

# **CONTROL<sup>of</sup> SILICA EXPOSURE in FOUNDRIES**

*AFS Safety & Health Committee (10Q)*

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**November 2007**

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# Purpose

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This document was developed as a product of the American Foundry Society (AFS)/Occupational Safety and Health Administration (OSHA) Alliance. This manual was prepared under the direction of the AFS Safety and Health Committee (10-Q) to provide foundries with information that can help control the potential hazards of respirable crystalline silica. Silica exposure control has been pursued by foundries for many years. This publication is intended to provide useful technical information for foundries and to show how important it is to share best practices in the control of worker exposures to silica.



# Foreword

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This manual focuses on the essential elements for success of any air contaminant exposure control program in industry: management commitment; worker involvement; hazard assessment and communication; exposure monitoring; operational and maintenance procedures for the process and its ventilation; housekeeping; respiratory protection and medical monitoring.

Limiting silica exposures is an ongoing process, not something that is done once and put to rest. A coordinated program is warranted, with planning and review, similar to any effective program of quality control.

Case histories are a unique contribution of this publication. The authors of these case histories represent a class of foundry professionals who have a clear vision of how the work environment should be managed. Their dedication to the cause of creating a healthy and safe foundry environment is manifested in their writing. A sincere thank you goes out to these professionals.

A special appreciation goes to principal author Bob Scholz and contributing authors Tom Slavin and Kay Rowntree whose technical knowledge and skills are shared with the metal casting industry. Additionally, our thanks also go out to the following individuals who served as reviewers.

AFS 10-Q Safety and Health Committee

Jim Barry, P.E.

Greg Hillmann, CIH

Gary Mosher, CIH

The AFS 10-Q Committee meets quarterly and is open to persons committed to foundry safety and health who either work at foundries or who serve the needs of foundries. The committee is always looking for new members to carry on our mission with efforts such as this one to support the need for updated information and guidance.

Fredrick H. Kohloff, CSHM

Director, Environmental Health & Safety

American Foundry Society, Inc.



# Section 1

## Silica in the Foundry

**Thomas J. Slavin CIH, CSP, CPEA, CSHM**  
**International Truck & Engine Corp., Warrenville, IL**

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The same sand that fills a child's sand box is associated with the risk of silicosis in foundry operations. How can this be? Are children safe when playing in the sand at home or on the beach? If so, why is silica exposure a risk to foundry workers? All this and more will be explained in this section.

### 1.1 Silica (Quartz) is Common

Silica occurs virtually everywhere on the earth's surface. It is present in most rock, gravel, sand, and soil. Lake or river bed sand that is used in many foundries is about 95 percent silica; granite contains 25 to 40 percent silica, shale 22 percent and sandstone 67 percent. The form of silica in all of these materials is quartz, a crystalline structure. Two other crystalline forms of silica are less common, namely: cristobalite and tridymite.

Cristobalite can sometimes be encountered in a foundry because it can be formed by very high temperature conversion of quartz. Cristobalite is also encountered as an ingredient in some core washes and refractory materials. In both cases, cristobalite is most likely to show up in cleaning room dust exposures and during refractory removal. Tridymite is not usually found in foundries.

To complete the picture, silica (chemically silicon dioxide or  $\text{SiO}_2$ ) also occurs in non-crystalline or amorphous forms as shown in Figure 1-1. Glass is one example of an amorphous form. Glass is made by heating crystalline silica until it becomes molten and then rapidly cooling it to prevent crystallization. Another example of amorphous silica is diatomaceous earth, which consists of the fossilized remains of diatoms (microscopic unicellular marine or freshwater colonial algae having cell walls impregnated with silica). Diatomaceous earth is now used for a variety of purposes including filtration. Diatomaceous earth can also be converted to crystalline silica (cristobalite) by calcining or applying very high heat.

There is a tendency to employ verbal conservation (shortcuts in terminology) when discussing crystalline silica. The predominant health hazards and associated health standards all involve crystalline silica, principally quartz that is respirable (*i.e.*, small enough in size to be able to be drawn into the gas-exchange region of the lung).

When used in the foundry or in this manual for that matter, the term “silica” is meant to represent “crystalline silica,” and more particularly “quartz.” References to other forms of silica, either crystalline or amorphous, will usually be spelled out.

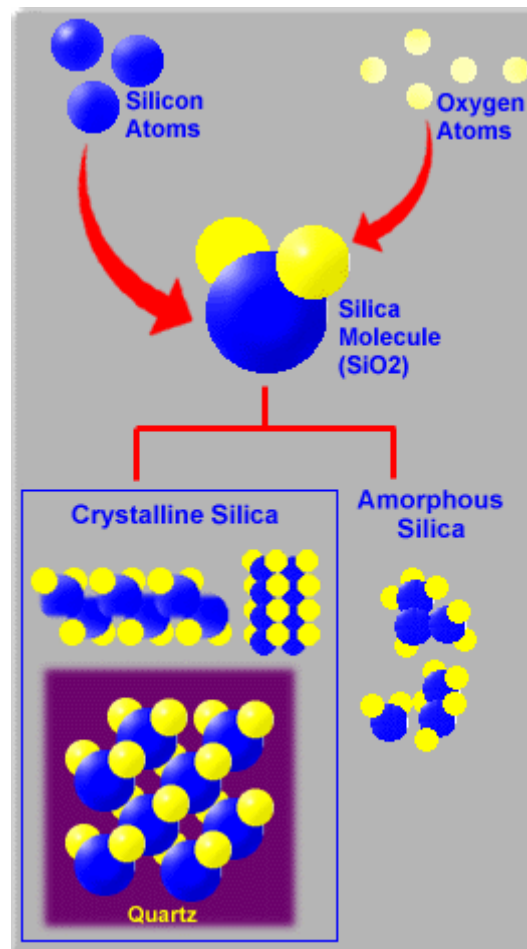


Figure 1-1. Quartz is a form of crystalline silica.

From <http://www.osha.gov/SLTC/etools/silica/silicosis/silicosis.html>

## 1.2 If It Is Just Sand Why Is It Hazardous?

Quartz has been associated with several health problems, but the principal concern is silicosis. Silicosis is a progressive, disabling lung disease caused by breathing dust containing respirable particles of crystalline silica. The silica particles become lodged in the air sacs of the lung, causing inflammation and scarring that damages the sacs. Consequently, the free exchange of oxygen and carbon dioxide is prevented between the blood and the air. Small bonded masses called nodules form and over time the nodules grow, making breathing increasingly difficult. Other symptoms may include severe and chronic cough, fatigue, loss of appetite, chest pains, and fever.

The particle size, dust concentration and duration of dust exposure are important factors which determine the extent of the development of silicosis. NIOSH has classified three types of silicosis: acute, accelerated and chronic.

- Chronic silicosis is the most common form and typically develops after more than 10 to 20 years of exposure. Symptoms can range from very mild to disabling or even fatal.
- Accelerated silicosis, although rare, can occur with high exposures over a period of time from 5 to 15 years. Symptoms are the same as chronic or ordinary silicosis except that they appear sooner and can progress rapidly. Similar symptoms of scarring and inflammation progress faster in accelerated silicosis than chronic silicosis. Accelerated silicosis usually leads to death within a few years of its development.
- Acute silicosis can occur with exposure to very high concentrations occurring in a short period of time ranging from a few weeks to 5 years. It occurs in occupations such as sandblasting and tunnel work. Again, the disease occurs in the same way as chronic or ordinary silicosis, except much faster and is almost always fatal.

The human body has developed amazing defense mechanisms against toxic materials. In the upper respiratory system, the tissues of the nose and throat are lined with cilia and coated with a thin layer of mucous. The cilia are hair-like structures that work together to push the mucous along and force it to flow up and out of the respiratory system. The airways of the upper respiratory system have several bends and turns. Larger particles tend to travel in a straight line instead of following the twists and turns of the airway and so they end up striking the side of the airway and getting carried along the mucous stream. That is why when people are exposed to a dusty environment they often notice deposits of dust in their nose several hours later as the mucociliary escalator slowly eliminates the particles.

In the deep lung (Figure 1-2), where gases are exchanged with the blood stream across the thin membrane of the alveolar spaces, there is no room for a layer of cells that secrete mucous. Another defense mechanism functions there, consisting of pulmonary macrophages, cells that are part of the immune system and related to white blood cells. These macrophages move along the surface of the alveolar space and engulf foreign bodies such as bacteria or dust particles. Once they have engulfed the foreign body they enclose it in a sac and release enzymes into the sac to destroy it.

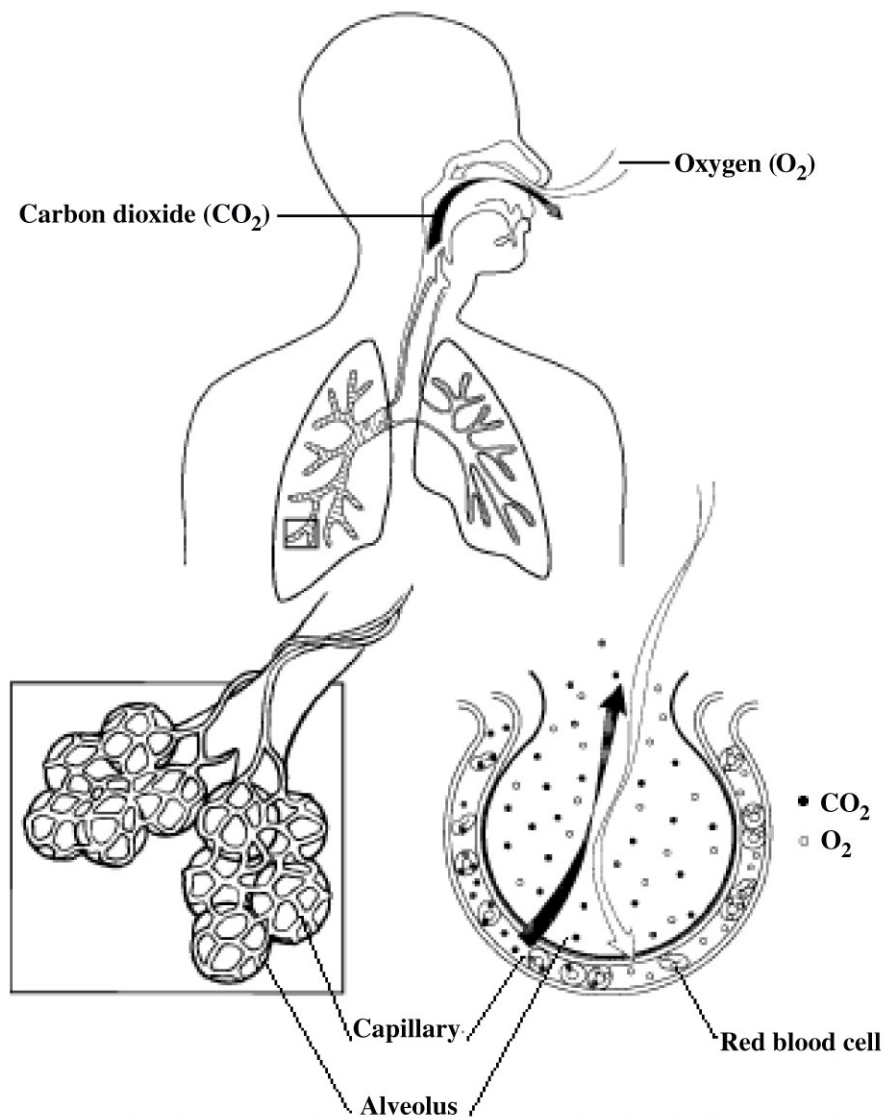
This macrophage defense system works well except for certain materials such as quartz. The enzymes cannot destroy the quartz particle and eventually destroy the macrophage itself instead, leaking the enzymes, damaging the lung surface, and resulting in formation of scar tissue. The surface area of the lung is quite extensive, 100 to 140 m<sup>2</sup> or about the size of half a tennis court. As more and more of the surface becomes scarred over time the area left for gas exchange gets reduced. The resulting loss of oxygen explains the symptoms of silicosis: shortness of breath, blue lips, etc.

Tuberculosis (TB) has been associated with silica exposures, mainly among people with silicosis. It appears that silicosis weakens the immune system and overwhelms the ability of the pulmonary macrophages to fight off the TB bacteria.

Occupational exposure to crystalline silica is classified as carcinogenic to humans. Several studies have found an increase in lung cancer, but some others have not. The positive studies have been mainly among populations with silicosis. It is likely that these populations have been exposed to higher levels of silica, and that possibility creates some question about whether the same effects occur at lower concentrations.

While silicosis has been recognized as a hazard for decades, more recent studies have suggested an excess incidence of several other disorders among crystalline silica exposed workers. These include auto-immune diseases such as scleroderma, lupus, and rheumatoid arthritis as well as kidney disease, including end stage renal disease which requires dialysis treatment. The mechanism for development of silicosis (scarring of the lungs) is well understood, but the explanation for these other reported effects is not clear.





*Transfer of oxygen of inhaled air into the blood and of waste carbon dioxide of blood into the lungs occur in the alveolus.*

Figure 1-2. The lungs provide a very large surface area (half the size of a tennis court) for the exchange of oxygen and carbon dioxide between the body and the environment.

Artwork source: [http://www.nhlbi.nih.gov/health/dci/Diseases/Copd/Copd\\_HowLungsWork.html](http://www.nhlbi.nih.gov/health/dci/Diseases/Copd/Copd_HowLungsWork.html)

The good news is that silicosis-related deaths have been declining according to Centers for Disease Control (CDC) records. Figure 1-3 shows that for 1968 to 1999 deaths due to silicosis as a primary or contributing cause declined from 1,200 to about 200 per year. The chart may underestimate the number of deaths because not every state is included in the report, but the clear downward trend is the key point.

In an analysis of occupationally associated deaths, foundry work was one of the more common occupations reported on silicosis death certificates (Figure 1-4). Construction and mining were cited more often. Both of these industries have developed and implemented better dust controls such as wet cutting methods and better substitutes for silica sand in abrasive blasting operations, so it is hoped that the number of silicosis deaths will decline.

### **1.3 Size Matters**

Back to the initial question of why quartz is hazardous to those exposed at work, but not in a child's sand box. The answer comes mainly down to particle size. Particle size is important because only very small particles, which we refer to as respirable size particles, reach the deep areas of the lung where scarring occurs. The sand particles on a beach or river bank are mostly much larger than this. The foundry air contains a mixture of large quartz particles and some smaller particles that have been reduced in size by various foundry processes.

Particles as large as 100 microns can be inhaled, but most of these are trapped in the nose and throat. A micron is 1 micrometer or 1 millionth of a meter. Particle sizes down to 10 microns are deposited in the upper (thoracic) region of the respiratory system. To reach the deep lung a particle must be about 5 microns or less in diameter. To put that in perspective, a human hair is about 75 microns in diameter and the limit of visibility with the naked eye is 50 microns. Therefore, if a particle is big enough to be visible it is too big to reach the deep lung. An exception to that rule is created by something called the Tyndall effect, whereby a light beam such as a ray of sunlight shining through a crack in the side of a barn reflects off tiny specks of dust as small as 2 microns and illuminates them. Small particles illuminated by a light beam in this manner often appear to be floating rather than falling.

Quartz sand particles are very large in physiologic terms and so hard that they are not easily broken down into smaller particles that can be inhaled and travel to the deep lung. Although more than 95 percent of the incoming sand may be quartz, the respirable dust in a foundry typically contains only around 0 to 15 percent quartz.

Most of the respirable size particles are made up of organic and inorganic carbonaceous materials, nitrates, sulfates and other miscellaneous byproducts of the foundry processes. Chipping, grinding, shot blasting, and other abrasive processes can fracture quartz particles and create smaller particles. Generally, the percent of quartz in respirable dust is higher in the cleaning room where particles are more likely to be broken down by harsh treatment.

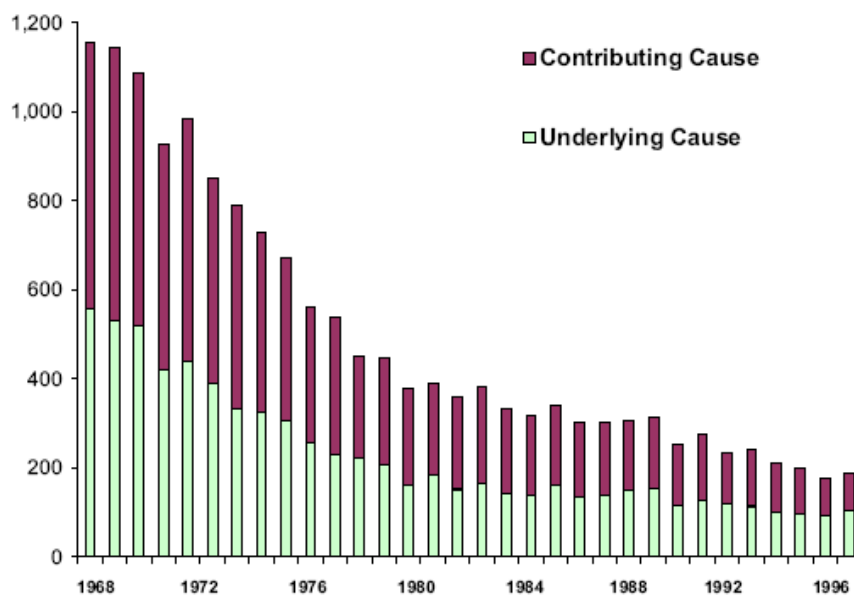
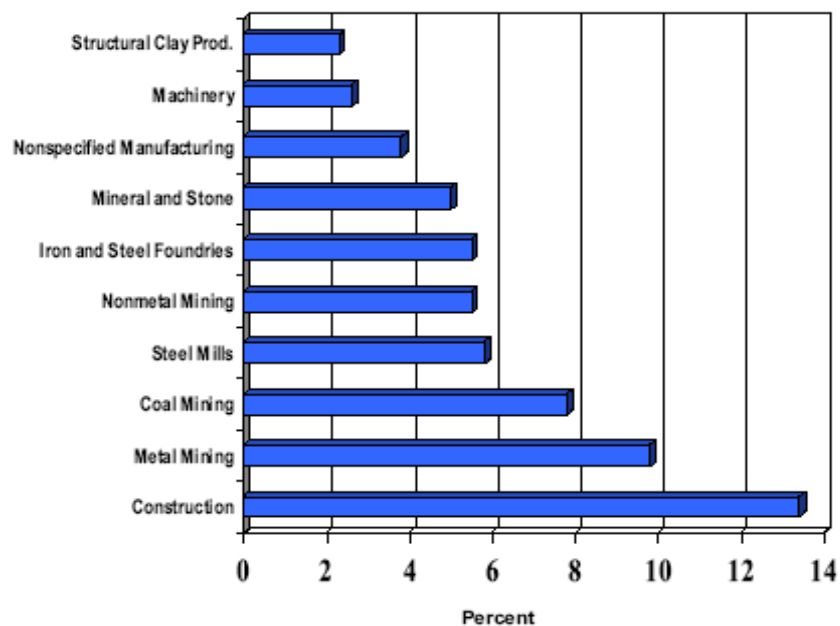


Figure 1-3  
Number of deaths of U.S. residents aged 15 or older with silicosis recorded as an underlying or contributing cause on the death certificate, 1968-1999.



Other occupations with exposure include farming, utilities, military, landscape work.

Figure 1-4

Silicosis: Most frequently recorded industries on death certificate, U.S. residents age 15 and over, selected states and years, 1990-1999. SOURCE: National Center for Health Statistics multiple cause of death data.

<http://www2.cdc.gov/drds/WorldReportData/pdf/Table03-06.pdf>

## 1.4 Size Matters II

As discussed above, particle size is an important factor in determining whether dust that is inhaled will reach the deep lung where damage occurs in the form of scarring. Size is also important for another reason. Larger dust particles settle out of air more quickly than smaller ones and are therefore less likely to be inhaled to begin with. Table 1-1 shows the settling rate for dust particles of different sizes. Large particles settle in less than a minute, but respirable particles (5 microns or less) take several minutes or even hours to settle. Those settling rates are for still air. In air that is turbulent, as is common in the foundry environment, those small particles may stay suspended for days.

**Table 1-1**  
**Settling Rate for Quartz Particles in Still Air**

<b>Diameter of Particle in Microns</b>	<b>Time to Fall 1 Foot (Minutes)</b>
100	0.02
5	2.5
2	14.5
1	54
0.5	187
0.25	590

It was once a fairly common practice to use compressed air to periodically “blow down” accumulations of settled dust from rafters and building surfaces as a form of housekeeping. That practice is less common now as vacuum systems have become more capable and as more foundries realize that blowing down dust removes the larger particles but suspends respirable ones. And the intermediate sized particles just settle on a different rafter.

## 1.5 Dust Exposure Limits

Limits have been established for exposure to dust containing crystalline silica. Compliance with these limits can be established by gathering full-shift dust samples in the breathing zones of workers, using battery-powered pumps drawing air through 37 mm diameter filters having a pore size of 5 micrometers. The limits are for respirable size dust, so a cyclone must be employed at the inlet to the sampler to capture the correct size particles while excluding larger ones.

The National Institute for Occupational Safety and Health (NIOSH) Recommended Exposure Limit (REL) for respirable crystalline silica (quartz, cristobalite or tridymite) is 50 micrograms per cubic meter of air (50 µg/m<sup>3</sup>). Unlike the NIOSH REL, that directly limits exposure to respirable crystalline silica, the current Federal Occupational Safety and Health Administration (OSHA) Permissible Exposure Limit (PEL) limits exposure to respirable dust which contains crystalline silica. The PEL has different dust limits depending on how much quartz is in the dust. The Federal OSHA PEL expressed in milligrams of respirable dust per cubic meter of air, or mg/m<sup>3</sup>, uses the formula:

$$\text{Exposure Limit for Respirable Dust Containing Silica} = \frac{10\text{mg} / \text{m}^3}{\% \text{ quartz} + 2}$$

For example, if respirable dust contains 8% quartz, the PEL is 1 mg/m<sup>3</sup> according to the OSHA formula [10/(8+2) = 1]. If dust contains 18% quartz, the OSHA PEL is 0.5 mg/m<sup>3</sup> [10/ (18+2) = ½]. The exposure limits for two other regulated forms of crystalline silica, tridymite, and cristobalite, are calculated based on one-half of the value calculated from the quartz formula.

When calculating the PEL according to the Federal OSHA formula, a quartz exposure limit of 100 µg/m<sup>3</sup> (0.100 mg/m<sup>3</sup>) is approached as quartz becomes the major constituent of the dust.

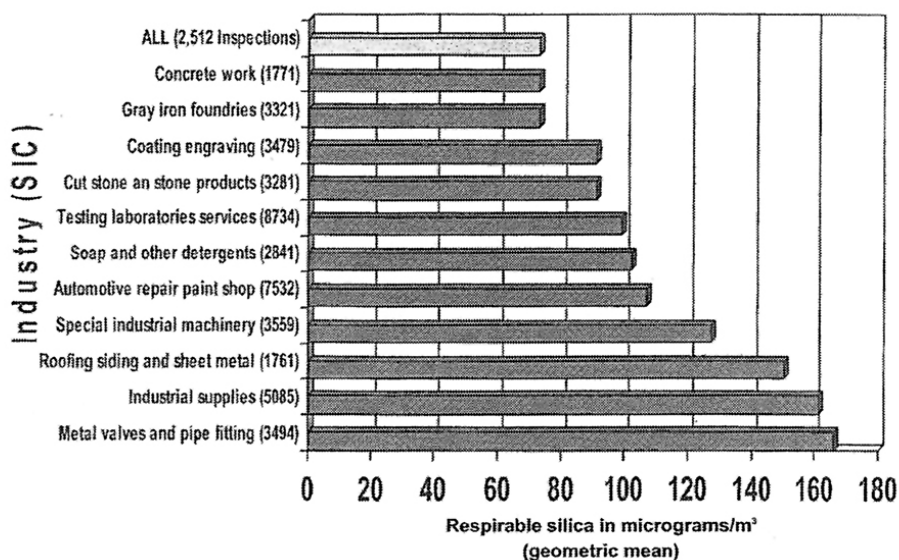
Meeting these exposure limits requires an active program of silica exposure monitoring and control which is described in the upcoming two sections of this manual.

## 1.6 Historical Exposure Levels

Review of historical findings of industrial silica exposures show that these exposures are declining, but that there still are exposure issues associated with respirable crystalline silica. A study of all OSHA crystalline silica samples collected over a 15 year period indicates that the average dust exposures at several industries were more than half the PEL (Figure 1-5). Exposures at gray iron foundries, for example, averaged more than 70 µg/m<sup>3</sup> of quartz. Since these are averages, it is likely that many of the exposures are below the average, but many are above the sample average and the 100 µg/m<sup>3</sup> limit for quartz exposure approached by the Federal OSHA PEL. These samples are undoubtedly not representative of the entire industry because OSHA compliance officers tend to target operations with higher dust levels for sampling. Nevertheless, it is clear that several industries, including foundries, experience considerable challenges in meeting the PEL.

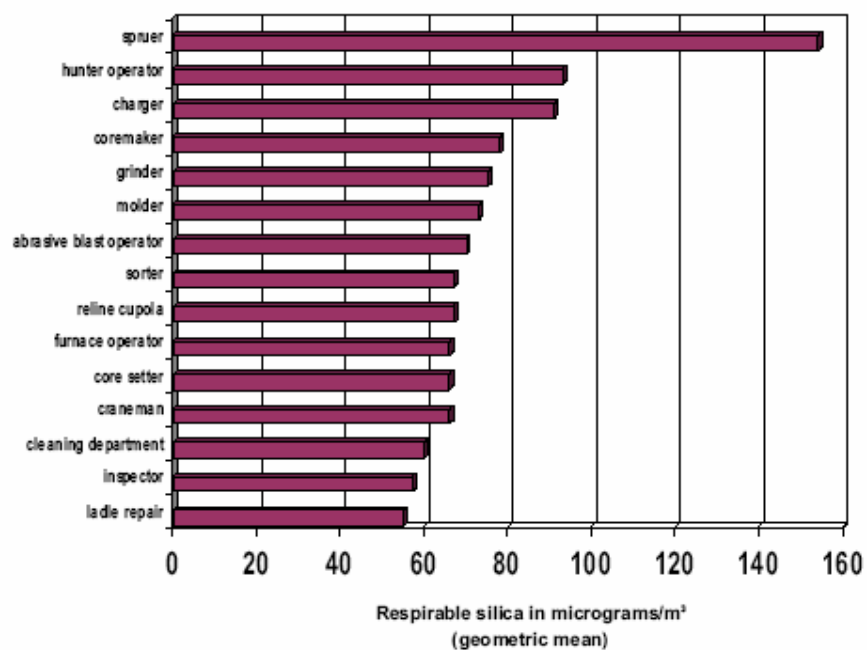
Within foundries, the jobs where the highest exposures have been found by OSHA sampling are shown in Figure 1-6. It is interesting to note that these results were generally lower than exposure results found in a similar review of OSHA sampling for an earlier 8 year period.

Average exposures found in the earlier period were much higher for several industries and for several foundry operations as shown in Figure 1-7. One operation for which more recent exposure results were higher was the spruer (*i.e.*, person who removes casting appendages after shakeout). However, this may be due to the selection of different foundries for the two periods. Because of limited number of samples and variations in operations sampled over the two periods, the overall downward trend across industries and operations is of more significance than individual occupations.



From Yassin A., Yabesi F., and Tingle R. Occupational Exposure to Crystalline Silica Dust in the United States, 1988-2003. Environmental Health Perspectives 113:3 p. 255-260. 2005.

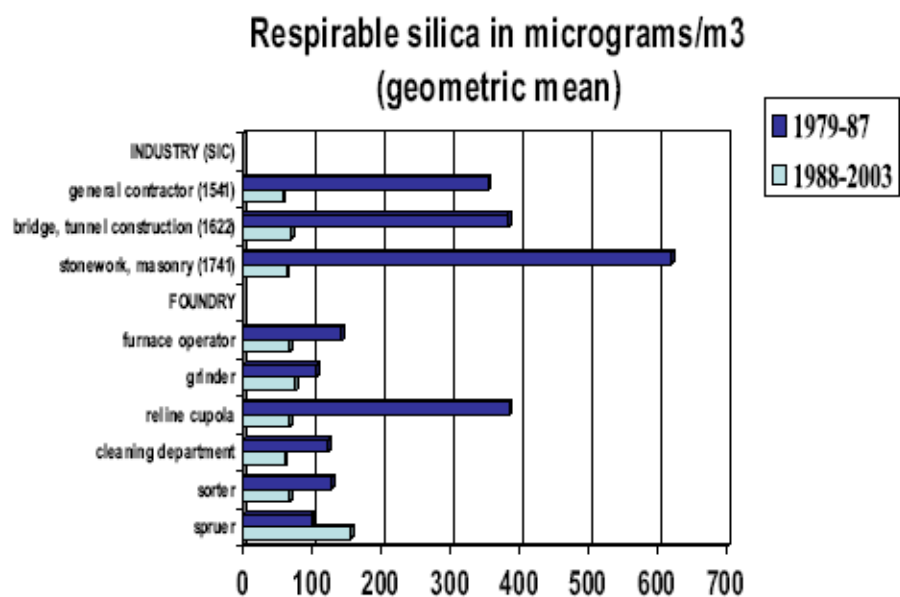
**Figure 1-5**  
Crystalline Silica Exposure Levels Measured by OSHA for Several Industries.



(From Yassin A., Yabesi F., and Tingle R. Occupations Exposure to Crystalline Silica Dust in the United States, 1988-2002. Environmental Health Perspectives 113:3 p. 255-260. 2005.)

Figure 1-6  
Crystalline Silica Exposure Levels Measured by OSHA for Several Foundry Operations.





(From Yassin A., Yabesi F., and Tingle R. Occupations Exposure to Crystalline Silica Dust in the United States, 1988-2003. Environmental Health Perspectives 113:3 p. 255-260. 2005.)

**Figure 1-7**  
**Reduction in Crystalline Silica Exposures Measured by OSHA Over Two Different Time Periods.**

## **Summary**

Although quartz is a very common material, it poses little risk unless it is fractured into respirable size particles that can reach the deep lung and cause scarring. Industrial processes such as mining, construction and foundries can produce exposures to fine quartz particles that cause silicosis, a disabling and often deadly disease. The good news is that the incidence of silicosis related deaths has dramatically declined over the past 40 years. In addition, the levels of occupational exposure to quartz have also declined over the past 20 years. Given that there is a long latency period between exposure and development of disease, it is likely that lowered exposure levels of the past 20 years will result in even lower incidence of silicosis in the years to come. Furthermore, if workplaces could all comply with the OSHA PEL (in 1998 and 1999 more than 40 percent of OSHA crystalline silica samples exceeded the PEL) occupational exposures would continue to decline and the incidence of silicosis would be reduced even further in the future.

# Section 2

## How to Manage Silica Exposure in Foundries

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Health damage to foundry workers from exposure to respirable crystalline silica can be prevented through a consistent program of identifying and monitoring employees at risk, and then using the means available to control exposures. Important aspects of an industrial hygiene program to protect workers are presented in this section.

### 2.1 Why is Monitoring Important?

The potential hazard of respirable silica dust to the lungs relates to how much silica dust is breathed, which is not the same for every foundry worker. The parameter typically used to describe the quantity of dust breathed is the average concentration of respirable dust in the breathing zone, along with its silica content. This data is referred to as time-weighted average (TWA) exposure and it is gathered with instruments worn by the worker while doing the job. Measuring the TWA silica exposure should be the mainstay of all silica exposure management programs for foundries. This sampling allows a foundry to prioritize exposure control initiatives on the basis of health risk.

Collecting representative air samples for silica is an essential part of protecting employee health. While dusty operations may obviously need to be controlled, most managers need to see data (usually air monitoring data) to decide if a new or improved control measure is necessary. Air monitoring is important for the following reasons:

- to determine which employees need to be protected and how much protection is necessary
- to assess whether controls are effective or are remaining effective
- to evaluate whether work practices need to be changed to reduce exposures
- to comply with OSHA regulations. If exposures are over OSHA PELs, there is an expectation on OSHA's part that employees will be protected with personal protective equipment until feasible engineering controls or work practice changes can reduce exposures below the PEL.

Evaluating and managing employee exposures to silica seems like it should be a straight forward task: pick an employee to monitor, the employee wear a sampling device, obtain the results, decide whether the employee is overexposed and then select controls that will reduce exposures. But have the right employees been selected to monitor? How many times do you need to monitor a job? Has the correct sampling procedure been used? What does the data mean? These are critical questions to answer if the data obtained is going to be used to determine if additional protective measures are needed to reduce employee risk.

Silica exposures are not uniformly distributed in a foundry. Developing a systematic approach to assessing exposures and then managing the risk will help direct industrial hygiene and control resources to those exposures of most concern. The following are steps that can be used to assess exposures:

- Understand the exposure risk
- Use prescribed methods to take samples
- Identify similar exposure groups
- Obtain data from these different exposure groups
- Interpret the data properly and use it to make decisions about reducing risk

## **2.2 Understanding Exposure Risk**

It is clear that the risk of developing silica related disease is related to the concentration of crystalline silica or quartz in the dust. Materials that contain more crystalline silica therefore present a higher risk than those with lower percentages of silica. This does not mean, however, that low silica content materials do not create exposures. If enough dust is generated by a process, overexposures can still occur.

At times, identifying where silica exposures can occur is quite easy - dust is seen and exposure is assumed - but there are many exposures that are less obvious or infrequent and therefore easily overlooked. Absence of visible dust does not mean there is not exposure (see Subsection 1.3). In addition, the confusing nature of silica terminology makes it easy to miss potential exposures when reviewing materials used in foundries.

Table 2-1 lists materials that may contain crystalline silica as well as acronyms used for crystalline silica. Material Safety Data Sheets (MSDS), if well prepared, should indicate whether or not a material contains crystalline silica. Unfortunately, not all MSDSs clearly identify whether or not crystalline silica is present in the product.

**Table 2-1**  
**Silica Nomenclature and Materials that May Contain Crystalline Silica (CS)**

Synonyms for CS	Materials that Likely Contain CS	Materials that do not Contain CS
Quartz	Flint	Silicone
Free Silica	Mica	Silicon
Silicon Dioxide	Silica Flour	Amorphous Silica
SiO <sub>2</sub>	Shale	Olivine
Cristobalite	Clay	Silica Gel
Tripoli	Lake Sand	Fused Silica
	Sand	

While sand casting operations have more opportunities for silica exposures than do investment casting, permanent molding and centrifugal casting operations, these other types of processes still can present exposure issues.

Some of the operations that have high potential silica exposures are often conducted on third shift or during plant shut-downs and therefore are often overlooked. Common examples of this are refractory work, such as relining a ladle or furnace, housekeeping tasks, and dust collector maintenance. It is critical to observe these processes and determine whether monitoring data should be collected.

A thorough exposure risk analysis includes an inventory of dust producing activities, along with worker interfaces with those activities. Table 2-2 assists in that review by listing a number of process-related factors which can impact silica exposure levels. Table 2-3 adds another group of potential silica sources arising from material handling and housekeeping activities.

## 2.3 Data Gathering and Review

Past data can be useful in identifying high risk exposures. This assumes, of course, that the data has been properly collected and interpreted. Data without supporting information regarding methods, calibration procedures, which person was sampled and what they were doing is not very useful since it is difficult to determine its validity or its context. Another problem is the confusing nature of the occupational exposure limits for crystalline silica; incorrect data interpretations leading to unnecessary actions or worse, no actions, is not uncommon (see Subsection 1.5). If past data is used, it should be carefully reviewed.

**Table 2-2**  
**Foundry Process Variables Affecting Silica Exposure Potential**

Area	Process Variables
Charge Preparation	<ul style="list-style-type: none"> <li>▪ Processing foundry returns having adhered sand and retained cores.</li> <li>▪ Dumping of totes with free sand at the bottom.</li> <li>▪ Charge delivery type and its method of being loaded.</li> <li>▪ Enclosure of charge preparation area.</li> </ul>
Melting	<ul style="list-style-type: none"> <li>▪ Method of charging furnace with scrap having adhered sand.</li> <li>▪ Proximity to charge preparation activities.</li> </ul>
Molding and Mold Assembly	<ul style="list-style-type: none"> <li>▪ Sand moisture control (green sand).</li> <li>▪ Provisions to remove sand spillage at mold machine.</li> <li>▪ Use of compressed air to clean mold before core setting.</li> <li>▪ Bag breaking activities.</li> <li>▪ Dust released by sand slingers.</li> </ul>
Coremaking	<ul style="list-style-type: none"> <li>▪ Integrity of seals on coreboxes during core blowing.</li> <li>▪ Amount of core finishing work (<i>e.g.</i>, filing).</li> <li>▪ Use of compressed air to clean coreboxes.</li> <li>▪ Dust filter leaks in pneumatic receiver tanks.</li> <li>▪ Bag breaking activities.</li> <li>▪ Dust released by ribbon flow blenders.</li> </ul>
Shakeout and Despruing	<ul style="list-style-type: none"> <li>▪ Dryness of sand at shakeout, affected by sand:metal ratio, pouring temperature and cooling time.</li> <li>▪ Size of mold and size of shakeout in relation to size of mold.</li> <li>▪ Mechanization of shakeout and despruing.</li> <li>▪ Amount of adhered sand and core materials remaining after shakeout.</li> <li>▪ Amount of free sand on vibratory conveyors.</li> <li>▪ Gate/riser design for easy removal.</li> <li>▪ Use of compressed air to clean shot blast residuals out of castings.</li> <li>▪ Throwing sorted castings and sprue into totes.</li> </ul>
Sand Return from Shakeout to Muller, Including Sand Screening, Cooling and Reclaiming	<ul style="list-style-type: none"> <li>▪ Wetness of sand throughout this series of process steps (green sand).</li> <li>▪ Mechanization of the sand transport process.</li> <li>▪ Moist conditions in sand pits and sand towers which clog ductwork (green sand).</li> <li>▪ Potential loss of negative pressure containment of dust in air/supplied sand coolers and mullers due to supply/exhaust air balance issues (green sand).</li> </ul>
Casting Finishing	<ul style="list-style-type: none"> <li>▪ Amount of adhered sand and core residuals fed to shot blast chamber.</li> <li>▪ Hanging castings on shot blast monorails.</li> <li>▪ Dumping castings into shot blast machines.</li> <li>▪ Shot blast cabinet seals and shot blast monorail seals.</li> <li>▪ Amount of burn-on, burn-in on casting surfaces during grinding.</li> <li>▪ Size of casting and extent of usage of portable grinding tools.</li> </ul>
Furnace and Ladle Relining	<ul style="list-style-type: none"> <li>▪ Crystalline silica content of lining materials.</li> <li>▪ Amount of refractory removal necessary.</li> <li>▪ Potential for cristobalite formation.</li> <li>▪ Amount of chipping required.</li> <li>▪ Methods used to introduce new liner materials.</li> <li>▪ Methods to remove and dispose of removed lining materials.</li> <li>▪ Size of the furnace or ladle.</li> </ul>

**Table 2-3**  
**Entrainment of Silica Dust into the Foundry Environment from**  
**Material Handling and Housekeeping Activities**

Location of Dusty Materials	Dust Producing Activity
Aisleways (indoors and outdoors)	<ul style="list-style-type: none"> <li>▪ Forklift truck traffic</li> <li>▪ Driving on unpaved vehicular routes</li> <li>▪ Use of brooms and shovels</li> <li>▪ Malfunctioning sweepers; uncontrolled dumping of sweeper catches</li> <li>▪ Wind turbulence outdoors and indoors through doorways</li> </ul>
Building Structures	<ul style="list-style-type: none"> <li>▪ Agitation of buildup of settled dust on floors and equipment in sand towers</li> <li>▪ Buildup beyond angle of repose on horizontal surfaces, followed by shedding</li> <li>▪ Vibration of processing equipment releasing dusty materials built-up on that equipment</li> <li>▪ Buildup of moist sand on walls, louvers, and in sand pits</li> </ul>
Mold/Coremaking Equipment	<ul style="list-style-type: none"> <li>▪ Removing sand spillage</li> <li>▪ Using compressed air to clean machines and areas around machines</li> </ul>
Dust Collector Maintenance	<ul style="list-style-type: none"> <li>▪ Filter changeout activities</li> <li>▪ Non-contained emptying of air cleaner hoppers</li> </ul>
Conveyors	<ul style="list-style-type: none"> <li>▪ Return belt loss, especially at belt support rollers</li> <li>▪ Dust liberated from unenclosed vibratory conveyors transporting return sand and castings with adhered sand</li> <li>▪ Belt spillage and conveyor transfer losses</li> </ul>
Handling/Transport of Castings/Sprue>Returns with Free Sand	<ul style="list-style-type: none"> <li>▪ Dust generation during filling and dumping operations</li> <li>▪ Dust shedding during transport of castings by hoists</li> </ul>
Transport of Bagged Materials on Pallets	<ul style="list-style-type: none"> <li>▪ Damage to bags from forklift tines resulting in spillage during handling</li> <li>▪ Bag breaking, emptying, and bag disposal</li> </ul>
Staging and Loading Debris for Disposal	<ul style="list-style-type: none"> <li>▪ Free dumping of mold debris into bunkers and roll offs outdoors in windy conditions</li> </ul>
Pneumatic Sand Transport	<ul style="list-style-type: none"> <li>▪ Uncontrolled relief venting of silos and hoppers</li> <li>▪ Leaks in transport lines and receivers caused by abrasion</li> </ul>

Common errors found in silica data include:

- Not using size separation devices (*i.e.*, cyclones) to collect the dust samples or using incorrect flow rates when using cyclones
- Lack of calibration data
- Assuming respirable dust and respirable quartz (or silica) are the same. They are not! Respirable silica is only one component of respirable dust (see Subsection 1.3).

Because only respirable particles are of interest for silica exposures, a size selective sampling device, a cyclone, which separates out particles by size, is necessary to collect silica samples. Various types of cyclones are available, all operating in a similar manner but each collecting slightly different ranges of particle sizes. Large particles spin out of the air stream and settle out in the bottom of the cyclone while the smaller, respirable sized particles stay in the airstream and get deposited on a collection filter. In this way, the larger, separated particles are excluded from the exposure sample. The speed of the air stream going into the cyclone is critical in determining where the size break will occur. Each manufacturer of cyclones specifies a flow rate that must be used for that particular cyclone in order to ensure that only the respirable fraction of dust is collected on the filter. For example, the MSA 10 mm nylon cyclone uses a flow rate of 1.7 lpm (liters per minute) while the SKC aluminum cyclone uses 2.5 lpm. Flow rates that are higher than the cyclone rating cause more particles to drop out of the air stream, including some of the respirable ones. Conversely, flow rates that are less than the cyclone rating allow some larger particles to pass through and be collected on the filter as respirable particles. Past data should be reviewed to find out how it was collected. If past sampling data was not collected using cyclones with the correct flow rate for that specific cyclone, the data cannot be relied upon.

The flow rate is determined through the use of a precision calibration device that measures airflow through the collection device. To have accurate data, the calibration device used must be a primary standard or be traceable back to a primary standard. Devices such as soap bubble meters (both automatic and manual), frictionless calibrators or rotometers that are periodically certified against a primary standard are reliable methods of calibration. The flow rate gauge on an air sampling pump, if one is provided, may or may not be accurate - even these need to be verified each time they are used to ensure they are correct. Air sampling records should specify the calibration method used and, again, if that information is not available, the data collected may be questionable.

Samples are analyzed by a laboratory for the amount of respirable dust on the filter (weight gain, reported as milligrams per cubic meter), the amount of respirable quartz or silica (reported



as milligrams per cubic meter) and the percent of silica in the sample. The *respirable quartz* value can then be compared to the American Conference of Governmental Industrial Hygienists (ACGIH) Threshold Limit Value (TLV) or to the OSHA PEL for respirable quartz in certain states that have state OSHA programs. For comparison with the Federal OSHA PEL, the amount of *respirable dust* (quartz plus non-quartz) is used (see Subsection 1.5).

TWA sampling, by its very nature, is limited in its ability to identify silica exposure sources, since it averages the contributions of all dust sources in the air that the worker breathes. However, visual surveillance of workers throughout the workshift and time study of their activities and locations, when combined with TWA sampling results and worker feedback, can produce insights into probable sources of dust exposure. Analyzing the sources of silica dust exposure is further pursued in Section 3 which follows.

Gaining a good understanding of a dust exposure requires more detailed observation of the sampling activity than simply assuring that the sampling apparatus is functioning properly. This distinction should be kept in mind when providing instructions to exposure sampling personnel. Further discussion of conditions for gathering meaningful exposure samples are presented under the topic of baseline exposure monitoring in Subsection 3.4.

TWA sampling as an industrial hygiene tool is intended to evaluate all of the activities conducted during the workshift, whether they are operational, maintenance, or housekeeping.

## **2.4 Identifying Employees with Similar Exposures and Obtaining Data**

It is not necessary to sample every worker but it is well known that an individual's work practices can impact the results of sampling. For example, one employee doing a refractory relining task may not place a ventilation duct close to the point of dust generation while another does. One employee may use compressed air to blow off equipment while another does not. Observations can help explain differences in air sampling results and also determine which workers are represented by the sample.

For small foundries, it may be necessary to sample a large percentage of workers because they might be doing unique tasks. For large operations, sampling everyone is not cost effective and the selection of workers must be made based on an understanding of the processes and the variables that impact exposures. For example, if there are 20 employees cleaning castings, some working on large castings, others on small ones, some working with downdraft booths and others with no ventilation, sampling of an employee in each of those four different subgroups would be reasonable since their silica exposures could vary. More certainty could be obtained by sampling two or more employees in each group to help deal with individual variability in work practices.

How often employees should be sampled is a difficult question to answer. It is better to base decisions on observations or process changes than to base it on a calendar schedule (*e.g.*, quarterly or annual monitoring). Clearly, if an operation has changed, exposures could also have changed and remonitoring is important. Beyond that, some priorities for remonitoring are as follows:

- Jobs where exposures exceeded the PEL, especially those that were much higher than the PEL.
- Jobs which had exposures close to the PEL, another approach is that jobs/tasks where exposures were 50 percent or more of the PEL should be remonitored.
- Jobs where, during previous sampling, conditions did not represent “typical” exposures for that task/job or where foundry production activities in general were not typical.
- Jobs where observations indicate an individual’s work practices may be different than others doing the same task.

## **2.5 Interpreting the Results**

Variability rather than consistency is the norm in industrial hygiene sampling and it is not wise to base control judgments on only one set of samples. If a task/job shows that exposures are clearly over the PEL, it is easier to make the decision that action is necessary, although repeat sampling to validate the results is still useful. If exposures are well below the PEL, additional control improvements may not be warranted as long as it is certain that the results represent the range of exposures that could occur for the task/job. For example, if an employee has a low result but one of the dusty processes he or she normally performs was not done on the day of sampling, then it is risky to make a decision not to improve exposure controls any further. As the results converge on the PELs, decision making becomes more difficult and more data is advised to be certain that an appropriate decision is being made especially with regard to the need for personal protection (*i.e.*, respirators).

In all cases, employees must be informed of the results of the sampling and any actions warranted by the sampling results. Moreover, employers must maintain records of the sampling and allow workers access to those records (CFR 1910.1020).

## **2.6 Recordkeeping and Working with Industrial Hygiene Consultants**

While some foundries may decide to collect their own air sampling data, others will rely upon industrial hygiene consultants to collect the data for them, interpret results and prepare reports.

No matter who collects the data, it is important that the person understand the need to prepare a good sampling strategy, carry out that strategy and interpret the results correctly.

Detailed notes are essential to understanding the meaning of sampling data. Sample data that consists of the laboratory report without any supporting information about what went on during the sampling can create problems. For example, high dust concentrations may be due to a malfunctioning ventilation system on the day samples were taken. If that critical information is not captured in notes, the employer may conclude that additional ventilation is necessary. Conversely, a dusty job may only run for half of a shift due to a production upset; thus lowering average exposure over the workshift. A field data collection form should be prepared and used to record data about who was sampled, equipment used, times of sampling, conditions of sampling, calibration data, unusual things that may have taken place during the sampling period and other observations. This data form should become part of the permanent exposure record that also includes the laboratory report, chain of custody or laboratory submission form and any other pertinent information. Exposure monitoring records need to be maintained for 30 years to meet the requirements of OSHA's Standard 1910.1020, "Access to Employee Exposure and Medical Records."

Many foundries choose to use an external industrial hygiene consultant to collect their data. Consultants should be selected who are familiar with foundry processes, who are proficient in collecting silica samples and who adhere to widely accepted industrial hygiene practices for the collection of data. The American Board of Industrial Hygiene (ABIH) maintains a website with a current list of individuals who are certified industrial hygienists (CIHs). The list indicates whether or not they offer consulting services. Be aware that even some CIHs and employees of OSHA consultation programs have incorrectly interpreted silica results and as a result provided misinformation based on the sampling results and the need to take action. It is important to ask questions of prospective consultants to determine their knowledge about the foundry industry, experience in collecting silica samples, procedures, reporting formats, turnaround times, laboratories used and pricing practices. Checking references and asking for certificates of insurance are also suggested.

## **2.7 Respiratory Protection for Silica**

The primary methods for controlling exposures to respirable silica are through engineering and work practice improvements. These methods are further described in Section 3 of this manual. The OSHA Respiratory Standard (CFR 1910.134) addresses situations where there is risk of overexposure during the course of implementing silica exposure control methods as well as in the case where feasible control methods, once installed, are not shown to provide adequate protection. Employing respiratory protection does not eliminate the potential hazard but it greatly reduces risk of occupational disease caused by breathing silica-containing dust.

Respirators used to protect employees from silica exposures fall into four categories:

- Half-mask air purifying respirators which include both disposable units and elastomeric facepiece styles fitted with disposable filters.
- Powered Air-Purifying Respirators (PAPRs) consisting of a battery operated fan equipped with filters to blow clean air across the face. They may fit tight or loose against the face.
- Supplied-air or airline respirators operated in a continuous flow or demand flow mode.
- Self-Contained Breathing Apparatus (SCBA), probably the least likely style to be used.

The OSHA Respiratory Standard (1910.134) should be reviewed for details on the regulatory requirements for respirators. Because of variations in people's faces, offering a variety of sizes and styles may be necessary to obtain a good fit with tight-fitting respirators (*i.e.*, those that seal against the face). Loose fitting respirators do not have the same fitting problems; however an adequate supply of clean air must be assured to maintain a positive pressure inside the respirator and prevent infiltration of air contaminants. Employees must also understand how respirators work, what they will protect against and how to use, store, clean and maintain them. Employees who wear respirators must be medically qualified to wear the chosen respirator and must be fit-tested when tight-fitting face piece styles are used. The only exception is for employees who wear a filtering facepiece respirator (*i.e.*, a dust mask) on a *voluntary* basis.

Respirators have Assigned Protection Factors (APFs) that indicate the degree of protection offered by that class of respirator. OSHA issued new APFs in 2006 and Table 2-4 should be consulted for details. Disposable half-mask respirators and half-mask elastomeric face piece respirators have the same APF of 10. This means they can be used in situations where the exposures are up to 10 times the PEL. PAPRs and supplied-air respirators have APFs of 25 for loose hoods or helmets, unless the manufacturer can demonstrate that they can actually achieve a higher APF by testing.

Another number associated with respirators is the filtering efficiency. For silica protection, non-powered, air-purifying, particulate-filter respirators should carry either a N95 or a N100 designation, indicating that the filter material is efficient enough to remove respirable dust. A N95 designation means the respirator is capable of removing 95 percent of particles that are 0.3 microns in size.

Beyond filter efficiency, there is another consideration, filter degradation, which must be taken into account when selecting nonpowered, air-purifying, particulate-filter respirators. Oil particles can rapidly cause the pore spaces of the filter material to plug, thus increasing the

effort to draw air through the respirator while at the same time reducing its filter efficiency. The respirators designated with an “N” are for use in the absence of oil particles. On the other hand, where fugitive oil mists can be created from coolant/lubricants or from the burning of oil layers on scrap metal during melting, filters with the designations “R” and “P” should be employed. Designation “P” is the most protective against oil-degradation of respirator performance.

It is important that supplied-air respirator systems have an alarm or other provision to assure that carbon monoxide (CO) is not delivered to the user. CO can be generated in oil lubricated compressors and can quickly become lethal.

**Table 2-4**  
**OSHA’s Assigned Protection Factors <sup>5</sup>**  
**(OSHA’s Table 1)**

Type of Respirator <sup>1,2</sup>	Quarter Mask	Half Mask	Full Facepiece	Helmet/Hood	Loose Fitting Facepiece
Air-purifying respirator	5	<sup>3</sup> 10	50	-	-
Powered Air-Purifying Respirator (PAPR)		50	1,000	<sup>4</sup> 25/1,000	25
Supplied Air Respirator (SAR) or airline respirator					
• Demand mode		10	50	-	-
• Continuous flow mode		50	1,000	<sup>4</sup> 25/1,000	25
• Pressure-demand or other positive-pressure mode		50	1,000	-	-
Self-Contained Breathing Apparatus (SCBA)					
• Demand mode					
• Pressure-demand or other positive-pressure mode		10	50	50	-
(e.g., open/closed circuit)			10,000	10,000	-

Notes:

- Employers may select respirators assigned for use in higher workplace concentrations of a hazardous substance for use at lower concentrations of that substance, or when required respirator use is independent of concentration.
- The assigned protection factors in OSHA Table 1 (Table 2-4 above) are only effective when the employer implements a continuing, effective respirator program as required by this Section (29 CFR 1910.134) including training, fit testing, maintenance, and use requirements.
- This APF category includes filtering facepieces, and half masks with elastomeric facepieces.
- The employer must have evidence provided by the respirator manufacturer that testing of these respirators demonstrates performance at a level of protection of 1,000 or greater to achieve an APF of 1,000. This level of performance can best be demonstrated by performing a WPF or SWPF study or equivalent testing. Absent such testing, all other PAPRs and SARs with helmets/hoods are to be treated as loose-fitting facepiece respirators, and receive an APF of 25.
- These APFs do not apply to respirators used solely for the purpose for escape. For escape respirators used in association with specific substances covered by 29 CFR 1910 subpart Z, employers must refer to the appropriate substance-specific standards in that subpart. Escape respirators for other IDLH atmospheres are specified by 29 CFR 1910.134 (d)(2)(ii).

## 2.8 Medical Surveillance Programs for Employees Exposed to Silica

The purpose of a medical surveillance program, often called health screening, is to identify changes in health early enough so that intervention can take place to prevent illness from occurring. It is important to detect pre-existing conditions that might place the exposed employee at increased risk, and to establish a baseline for future health monitoring. Physicians familiar with the health effects of silica should be consulted when establishing and maintaining a medical surveillance program. Examination of the respiratory system and cardiovascular system should be stressed.

In the case of silica, various recommendations have been made regarding who should be screened, what tests should be performed and how often they should be performed. Many OSHA health standards require medical surveillance when employees are exposed at or above the Action Level (AL), typically set at one-half of the PEL. There is some consensus about what should be included in an examination for employees exposed to silica:

- Physical examination, health and work history.
- Chest x-ray which is classified according to the latest ILO (International Labor Organization) guidelines by NIOSH Certified “B” Readers. These physicians have demonstrated that they are proficient in classifying chest x-rays for diseases such as silicosis through examinations administered by NIOSH. There are not many NIOSH Certified B Readers but it is very important that one be used to read the x-rays to ensure that early changes are properly identified. NIOSH maintains a list of certified B-Readers on their website (<http://www.cdc.gov/niosh/topics/chestradiography/breader-list.html>) that is searchable by state.
- Pulmonary function testing (PFTs), although some experts feel that routine PFTs are not useful for early detection of silica related lung disease since most abnormalities detected are due to conditions not related to work. If PFTs are done, they should be performed by someone who has demonstrated proficiency in conducting the tests.
- A TB test for workers who show evidence of silicosis and who have not been previously tested

The frequency of the examinations will vary depending on the advice of the physician administering the examination. OSHA has recommended in their Special Emphasis Program for Silica that examinations should be conducted upon hire (baseline), at least every 5 years for those with less than 20 years of exposure and every 2 years for those with more than 20 years of exposure to silica. More frequent examinations are needed for employees showing signs of silicosis. An examination should also be given upon termination of employment. Other groups such as the American College of Occupational and Environmental Medicine (ACOEM)

recommend a different schedule although their schedule also varies depending on how long the employee has been exposed and whether or not there is evidence of disease.

What should be done with employees who exhibit abnormalities consistent with silicosis? OSHA recommends in their Special Emphasis Program that employees who have a positive chest x-ray (reading of 1/0 or greater) be placed in a mandatory respiratory protection program and referred to a physician specializing in lung disease for further follow-up. The affected employee should also be counseled about silicosis prevention, safe work practices, and smoking cessation.

As with any occupational medical surveillance program, a close working relationship with the medical provider needs to be established and employers must understand the ethical and legal obligations medical professionals must adhere to regarding medical records, information disclosure and employee counseling.





# **Section 3**

## **How to Identify and Control Sources of Silica Dust Exposure**

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To manage silica dust exposure in foundries effectively, it is necessary to identify and control significant sources of airborne silica dust. There are many potential sources of silica dust in foundries which use silica sand for moldmaking and coremaking (Tables 2-2 and 2-3). Identifying which sources are significant and establishing ways to control exposures from these sources can be challenging. This section identifies a strategy to meet this challenge.

In Section 2, personal exposure monitoring was described to identify workers at risk of being over-exposed to respirable silica dust. This method averages the silica exposure concentration over the entire workshift. Silica exposure concentration can vary over the workshift, depending on worker involvement with dust-producing processes and the background air silica concentrations of those parts of the foundry in which the worker spends time. There are air sampling methods available to evaluate the causes of exposure that relate to the work operation itself and the causes of exposure that relate to the foundry air environment. In the field of industrial hygiene, these sampling methods are commonly referred to as "engineering sampling" methods. This section describes some engineering air sampling methods and goes on to list the control measures which can address the root causes of silica exposure.

### **3.1 Real-Time Dust Exposure Monitoring**

Current technology permits measuring and recording exposure to respirable particulate matter (PM) in real-time using available portable instruments. One of the principal benefits this technique has provided is a growing appreciation for the fact that dusty activities which occur over short periods can result in significant impacts on overall time-weighted-average (TWA) exposure. Figure 3-1 shows a setup typical of what was used in Kennedy Valve's program to improve the dust exposure protection provided by bench grinding ventilation (Case History A).



Figure 3-1  
Worker wearing portable real-time monitor for respirable dust.

The data-logging sensor, often employing an optical, scattered light approach, is mounted on the upper body by a harness which fits over the shoulders. A battery powered pump, identical to that used for filter cassette sampling, is mounted on the waist and used to draw air first through a cyclone at the inlet to the sensing chamber, and then through the optical chamber of the instrument. A filter, mounted on the discharge of the sensing chamber is used to calibrate the instrument for respirable dust concentration.

Analyzing the dust calibration filter for silica content can provide the average silica percentage of the dust concentration measured with this instrument over time. It should be noted; however, that since silica content of the dust varies continuously, knowing average silica content of the dust does not allow one to generate a real-time plot of silica concentration from this data. The method is limited to assessing respirable dust levels.

The data logged by the instrument is subsequently downloaded. A correlation to real-time activities is provided either by manual note taking with notations of time, or by simultaneous video recording.

### **3.2 Respirable Dust Concentration Mapping of the Workplace**

Industrial ventilation engineering experience has shown that air contaminants migrate and concentrate in the workplace environment depending on the locations and emission rates of fugitive air contaminant sources and on ventilation rates and patterns. In some cases, personal sampling apparatus has been used to gather “area samples” of the foundry workplace. The limitation of this method is that a significant number of areas samples are needed to adequately characterize background air quality. An alternative method is available that can allow mapping of respirable dust concentration levels everywhere in the foundry. The data can be gathered using the same real-time analyzer that was prescribed for personal exposure monitoring in Section 3.1. The method is further described in the AFS publication, “Managing the Foundry Indoor Air Environment,” Section 8, contact the AFS e-store at: <http://www.afsinc.org/estore> . The method is also described in AFS Transaction 01-152, “A Measurement Method to Pinpoint and Assess High Contaminant Zones within Foundries,” contact the AFS Library at: <http://www.afslibrary.com> .

The dust concentration map can be presented as a plan view contour mapping of concentrations which occur throughout the foundry at breathing zone height. An example of mapping of respirable dust concentration in a foundry is shown in Figure 3-2. The foundry layout is shown beneath the contour map. This contour was produced by gathering readings of respirable PM at a series of points throughout the area of interest or throughout the entire foundry. For this reason, the method is sometimes called “grid sampling.”

Experience in dust concentration mapping in foundries has demonstrated that these concentration patterns are quite stable. For this reason, they are sometimes referred to as “standing profiles.”



### 3.3 Scope of Exposure Control Methods

There are provisions which can be made in the design, operation, and maintenance of foundry processes, equipment, and facilities to reduce the silica exposure hazard. Exposure controls can be generally classified as engineering controls, work practice controls, and administrative controls.

Engineering controls are the primary method for controlling exposures to respirable silica dust. Engineering controls focus on:

- Process equipment, material handling, tools, materials, and procedures. Process control involves maintenance as well as operation.
- Facility, with its layout, work surfaces, traffic routes, and housekeeping provisions. (The term “facility” as used here includes all of the space in which foundry operations are conducted, both indoors and out).
- Ventilation systems, including both local and general supply and exhaust systems.

The field of industrial hygiene has traditionally categorized engineering controls for air contaminant hazards as: substitution, isolation, and ventilation. Substitution is a broad term used to include techniques for replacement of hazardous materials, processes, or pieces of equipment with less or nonhazardous ones. Substituting with a low or no silica-containing material is a prime example of this silica exposure control technique. Isolation of hazards is done by interposing a barrier between the worker and the hazard. Isolation can involve a physical barrier, a suitable distance between the worker and the hazard or a time lapse to provide a safety factor against exposure.

Work practice controls include specific actions taken by workers to minimize the generation and dispersion of dust into their own breathing zones as well as into the breathing zones of nearby workers or into the general inplant environment. Some fundamental work practices are:

- Good housekeeping;
- Appropriate personal hygiene practices;
- Periodic inspection and maintenance of process and engineering control equipment;
- Proper procedures to perform a task;
- Appropriate supervision to assure that proper procedures are followed.

Administrative controls include options such as exposure monitoring, medical surveillance, education and training. Administrative controls can involve limiting exposure in structuring work assignments.

### **3.4 Exposure Control Focuses on Process and Material Handling**

In foundries using silica sand for moldmaking and coremaking, making quality castings requires close control of sand systems. This close control has a significant impact on the production and dispersion of silica dust into the foundry environment. Here are some examples of process areas where good foundry sand management can reduce the potential for exposure to silica dust.

#### **Green Sand Compaction**

Proper compaction is critical to green sand molding. Besides providing the correct mixture of ingredients, it is also essential to maintain moisture and temperature control. When temperature of molding sand rises above 120°F, molding sand dries out quickly and loses its compactability. The amount of moisture required for compaction is sufficient to suppress the emission of fines from molding sand.

#### **Surface Finish at the Molten Metal Interfaces with Molds and Cores**

Mold and core surfaces are intended to minimize metal penetration (*e.g.*, burn-on, burn-in) which shot blasting cannot effectively remove. Excessive metal penetration results in the need for dust-producing manual grinding operations.

#### **Maintenance of Seals during Blowing of Sand into Molds and Cores**

Seals on pressure blown sand systems are necessary for complete filling of mold and core boxes. Seal leaks on the other hand, result in dispersion of dust and loss of sand delivery efficiency.

#### **Shakeout Efficiency**

The term “shakeout” as used here includes all mechanical methods such as dump-off conveyors, vibrating tables, rotary drums, and preblast conveyors which are used to achieve the separation of the cast metal from mold and core materials prior to handling and processing the casting and its appendages. Employing shakeout techniques which are effective at removing adhered sand and cores from castings is critical for several reasons:

- To minimize dust exposure during manual despruing and sorting operations and all casting finishing operations that follow. These casting finishing processes provide some of the greatest challenges to the use of local exhaust ventilation to control worker exposures.

- To reduce wear and tear on shot blast equipment as well as to confront the challenge to the dust control provisions of that equipment when excess sand is removed by blasting equipment.
- To reduce adhered sand and cores on foundry returns, which causes dust issues in the charge preparation and melting areas, which ultimately creates excess dross and reduces the life of furnace linings. Furnace relining operations have high silica exposure potential; extending the life of furnace linings reduces the amount of this work which is required.

### **Sand Containment in Material Handling Systems**

Of the foundry process variables affecting silica exposure potential listed in Table 2-2, about one-fourth directly involve material handling of silica-bearing materials and many other items involve feeding, processing, and discharge of this material. Dust control from silica-bearing materials is facilitated when these materials are contained and prevented from falling onto floor surfaces that are traversed by workers and vehicles. Even during material handling and processing of sand in mechanized systems there is potential for significant dust emissions from:

- Conveyor belt spillage and spillage at transfer points;
- Return belt shedding of adhered materials;
- Leaks in pneumatic transfer lines;
- Vibratory dispersal of dust from oscillating conveyors.

Material handling spillage can occur in relatively inaccessible or confined conditions, necessitating manual cleanup with its dust exposure hazards.

## **3.5 Ventilation of Silica Dust Sources**

Silica dust that is controlled at the source through local ventilation can be prevented from entering either the breathing zones of workers located close to those sources or the general inplant air environment.

Local exhaust ventilation to isolate and capture the dust sources is a method that is generally understood. Local supply air techniques which are equally essential for effective dust exposure control are not as well understood. A relatively new technique for supply air to fixed work stations called “supply air island” uses a low velocity distribution of air from a close overhead position either directly above or to the side and angled downward at the worker. This supply air envelops the worker, yet it does not interfere with exhaust hood capture and it reduces the need for disruptive portable, circulating fans. Wescast Industries, Inc. in Case

History B describes how they have successfully employed the supply air island approach to protect workers from silica exposure and are now continuing to refine it.

Integrated ventilation design involving area-wide balanced supply and exhaust is a strategy which Acme Foundry has advanced in its design of a ferrous casting finishing facility (Case History C).

Information on how to design foundry ventilation is available in a number of sources, among them:

- “Industrial Ventilation Manual of Recommended Practice” of the American Conference of Governmental Industrial Hygienists (ACGIH). This manual, updated every three years, is available at:

American Conference of Governmental Industrial Hygienists  
1330 Kemper Meadow Drive  
Cincinnati, Ohio 45240-1634  
513-742-2020  
[www.acgih.org](http://www.acgih.org)

- “Managing the Foundry Indoor Air Environment” written by the 10Q Safety and Health Committee of AFS. Sections 5 through 7 of this manual include detailed discussions concerning the use of ventilation to control dust emissions in sandcasting operations. This manual is available at:

American Foundry Society  
1695 N. Penny Lane  
Schaumburg, IL, 60173  
800-537-4237  
[www.afsinc.org/estore](http://www.afsinc.org/estore)

### **3.6 Silica Exposure Control Program Strategy**

The ideal situation for gathering exposure samples and assessing the need to improve exposure control is for all of the silica control measures used at a foundry to be in place and functioning as designed during exposure monitoring. Sampling under this condition is termed “baseline exposure monitoring.” Where this occurs, exposure sampling in turn is able to define the capability of the exposure controls. If such sampling indicates an overexposure condition, exposure control improvements are thereby shown to be warranted. If, on the other hand, not all controls are functioning properly at the time of the sampling, a condition is created which does not define control capability and is very difficult to interpret.



Figure 3-3 presents a flow chart associated with use of the baseline exposure monitoring approach. On the bottom of the figure, the logic is presented in a flowchart. On the top of the figure, the procedure is presented as a series of steps to be taken.

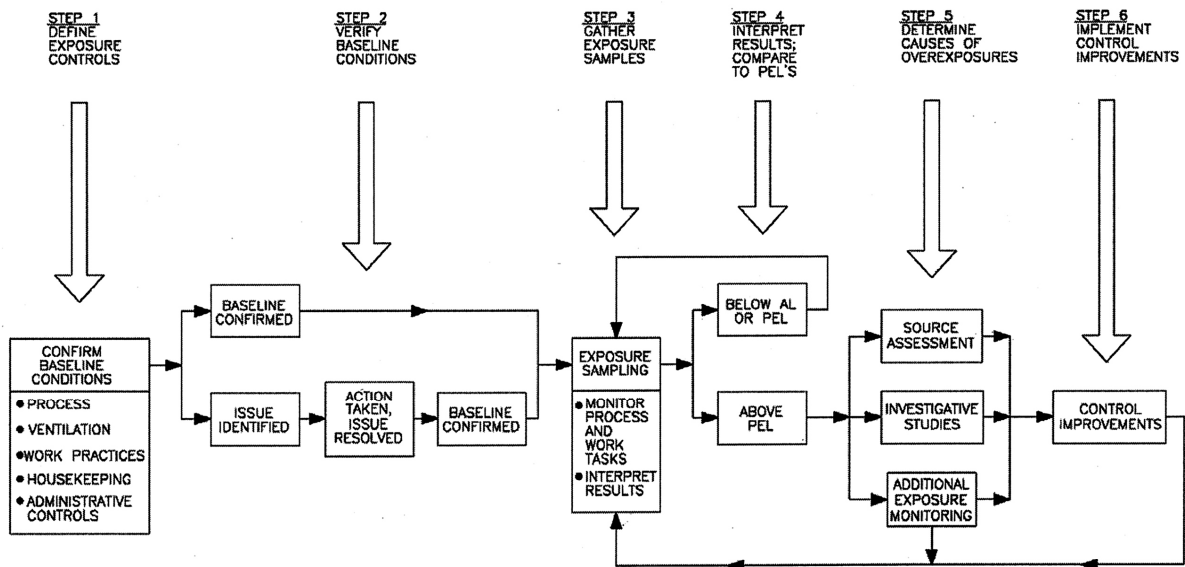
As can be seen in Step 1, the baseline conditions include all facets of exposure control. Continuous operation at baseline conditions is sought, not focus on “doing it right” during exposure testing. Checklists are useful to confirm that baseline conditions are being met continuously. In some foundries, the operation of ventilation devices is decentralized and it may not be obvious that all of the needed ventilation devices, including powered makeup air devices, are operating as planned. Some foundries conduct regular, periodic ventilation assessment and when they follow-up on ventilation system issues identified by these evaluations, these foundries achieve continuous compliance with baseline conditions. The AFS Manual, “Managing the Foundry Indoor Air Environment” presents a strategy in Section 9 for maintaining ventilation system performance.

Step 2 allows for correction of issues prior to sampling. In certain cases, it may be necessary to continue to Step 3 without having resolved all issues when the time period to resolve an issue would unreasonably postpone the assessment.

The need to thoroughly monitor the exposure sampling conducted in Step 3 which was discussed in Subsection 2.5 cannot be overemphasized.

If overexposures are identified in Step 4, further effort is required in Steps 5 and 6 to evaluate and resolve exposure sources. Foundry experience has shown that it is cost effective to demonstrate potential silica exposure control improvements on a prototype basis before instituting them on a permanent basis. Case History A by Kennedy Valve describes a controlled development program undertaken in an isolated setting in a foundry to optimize the control of grinding dust prior to implementing the new technique in the entire grinding operation. Case History D by Grede Foundry describes a program which was implemented to upgrade an existing degating and sorting station, using exposure monitoring to assess and redirect the effort.

## IMPLEMENTATION STEPS



**Figure 3-3**  
**Air Contaminant Exposure Control Program**

**Case History A**  
**Silica Dust Control Improvement:**  
**Grinding of Iron Castings with Portable Tools**

**Kennedy Valve**  
**Elmira, New York**

**Arne Feyling, Assistant General Manager**  
**Mike Maziur, Plant Manager**  
**Tom Shaw, Health and Safety Manager**

**Introduction**

The control of airborne silica dust is a constant challenge in a sand casting foundry, where large volumes of sand are used in the molding processes. Kennedy Valve, a sand cast iron foundry that manufactures fire hydrants and valves for waterworks applications, has developed an innovative approach to the ventilation of its grinding operations that has helped to overcome some of these challenges. This case study will describe the approach and successes achieved by Kennedy Valve, in the hope that others who face similar challenges can benefit from Kennedy Valve's efforts.

Kennedy Valve is a division of McWane, Inc. a manufacturer of iron pipe, valves, hydrants, fittings, fire safety equipment, and other products for the plumbing and waterworks industries, operating thirteen foundries and numerous other manufacturing facilities across the U.S., Canada, China, and Australia. Kennedy Valve, part of the Valve and Hydrant Group, employs more than 430 employees, who produce first-rate products for cities and towns across the United States and around the world. Elmira, New York, has been Kennedy Valve's home for 100 years.

McWane, Inc. is committed to achieving the highest standards for health and safety in each of its facilities through the use of cutting edge programs that meet and exceed regulations. To address these critical issues, they have implemented a comprehensive Environmental and Safety Management System based on ISO 14000, OHSAS 18001, and OSHA's Safety Management Guidelines. One of the foundations of this EHS Management System is the commitment to search for innovative engineering solutions that will reduce hazards in the workplace. The demanding foundry environment presents unique safety and environmental challenges. To meet these challenges, Kennedy Valve involves all levels of employees in safety and health teams and other facets of the overall safety program. Health and Safety Department staff, along with external experts, coordinates all of the industrial hygiene and occupational health programs.

**Search for an Exposure Reduction Approach**

One challenge that frequently arises in a sand foundry is the control of airborne silica resulting from the chipping and grinding of castings, particularly when portable tools are used. While workers have been protected in these jobs through a combination of personal protective gear (primarily respirators)

and ventilation, Kennedy Valve has been searching for an engineering solution that would provide a more consistent and higher degree of protection for workers against overexposure to silica at these work stations. Finding an engineering solution for this problem proved especially difficult because of the limitations of current ventilation controls for this process. Ventilated tools have not yet proved feasible for this work, while the protection offered by stationary exhaust hoods such as downdraft or backdraft benches is limited if the stream of particles (grinding swarf) emitted from the tools cannot be continuously directed at the exhaust openings. Thus, Kennedy Valve determined that it needed to devise a new approach for ventilation controls for portable grinding tools on sand castings nearly three feet wide.

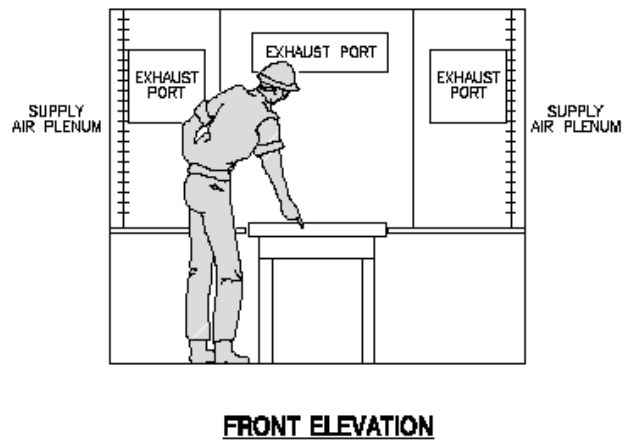
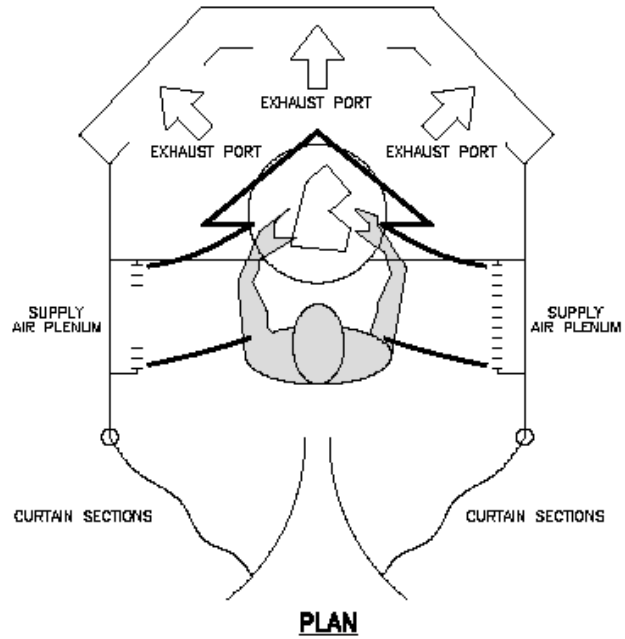
Kennedy Valve augmented its own technical team with a foundry ventilation consultant to investigate the feasibility of silica exposure reduction from the grinding process. The foundry already employed grinding benches with backdraft slots; however, they sought more effective controls.

A broad search of information on available ventilation control methods for grinding with portable tools resulted in identification of a ventilation approach which had been demonstrated to be effective on control of emissions from another foundry process, called air carbon-arc gouging, conducted on work benches with steel castings. This method had been identified and documented by the National Institute for Occupational Safety and Health (NIOSH) as Case History #6 in their "Evaluation of Occupational Health Hazard Control Technology for the Foundry Industry" (DHEW Publication No. 79-114).

The scarfing process is as difficult to control as portable grinding, if not more so. The tabletop booth presented in NIOSH Case History #6 incorporated a wrap-around design, a three-foot diameter turntable for casting repositioning, and a unique way of introducing supply air so that it swept past the worker on both sides of the body (Figure A-1). This design appeared to incorporate the best features seen to date on a ventilated booth. It was decided to determine whether the design could satisfy the ventilation requirements for grinding castings at Kennedy Valve.

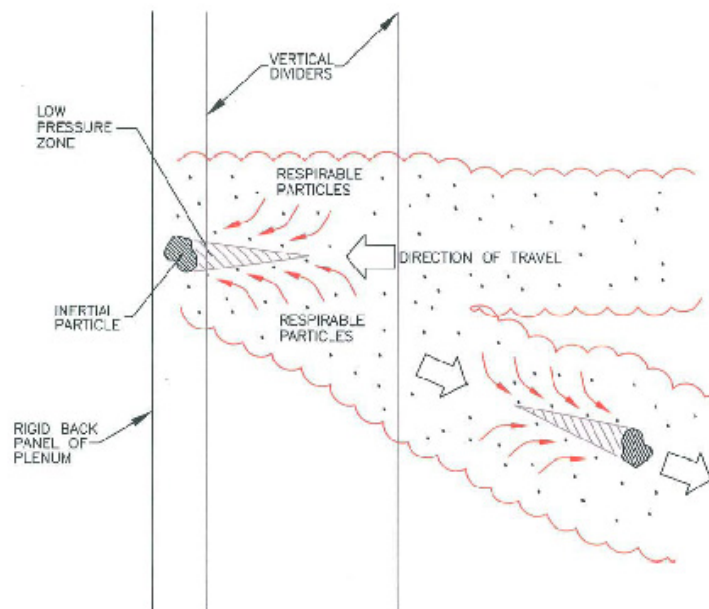
There was one design characteristic of the booth that NIOSH evaluated on fume-producing processes that appeared as though it could create a rebounding issue when applied to grinding. That characteristic was the use of spaced exhaust openings along flat collecting surfaces. The situation can be better understood with the aid of Figure A-2. Respirable-sized dust follows in the low pressure wake of the large (inertial) particles in the grinding swarf. If the large particles rebound off of a solid wall, the dust will rebound with them and head toward the worker's breathing zone.

Mike Sylvester, an industrial ventilation designer who is also a firearms instructor, offered a way to address this issue. He cited the method of stopping air rifle pellets using an energy-absorbing hanging curtain. In this case, if the grinding swarf impacted a hanging curtain, the large particles would be stopped "in their tracks" and not able to rebound (Figure A-3). The fine dust particles at that point would be pressed up against the curtain. If vertical dividers were employed to restrict sideways air motion, the fine dust could be readily directed through suction into exhaust plenums both above and below the impact zone for the grinding swarf and be removed from the bench (Figure A-4).



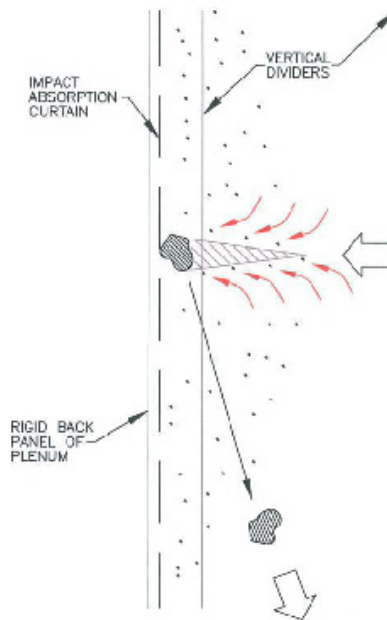
**GRINDING HOOD WITH SUPPLY AIR PLENUMS**  
**NIOSH FOUNDRY VENTILATION ASSESSMENT**

**Figure A-1**



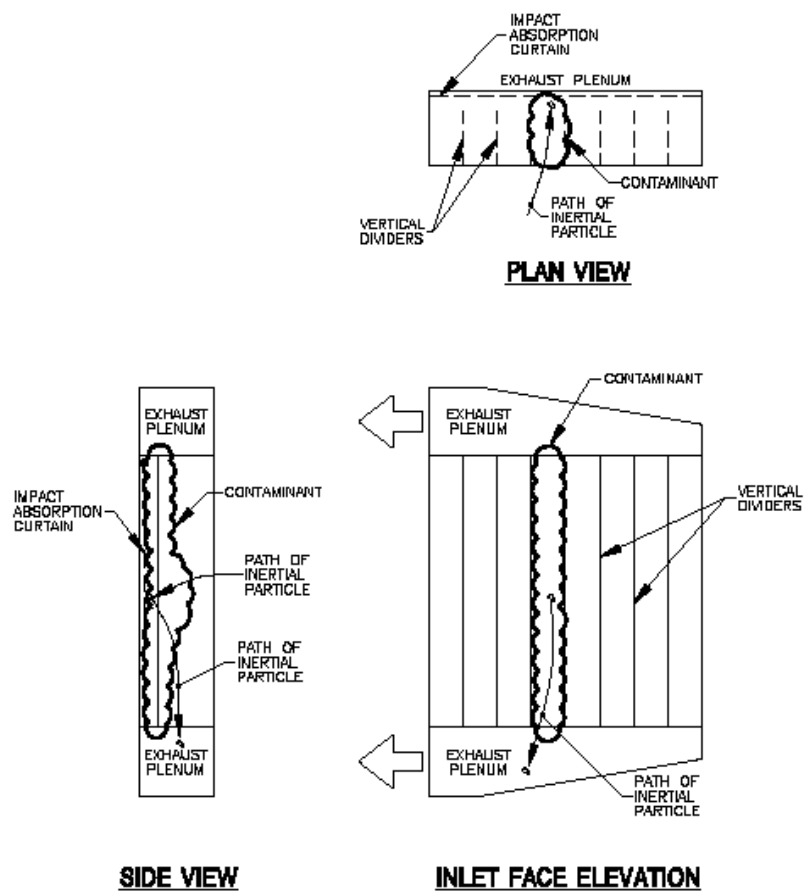
**EFFECT OF INERTIAL PARTICLE REBOUND FROM  
A RIGID SURFACE CAUSING  
RESPIRABLE PARTICLES TO ESCAPE FROM  
THE EXHAUST PLENUM**

**Figure A-2**



EFFECT OF INERTIAL PARTICLE NOT REBOUNDING  
FROM A ENERGY ABSORBING SURFACE CAUSING  
RESPIRABLE PARTICLES TO REMAIN IN  
THE EXHAUST PLENUM

Figure A-3



**EXHAUST PATTERNS IN THE GRINDING  
HOOD EQUIPPED WITH IMPACT ABSORPTION  
CURTAINS TO TRAP RESPIRABLE PARTICLES  
IN THE THE EXHAUST PLENUMS**

**Figure A-4**



### **Demonstration of Dust Control Effectiveness**

Figure A-5 shows the method in the form considered suitable for the demonstration phase at Kennedy Valve. A prototype grinding booth was constructed for the demonstration and subsequently tested in an isolated part of the facility, where the potential for cross-contamination from any other silica-producing process was eliminated. Figure A-6 shows the grinding booth following the prototype demonstration, in its current form for production grinding. Castings are moved on and off of the work surface by overhead hoist. After the castings are set down on the workbench, they may be rotated via a turntable for better access to surfaces to be ground, to assist the ergonomic aspects of the work, and to allow the grinding swarf to be directed as far as possible into the capture zones. The worker can initiate the turntable using a “bump” switch which does not require hand use and, thus, does not slow down the grinding operation.

In the process of evaluating the ventilated grinding booth, respirable dust was measured in the breathing zone of the grinding operator and in the general background air next to the grinding booth. For this purpose, two real-time particle sensors (Thermo Electron Corporation Model PDR 1200 dataRAM) were used. Each sampling inlet was fitted with a cyclone to remove the non-respirable portion of dust. These instruments simultaneously logged respirable dust during grinding operations that were also video recorded. The particle sensor data was subsequently downloaded to a computer and graphed.

A battery-powered (SKC) pump drew air at a regulated flow rate through each instrument to produce an active sample. The pumps were calibrated before and after each measurement session using a Mini-Buck M-30 primary standard calibrator.

Since the particle sensors did not provide a real-time measure of silica in the dust, it was used to evaluate general dust control from the process. Follow-up testing would ultimately be necessary to determine the time-weighted-average (TWA) of respirable silica dust throughout a workshift in which both respirable dust levels and silica content of that dust were measured and averaged.

The first testing was done on a single type of casting (i.e., large fitting with 4-inch flanges) selected to eliminate variability of the work in the initial assessment. Figure A-7 shows personal worker exposure to respirable dust during the grinding of multiple castings over a 35-minute duration. Multiple tool positions were used as the operator removed material using a portable grinder from all internal and external surfaces around the casting. The resultant data profile consisted of a relatively level baseline exposure with a number of spikes. The time-weighted average throughout this grinding session was  $0.455 \text{ mg/m}^3$ , a value which was relatively independent of the rapidly decaying data spikes (i.e., the exposure associated with the spikes did not measurably affect the average dust exposure). From a visual standpoint, the only obvious exposure was associated with the manner in which dust was emitted from the inside of the casting in a “chimney effect” during internal grinding. This dust was discharged very close to the breathing zone before it was withdrawn by the push of the supply air and the pull of the hood exhaust. The dust produced by one particular task was directed in such a way that the exhaust hood could not directly capture it.

The task in question involved grinding a portion of the casting which was overhanging the front edge of the bench. The grinding swarf was directed downward toward the floor. This type of grinding did not appear to affect the dust exposure to the same extent that the chimney effect did, but the dust induced into the grinding swarf was definitely fugitive to the ventilated grinding bench. For this reason and also because of the anticipated housekeeping issue associated with directing grinding swarf at the floor, the decision was made to alter the basic prototype bench to add a small hood in front of the grinding bench to capture the grinding swarf and the dust induced with it when grinding was conducted on the overhanging portions of castings (Figure A-7).

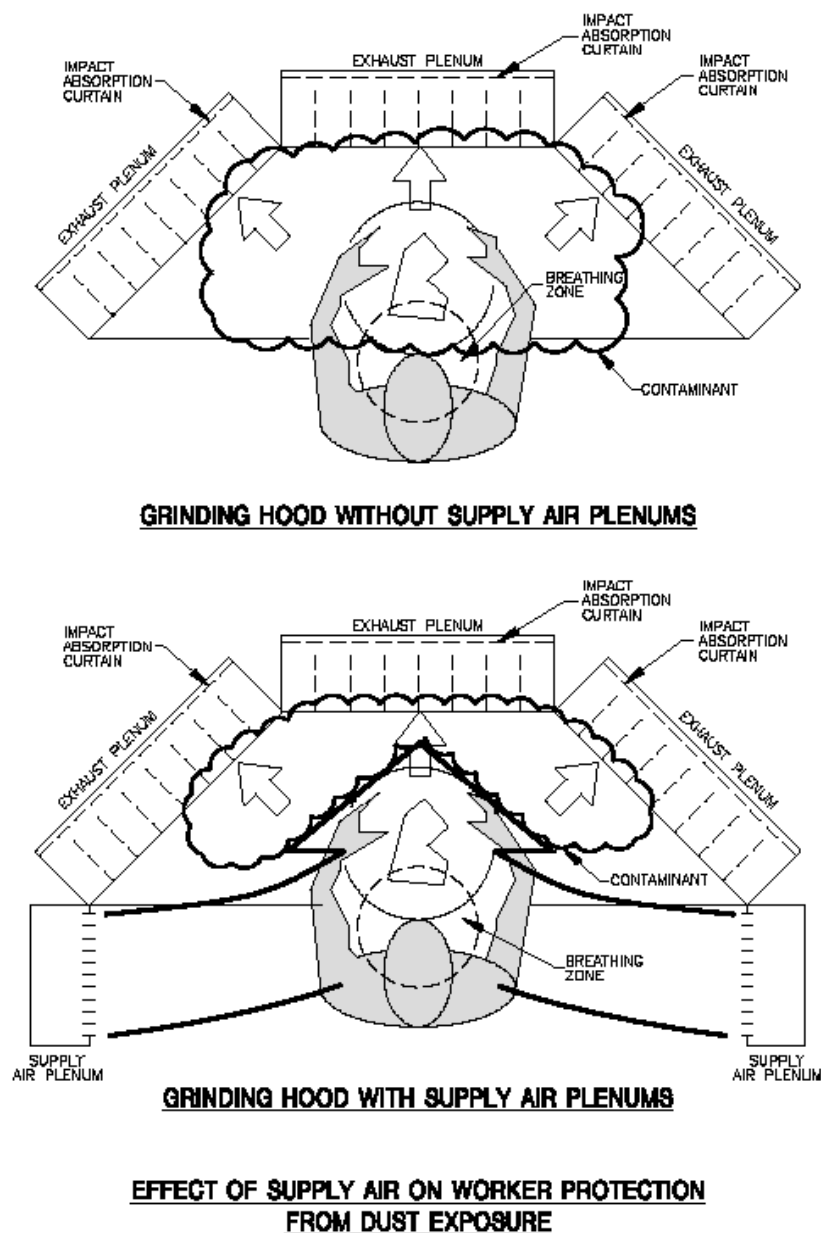


Figure A-5



Production model of grinding booth during grinding of a casting.

Figure A-6

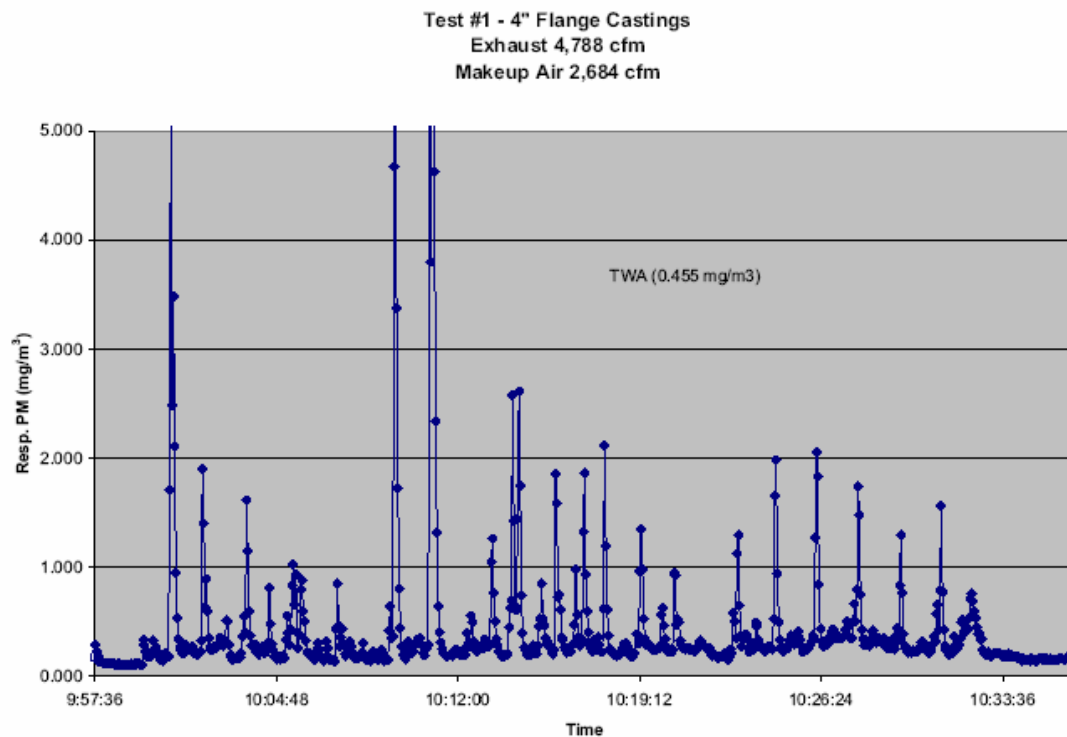


Figure A-7  
Real-time respirable dust exposure with exhausted workbench with supply air.

The tests also included measurements made without the supply air operating. This data is presented as Test #3 and is shown with the time axis expanded almost threefold (Figure A-8). The absence of supply air almost doubled the average dust exposure level. It is postulated that supply air improved the speed of dust removal by pushing the air which was just in front of the operator into the capture hood, thus reducing the residence time of this potentially dust-laden air in the breathing zone.

After the supply air was validated as important to the protection offered by the ventilated bench, it was decided to try to optimize the interworking of the exhaust and supply airstreams to enhance the benefit received. It had already been established that testing would be conducted over a range of exhausts from roughly 2,000 to 6,000 cubic feet per minute (CFM). Dampers had been installed to adjust airflow rates and a flow meter (TSI Thermoanemometer) was used to measure these rates. Three exhaust rates were chosen for test and at each of these exhaust rates baby powder was used to set supply air at what appeared to be the most effective, non-turbulent pattern.

The time-weighted-average dust concentrations measured during grinding of the test casting at three different ventilation rates are presented in Figure A-9. The lowest personal dust exposure occurred at the middle ventilation condition. This finding was consistent with expectations for, and observations of, the capture efficiency of the grinding bench. At the lowest ventilation rate, evacuation of dust appeared to be complete but not rapid. The dust seemed to dwell above the bench briefly before being extracted. At the other end of the spectrum, the highest ventilation rate produced a near-turbulent condition which tended to spread the dust. Area samples taken simultaneously with the personal samples showed consistent readings for the lower two ventilation rates, with a sharp increase at the highest ventilation rate. This finding is consistent with the observations summarized above, which suggested that turbulence could lead to dust loss from the capture zone of the bench.

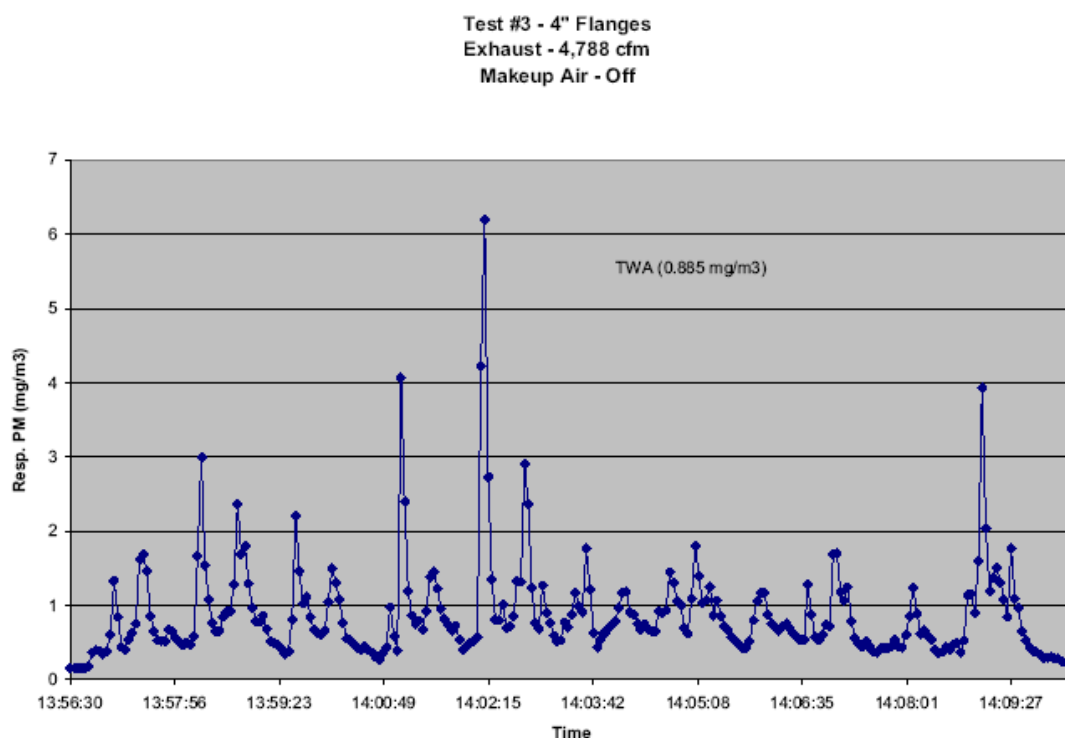
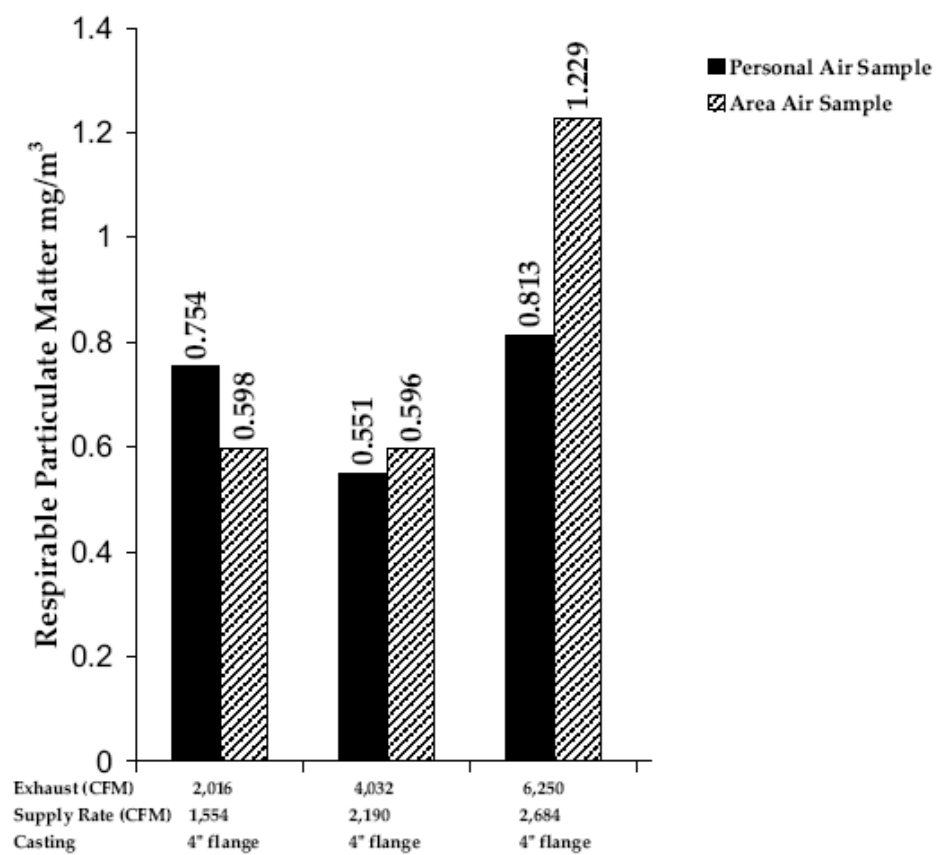


Figure A-8  
Real-time respirable dust exposure with exhausted workbench and no supply air.



Measurements of Respirable Particulate Matter for  
Three Different Castings and at Different Grinding  
Bench Ventilation Rates

Figure A-9

### **Full Scale Operations**

After successful completion of the prototype test program, fifteen production booths were constructed and installed in the renovated finishing area. These benches have consistently controlled silica exposures during grinding to below OSHA's Permissible Exposure Level (PEL) for Kennedy Valve's grinding needs when operating at exhaust rates down to 3,000 CFM and supply airflow rates at half of that flow rate. The supply air is provided by a tempered (i.e., heated in winter) makeup air unit with proportional heater control for steady temperature conditions.

The particles which are "stilled" through contact with the enclosure walls readily fall out into collection areas in the workbench. This feature has reduced the loading of abrasive particles on the filter media in the baghouse. Prototype demonstration is recommended for incorporating an approach such as this into different foundry settings. The expected effectiveness would be dependent on a number of variables, key among them:

- Extent of sand burn-in/burn-on on the castings.
- Effectiveness of shot blasting in removing sand material from surfaces.
- Amount of grinding performed on a casting.
- Proportion of grinding internal to the casting.
- Ability to perform all grinding on top of the workbench.

### **Conclusion**

Kennedy Valve workers performing this grinding have long been protected via controls like a respirator program. Only this past year, through the team effort of internal and external resources, has the use of engineering controls been able to reduce worker exposures to levels consistently below the current OSHA PEL for silica. The worker in Figure A-6 voluntarily continues to wear the air-supplied helmet. Workers appreciate the eye and face protection and the stream of air circulating around the head. Spikes in exposure are not impossible with any local ventilation method applied to manual processes; the air supplied helmet provides a safety factor against these spikes. Although not easy, we are closer to our goal of state-of-the-art processes, including worker protection, for cleaning a variety of castings.





## **Case History B**

### **Heat Relief and Improved Air Quality in Foundries**

#### **Wecast Industries, Inc.**

#### **Wingham, Ontario, Canada**

##### **Michelle Schaefer, Mechanical Projects Coordinator**

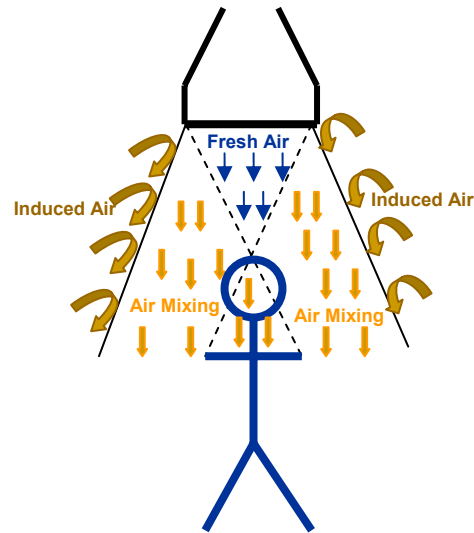
Wecast Industries, Inc. (Wecast) is a Canadian corporation providing exhaust solutions for an extensive range of engines in the global automotive market. We are the world's largest supplier of cast exhaust manifolds for passenger cars and light trucks. Wecast has business units in North America, Europe, and Asia.

Wecast is committed to providing a healthy, safe and environmentally sound workplace for all employees. The safety policies and programs at Wecast are based on the belief that all injuries, occupational illnesses, and accidents can be prevented. In support of this commitment, Wecast focuses on the following objectives:

- Continuously improve health, safety and wellness performance.
- Meet or exceed applicable laws, regulations and standards for environment, safety, and health.
- Communicate information and involve appropriate levels and functions on health, safety, and wellness initiatives.
- Routinely review and assess the Health and Safety Policy to ensure continuing suitability, effectiveness and success.

My responsibility to this commitment, as a member of the Engineering Team, is to provide technical support and expertise to continuously improve Health and Safety in the workplace. I work closely with Maintenance and the Health and Safety Department to ensure that the ventilation systems in our facility are working properly, and to continually improve those systems.

After our manufacturing facility started up in 2000, the employees were very dissatisfied with the cooling that was provided at their work stations. There were large volume supply air plenums blowing air onto the workers, however, the supply air plenums were located too high off of the floor. This allowed for air mixing of the clean supply air. By the time the air reached the breathing zones of the employees it was hot and stale, providing little or no cooling. This air mixing occurred due to an induction effect which is shown in Figure B-1. Surrounding air is induced into the moving air stream at its boundary, creating a mixing zone of fresh and surrounding air. At some point, all of the fresh air is mixed with the surrounding air. Such was the case of the elevated supply air plenums at Wecast. The fresh air was all mixed into the work zone air prior to the air contacting the workers.

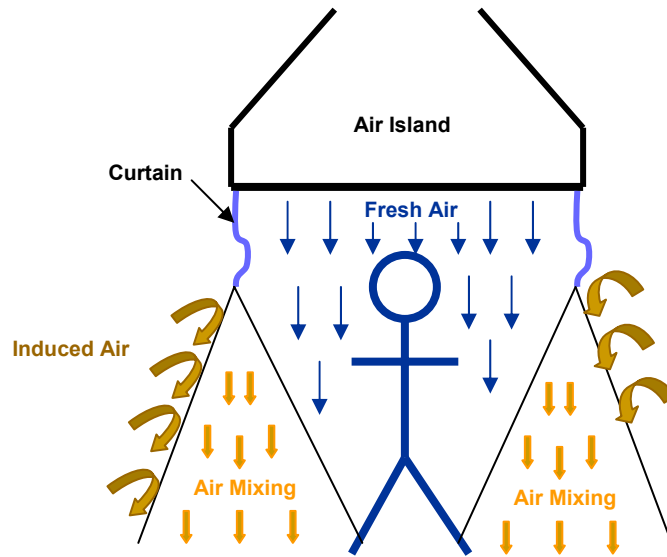


**Figure B-1**

**The size of the mixed air zone around the worker depends on the velocity of the supply air, the supply air distribution area, and the distance between the supply air discharge point and the worker.**

The Joint Health and Safety Committee met to discuss issues associated with the ventilation systems. As project manager, it was my responsibility to investigate, design, and execute a solution before spring. My challenge in a participative management system was to get input from all the stakeholders on the proposed solution, and implement it within a tight time frame. Personal cooling in the workplace is a tough problem to solve; it is very difficult to get a consensus among a large group of employees. The level of heat stress an individual feels depends on personal characteristics such as age, weight, fitness level, medical condition and acclimatization to heat. The workers at Westcast rotate jobs, and, therefore, a large spectrum of employees share workstations. The solution would need to protect the majority of the workforce. After some research, a consultant was contacted with expertise in foundry ventilation. He suggested the *air island* approach for cooling and controlling air contaminant exposures. The *air island* approach uses low velocity air supplied directly above the worker, to constantly supply fresh air to the breathing zone (Figure B-2). This technique would cool our employees more effectively, and help reduce the silica and SO<sub>2</sub> exposures.

At department team meetings I presented the pros and cons of high velocity cooling vs. low velocity cooling. High velocity supplied air stirs up dust and debris in the air, contaminating it before it enters the breathing zones of the workers. High velocities also negatively affect exhaust systems which are located near the air supply. Low velocity air may not feel as comfortable for the few days a year when the outdoor temperatures exceed 30°C (86°F), but for the majority of the year low velocity supply air plenums provide cleaner and cooler air. The workers agreed to use the *air island* approach and *air islands* were then implemented.



**Figure B-2**

**The goal of supply air island design is to limit the amount of air mixing that occurs before the fresh air enters the breathing zone. Curtains extending down from air islands can lower the point at which air mixing starts.**

Supply *air islands* are useful where employee work stations are relatively fixed, both in situations where exhaust control at the source is feasible and when it is not. Where it is physically impossible to locate a supply air island directly overhead, it may be moved to the side and angled down at the worker. The best results occur when the pattern is straight down.

The challenge with this technique for personal cooling is perception. Workers prefer high velocity air; it is felt immediately on the skin as it evaporates the sweat. Low velocity air, although cleaner with one air exchange per minute, does not feel as cool to the body.

Some air quality measurements were taken to quantify the actual mixing which took place when a supply air island was placed over a work station. In this case, the work station was a workbench area in the melt department. The 4-foot by 6-foot air supply island was installed in front of the bench (Figure B-3). The side to the left of the bench was blocked off completely between the supply air island and the floor; the back was also blocked off, as well as the back half of the right side. The front area was completely open.

The clean air contained very low levels of respirable dust and, thus, measurements of dust levels beneath the supply air island represented the extent of dilution which took place between supply air and room air. We used a Thermo Electron DataRam 2000 to measure the respirable particulate matter (PM) levels. For measurement purpose, the area under the air island was divided into three levels, 24," 48," and 60" from the floor level. The air island height was 72 inches from the floor. Each level was then divided into a 6 inch grid in the x and y axis. We took measurements with the DataRam, and plotted them on a graphing program.

The data, shown in Figure B-4 and expressed as micrograms per cubic meter of respirable particulate matter, show the largest variance in respirable PM from front to back. The front area with no curtains and unrestricted mixing witnessed significant induced air. The air introduced at the back wall, on the other hand, retained its purity as it descended. The usefulness of a quantitative test method to study supply air introduction became apparent because none of these dilution effects could be seen visually. This test clearly demonstrated the value of the air curtains.

This information was ultimately reviewed at all the employee team meetings and led to the establishment of the following design criteria:

- Distribute 125 to 175 fpm of supply air, giving the operator one air exchange per minute.
- Locate supply air discharge point directly above the worker at about 7 feet above the floor. This will ensure fresh air supply without undue mixing.
- Temper supply air.
- Extend curtains down to shoulder height around the perimeter of the island if possible to maximize the fresh air zone (Figure B-2).



**Figure B-3**

**Supply air island at workbench in melting area where fresh air dilution was studied.  
(Right side curtain, normally down, was raised to reveal the inside of the booth)**

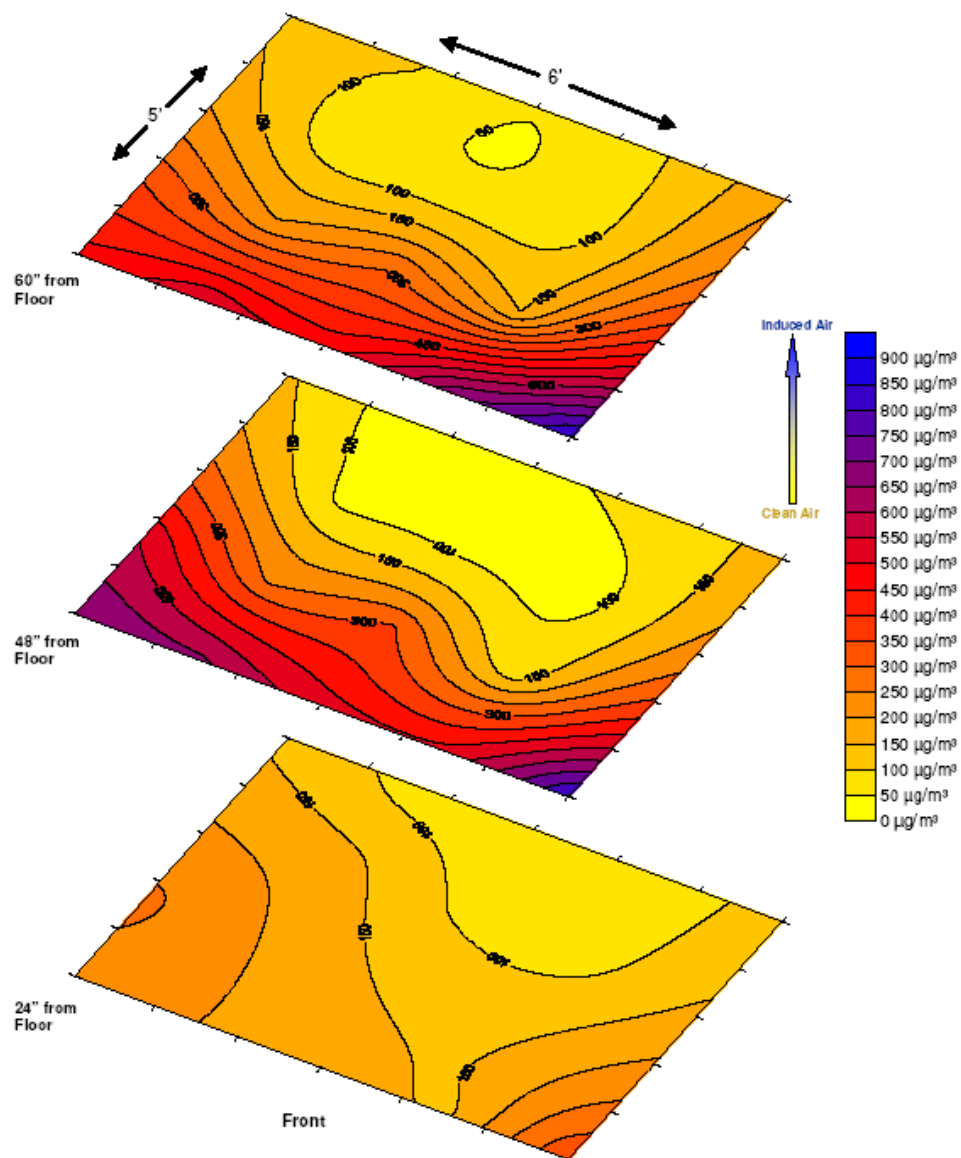
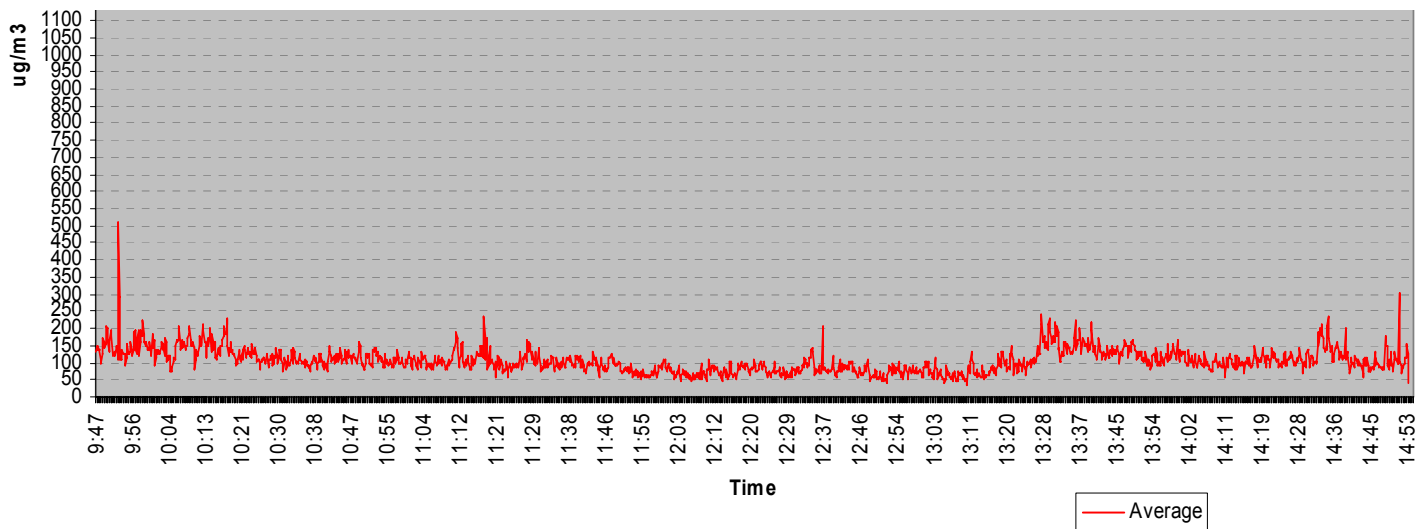


Figure B-4  
Profiles of concentration of respirable particulate matter measured at several distances  
beneath the supply air island shown in Figure B-3.

The implementation of the *air islands* in the Finishing Department was very successful (see Figure B-5 for some sampling results). In the case of sorting, a dynamic record of PM concentration was gathered by placing the real-time monitor at a fixed location beneath the supply air island and above the worker. The data shows that the diluted air quality at this point was very stable and consistent (Figure B-5).

## AIR SAMPLING AT MANUAL SORTING



**Figure B-5**  
**Real-time recording of particulate matter in the supply air stream above a manual casting sorting operation.**

The project objective to increase cooling was moderately successful; the outstanding success with the *air island* project was the improved air quality. Westcast still has struggles on very hot summer days with the workers being dissatisfied with the cooling. We constantly work towards making improvements with the ventilation systems. The Health and Safety Department expends great effort heightening the awareness of foundry staff concerning the need to cooperate with the program in place to control silica exposures. Workers are educated on the need to employ the ventilation methods which the company provides and to provide feedback. Employee training occurs both formally and informally on the attributes of our particular ventilation system operations.

Our foundry has taken large strides to improve air quality; most fixed work stations have supply *air islands*, and we continue to brainstorm continuous improvement ideas. The initiative for 2007 is to investigate retrofitting our makeup air units with evaporative coolers, to address the cooling issue. We are committed to having a safe and healthy work environment for our workers, and are dedicated to continuing that progress in the future.

## **Case History C**

### **Clearing the Air at Acme Foundry Integrated Engineering Design of a New Casting Cleaning and Finishing Facility**

**Acme Foundry, Inc.  
Coffeyville, Kansas**

**Don Pusa, Vice President, Engineering  
Mark McCullough, Maintenance Supervisor**

Acme Foundry, Inc. is located in Coffeyville, Kansas, and produces 19,000 tons/year of gray iron castings, primarily for the hydraulic valve industry. The foundry has recently planned and implemented an expansion of its cleaning and finishing area to meet the increasing casting demand. From the inception of this project, Acme Foundry committed itself to creating a processing facility that would be a safe, productive, and desirable workplace. Accordingly, engineering was coordinated so that appropriate consideration was given to, among other things, material flow, ergonomics, silica dust exposure, stack emissions, noise, climate control, and lighting. What has resulted from this integrated engineering program is a production facility that meets company goals and satisfies the needs of customers and the community-at-large. This article is intended to summarize the program, highlighting some of its features and test results.

#### **Engineering Effort**

The engineering effort was supervised by Don Pusa and was supported by plant engineering and maintenance staff. Outside consultants were employed as needed. A team was thus formed which assured the desired project integration by deliberating all engineering issues face-to-face to achieve consensus on the design prior to any construction commitments by the foundry. After design concepts were finalized, plans and specifications for construction were drawn up and used to solicit competitive bids.

#### **Cleaning and Finishing Processes**

The cleaning and finishing department was earmarked for expansion prior to undertaking a planned molding department renovation and expansion. From a casting processing standpoint, the expansion of cleaning and finishing began downstream of the desprueing and shot blasting operations. After castings are blasted, they are now segregated by size as they are transported into cleaning and finishing. Large castings (50 to 300 pounds) move along roller conveyors to casting grinding booths, where they are hoisted onto ventilated workbenches (Figure C-1).



Small castings (2 to 50 pounds) are moved on conveyor belts to an elevated sorting and inspection station (Figure C-2). From here, castings slide down chutes, first to snag grinding stations (Figure C-3) and from there to ventilated hand finishing benches. A series of workstations within the room are dedicated to detailed inspections of the internal cavities of valve and cylinder castings, using optical magnification devices (Figure C-4). Castings arrive in the inspection department in customer containers, which group castings throughout the quality control and shipping steps. Layout of the room was focused on material handling; however, consideration for noise control resulted in isolating the powered cleaning stations from final inspection operations.



**Figure C-1. Large casting grinding is done on ventilated workbenches in semi-enclosed booths (center) and in enclosed booths (right).**





**Figure C-2. An elevated sorting conveyor is equipped with a continuous, overhead “air island.”**



**Figure C-3. Snag grinding stations with ventilated hoods and overhead “spot” ventilation drops.**



**Figure C-4. An inspection station equipped with an exhaust hood and air drops.**

### **Dust Control and Climate Control**

All dust-producing cleaning and finishing operations are locally exhausted (98 stations). The close capture hoods employed were designed based on parameters recommended in the “Industrial Ventilation Manual” of the American Conference of Governmental Industrial Hygienists (ACGIH). The hoods are manifolded and ducted to a series of air cleaners, most of which are located on an elevated mezzanine within the department. The indoor location was selected because it was desired to recirculate the cleaned exhaust back into the foundry.

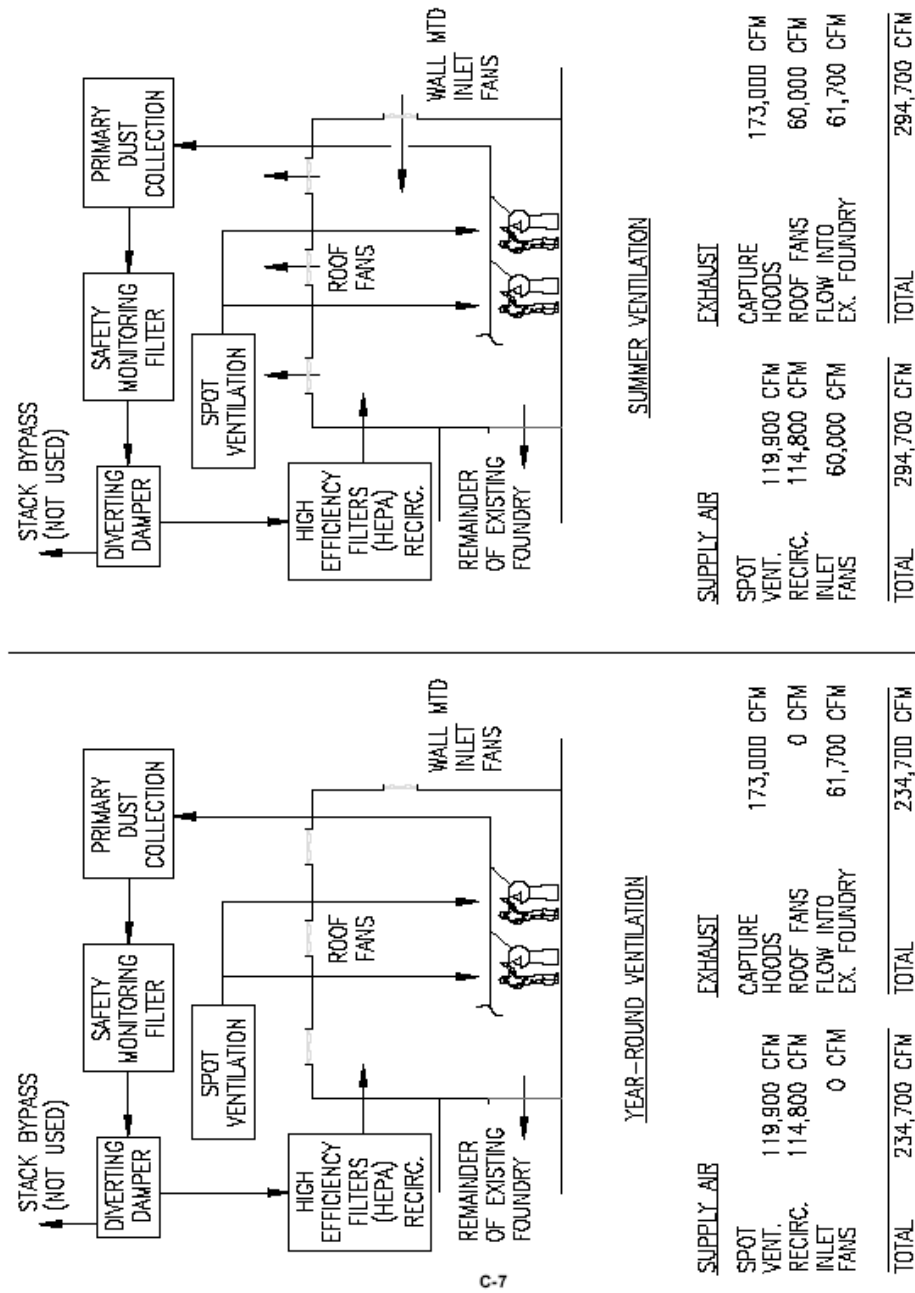
Cartridge-type collectors were employed to accommodate the available height of the mezzanine. One air cleaner, a non-recirculating baghouse handling snag grinders, was located outdoors. A baghouse was selected for snag grinding to guard against the bridging of cartridge pleats with fibers. Bridging has been known to occur with the use of the high-speed, vitreous bonded wheels used on foundry snag grinders. Precautions against blinding were taken in all cartridge filters by using open pleat designs.

Dust consolidation and disposal was simplified through the use of a pneumatic transport system. It transfers the collected dust from all of the air cleaners on the mezzanine to a single ground-level filtered receiver where the dust is automatically loaded into large sacks.

Recirculation of cleaned exhaust air back into the cleaning and finishing area is very reliable because of the use of a three-stage filter system. Air passing through the primary dust collectors is automatically refiltered by secondary dust collectors, referred to as safety monitoring filters (SMF). If a cartridge in a primary filter unit develops a leak, the SMF will filter out any dust leakage through its automatically recleaned filters and signal that there is a leakage. High efficiency, particulate air (HEPA) filters are employed as a final stage, to backup the recirculation system.

The air mass balance of the new casting cleaning facility is presented in Figure C-5. The facility has positive pressure in those foundry areas that are attached to the system. This pressure is created by tempered (i.e., heated or evaporatively cooled) makeup air units, which direct air to 98 individual adjustable air drops at the workstations. These air drops are preferred by workers because they are located close above their heads and are individually adjustable in terms of amount and direction of the air. Their use completely eliminates the need for pedestal fans to cool workers. The roof fans and sidewall supply fans provide summer heat relief only.

The entire ventilation system is continuously monitored by a programmable computer with a touch screen. Airflow parameters are controlled within preset ranges, with alarms to indicate any out-of-range parameter.



**Figure C-5**  
**Air Mass Balance for New Cleaning and Finishing Facility**

### **Ventilation System Performance**

Following completion of construction and commencement of process operation, air sampling was conducted to assure that stack emissions met the limits set by permit and that exposure of the workers to respirable silica met the Occupational Safety and Health Administration's (OSHA) permissible exposure level (PEL). Worker training is ongoing in the new facility to educate workers how to process a myriad of different size and shape castings while conducting the work in such a way that the maximum effectiveness of exhaust capture hoods is realized.

### **Summary**

Acme Foundry, its employees, customers, and neighbors are reaping the benefits of a well-engineered foundry process addition. The same good results are anticipated for the ongoing program of expanding and upgrading the foundry's molding and casting department, which is being conducted in the same integrated fashion.



## **Case History D**

### **Ventilation Upgrade Reduces Silica Exposure at Grede Foundries, Inc. Reedsburg, Wisconsin**

**Peter Mark, Sr. Safety, Health, and Environmental Engineer**

Grede Foundries, Inc. was established in 1920 and is an international leader in the foundry industry. Grede has eight foundries in the United States and a joint venture in Mexico that produce gray iron, ductile iron, steel, and aluminum castings. The Reedsburg, Wisconsin, plant was acquired by Grede Foundries in 1951 and in 1954 was converted to produce ductile iron castings. The 300,000 square-foot facility can generate up to 130,000 tons of ductile iron castings: calipers, crankshafts, flanges, yokes, bearing caps, carriers, cases, knuckles, and exhaust manifold castings per year.

The safety and health culture established at Grede Foundries can be summed up with the following statement: *"No job is so important and no service so urgent that we cannot take time to perform our work in a safe and healthful manner."*

Grede's safety record has been continually improving for more than a decade. With the use of a specially-designed safety manual, specific training, attitude seminars, safety audits, certifications, hard work, and commitment, Grede has reduced the incidence of OSHA recordable cases to 1.9 cases per 100 employees per year. The national average for iron and steel foundries is 14.8.

Although the company's record exceeds the industry average, Grede believes safety and health is a managed function and the goal is to manage accidents and job-related illness out of the workplace. Part of this effort involves monitoring the air quality within the workplace. Grede Foundries has a very aggressive industrial hygiene testing program and works diligently to minimize employee exposures to hazardous chemicals using engineering controls, employee rotation and respiratory protection devices.

Over the last several years, the Grede facility in Reedsburg has been working to improve employee air quality (silica exposures) in the knockoff areas, concentrating on eliminating the source of the dust. Exceptional silica exposure reductions were made in the cold knockoff area from a Disamatic mold line. Process changes were made to achieve these exposure reductions and are detailed as follows.

#### **Process Background**

The knockoff process is conducted by one operator working within a booth. Much of the knockoff operation is completed by manually striking the castings against the edge of the vibratory conveyor or against the top of the metal sorting barrier. The trunk of the worker is bent slightly forward over

the conveyor during the course of the knockoff work. Dust is generated during the vibratory conveying of the castings through the booth as well as by the knockoff process itself. As much of the residual sand as possible is removed from the castings prior to entering the booth on a vibratory conveyor. Minimizing adhered sand is essential to protecting workers from dust exposure whose breathing zones are close to the dust source.

At the workstation, a local exhaust hood behind the conveyor was intended to pull dust back away from the worker and evacuate the dust (Figure D-1). Supply air was located above and behind the worker to support this airflow pattern and keep the air environment inside the enclosure well diluted. The exhaust rate from the booth was around 8,000 cfm (ft<sup>3</sup>/min). In order to allow the operation of an auto knockoff device on a monorail, the top of the side draft hood was angled back from the base (normally the top of a side draft hood angles forward from the base). The “opposite” angle of the side draft hood drew the emissions away from the point of dust generation (vibratory conveyor) in an arced pattern which raised the airborne dust toward the breathing zone prior to drawing the air into the capture hood.

The worker’s forward leaning of his upper body caused the air to “roll” in front of the operator and confine some of the dust generated by the process into the vicinity of the breathing zone. Makeup air was pushed unrestricted into the plenum over the workers head. Most of the makeup air exited the front of the plenum and went directly to the collection exhaust hood, which was believed to multiply the “rolling” action of the air in front of the worker. Much of the air behind the operator was stagnant and became saturated with dust and silica. When the worker stood up straight during process breaks his breathing zone was in the stagnant dust-saturated air.

### **Process Changes Made to Reduce Exposure**

The makeup air was redistributed through the air supply plenum over the worker’s head by dividing the plenum in two sections, front and back. The front section (closest to the worker) would have a controlled airflow velocity of 125 to 175 ft/min using 25 percent perforations and the back section would have a lower airflow velocity with 50 percent open perforations.

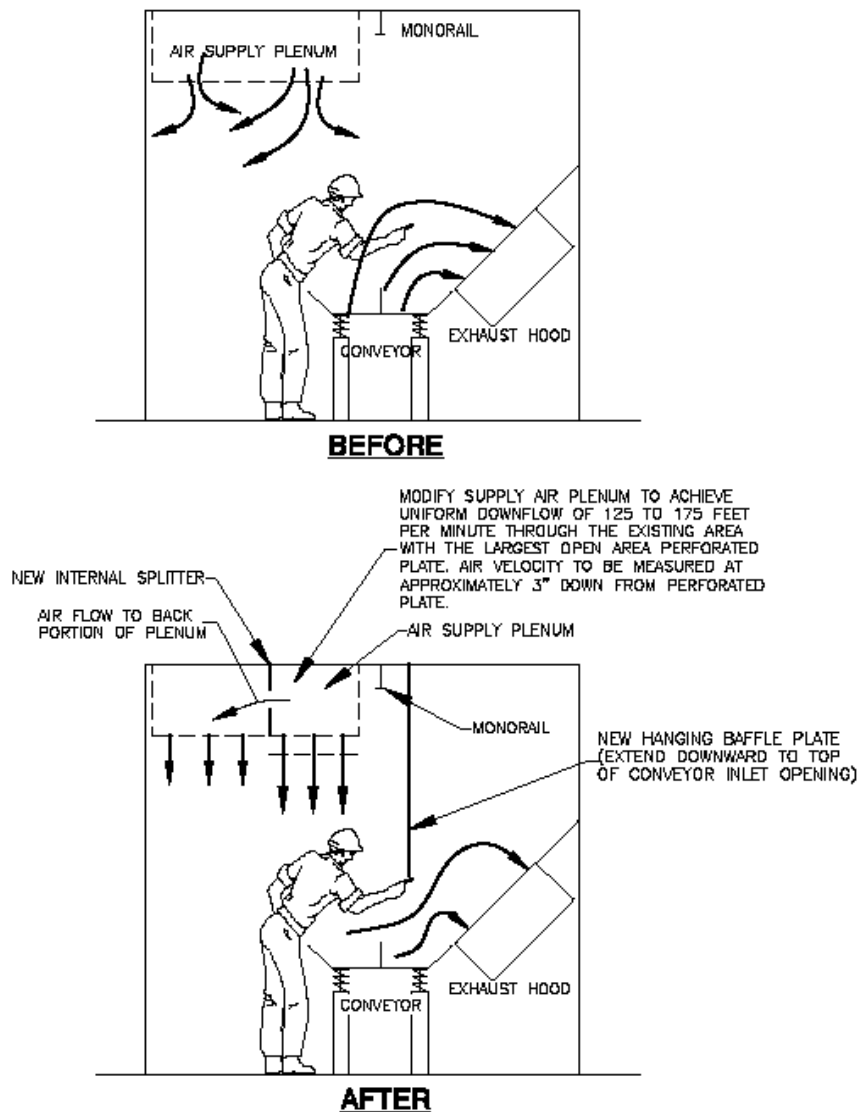
A baffle plate was added in front of the worker near the back side of the conveyor. The baffle plate extended from the ceiling of the booth downward to the middle of the exhaust inlet opening. A rubber material was used for the baffle plate to prevent injury if the worker accidentally struck the plate while raising his hand/arm during the knockoff process.

The redistribution of the air in the plenum above the operator caused all the air in the booth to move downward to about waist level and then over to the collection exhaust hood. The baffle caused the dust emissions from the conveyor to cut under the baffle and “roll” behind the baffle away from the worker’s breathing zone.



### **Benefits of the Process Changes**

Silica exposures were reduced by more than 50 percent to a level well below the OSHA permissible exposure limit. Workers are no longer required to wear a respirator during this operation. Because there is air flow throughout the entire booth the workers indicate they feel that the booth is cooler during the warmer seasons and because the makeup air no longer blows in one small area the employees do not turn off the makeup air unit during the cold season.



**Figure D-1**  
**Changes to Improve Dust Capture During Knockoff Operations**



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