increase the exposures of any workers who happen to be working downwind). If the dust collector hoses are accumulating enough dust to result in plugging of the hoses, there is either a design issue with the control system (which should be addressed by the manufacturer), such as insufficient air velocity to transport the dust, or a maintenance issue related to adjusting the air flow rate, which should be addressed after consulting with the manufacturer.

Until the plugging issue can be resolved (in consultation with the manufacturer), it would be wise to explore alternative means to accomplish the tasks that currently rely upon the use of the air lance, such as using a pneumatic vacuum cleaner in its place. The vacuum cleaner could also be used to clean the dust collection filters if the reverse pulse is not effective.

This was the first site visited during this study where the practice of using compressed air was used to clean drilled holes (the other sites epoxied the dowels in the drilled holes without cleaning the holes), but the other sites drilled narrower and shorter holes (28.6 mm (1⅛ in) in diameter and 24 cm (9½ in) at both sites). The dust clouds that result from the periodic purging of the system with the air lance and cleaning the filters seem to defeat the purpose of an industrial ventilation system – to reduce exposures by capturing the contaminant. In other words, it does little good to capture the concrete dust during drilling only to re-aerosolize a portion of it during a maintenance task.

Air flow measurements on the dust collectors at this site ranged from 9.9 L/sec (21 cfm) to 41 L/sec (87 cfm). For a 5 cm (2 in) diameter duct, this equates to a range of transport velocities of 5.1 m/sec to 20 m/sec (1000 to 4000 feet /minute (fpm)). The ACGIH® industrial ventilation manual recommends a transport velocity of 3500 to 4000 fpm for "average industrial dust" (e.g., granite or limestone dust, brick cuttings, silica flour) [ACGIH® 2010b]. The observed lower flow rate in some parts of the systems used on this site may explain the tendency for dust to settle in the corrugated hose and the need to periodically purge the dust collection system with the air lance to maintain performance.

Options that may help to improve the performance of the dust collection system include increasing the air flow through the dust collection system that were deficient to achieve the recommended transport velocity, using smooth-bore flexible duct, and minimizing the use of flexible duct to the extent possible (using rigid duct for long horizontal runs, for example).

Installing a static pressure gauge across the filter would give the drill operator information on when the filter needed to be cleaned by briefly pulsing the system. This would preclude the need to remove the filter for cleaning and indicate when the filter should be replaced. A static pressure gauge installed near each hood would indicate when the system was clogged with dust. NIOSH is willing to work with the paving contractor and the drill manufacturer to help implement any of these recommendations.

Despite the lower exposures, the respirable dust exposures of one employee exceeded the OSHA PEL for respirable dust containing >1% quartz on two days. Employees should continue to wear half-facepiece air-purifying respirators with n-95 filters for protection against the respirable dust exposures they encounter while dowel drilling [NIOSH 2008]. The respirators should be used as part of a comprehensive respiratory protection program with elements that include training, fit-testing, and medical qualification of the users [29 CFR 1910.134 2003c, NIOSH 1987]. Worth noting is the fact that the highest individual respirable dust concentration measured, 9.1 $mg/m^3$ occurred when worker 1 only drilled 6 holes. He spent that hour setting up – dumping buckets, cleaning filters, marking pavement, and moving the drill.

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