WALK-THROUGH SURVEY REPORT:

CONTROL TECHNOLOGY SUPPORT FOR SENSOR

AT

Ingersoll-Rand Company
Foundry Division
Phillipsburg, New Jersey

REPORT WRITTEN BY:
Dennis O'Brien
Phillip Froehlich
Ronald Hall

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NATIONAL INSTITUTE FOR OCCUPATIONAL SAFETY AND HEALTH
Division of Physical Sciences and Engineering
Engineering Control Technology Branch
4676 Columbia Parkway
Cincinnati, Ohio 45226

PLANT SURVEYED:	Ingersoll-Rand Company Foundry Division Phillipsburg, New Jersey 08865
SIC CODE:	3561/63
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SURVEY CONDUCTED BY:	Dennis O'Brien (NIOSH) Phillip Froehlich (NIOSH) Ronald Hall (NIOSH) David Valliante (NJ Dept. of Health)
EMPLOYER REPRESENTATIVES CONTACTED:	William L. Coccia Foundry Manager Lee L. Kongsiri, CIH Corporate Industrial Hygienist
EMPLOYEE REPRESENTATIVES CONTACTED:	Dick Engler Shop Steward Ray Foose Safety and Health Representative United Steel Workers of America Local 5503 41 3rd Street Phillipsburg, New Jersey

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I. INTRODUCTION

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

Since 1976, ECTB has conducted a number of assessments of health hazard control technology on the basis of industry, common industrial process, or specific control techniques. The objective of each of these studies has been to document and evaluate effective techniques for the control of potential health hazards in the industry or process of interest, and to create a more general awareness of the need for or availability of an effective system of hazard control measures.

In 1987, NIOSH initiated the SENSOR program (Sentinel Event Notification System for Occupational Risks), a cooperative state-federal effort designed to develop local capability for the recognition, reporting, and prevention of selected occupational disorders. Under this program, the state health department (or other agency) launches three types of actions upon notification of a case of occupational disease: first, disease management guidelines will be made available to the health care provider; second, medical evaluations of co-workers who may be at risk of developing similar disorders will be conducted; and finally, action directed to reduce work site exposures will be considered. To assist the states in developing intervention plans for exposure reduction, ECTB will conduct a pilot engineering assistance project with selected states participating in SENSOR. This assistance may include specific control recommendations for an individual plant identified and selected by the state, or for an industry that would be selected based on the state disease records, with the intent of developing guidelines for the elimination of occupational disease in the entire industry.

Since 1984, the New Jersey Department of Health (NJDOH) has been involved in the surveillance of the occupational disease, silicosis, under the NIOSH Capacity Building Program. This surveillance system utilizes morbidity (hospital discharge) data and mortality (death certificate) data to identify cases of silicosis. NJDOH is currently participating in the SENSOR program for occupational asthma and silicosis, which utilizes physicians' reports of silicosis. Health department surveillance data indicate the largest number of silicosis cases in the state exist in the sand mining and processing, foundry, and pottery (sanitary ware) industries. This disease is caused by exposure to crystalline silica in these industries.

At least one study is being conducted by ECTB in a facility of each of these industries to develop specific control recommendations to eliminate future cases of disease; to train state personnel in the application of engineering control; and to develop a model protocol for the identification and control of exposure sources.

This report describes a walk-through survey conducted as a part of this federal-state effort at the Ingersoll-Rand Company, Foundry Division, located in Phillipsburg, New Jersey. Since the NJDOH has shown the foundry industry to be a high silicosis risk industry, this plant was one of three foundries visited to select a site to demonstrate the feasibility of effective intervention in reducing the silicosis risk; to develop effective risk reduction programs for use in this and in similar type plants; and, thereby, to reduce the incidence of silicosis in this industry.

The specific purposes of this survey were to identify a plant for in-depth study; to evaluate potential worker exposures to silica-containing dusts; to qualitatively evaluate the effectiveness of current engineering controls, work practices, and administrative control programs in reducing dust exposures; and to recommend basic improvements in the dust control and disease prevention programs.

II. PLANT AND PROCESS DESCRIPTION

Plant Description:

The Ingersoll-Rand Company has operated both gray iron and steel foundries at this site. The gray iron foundry closed in 1978. The steel foundry is both newer (built in 1953) and smaller. The New Jersey Health Department identified several cases of silicosis at Ingersoll-Rand. The distribution of these cases between workers at the gray iron and steel foundries is unknown.

The plant employs 74 hourly and 13 salaried workers and operates on one shift (6:00 a.m. - 2:30 p.m.), except for melting and shakeout which begin at 5:00 a.m. Addition of a second shift is contemplated.

The main foundry is an L-shaped building consisting of a steel skeleton covered with steel siding. The floor is concrete covered with molding sand in the molding and melting department. Two air-handling units provide make-up air and space heating. One unit is located in the melting/molding area and the other located in the casting cleaning department. A schematic layout of the plant is included as Figure 1.

Process Description:

Melting--

The plant is a captive foundry producing steel and stainless steel castings for the parent company. Production is divided approximately 40 percent steel, 60 percent stainless steel. Five induction furnaces (1 - 1,000 pound capacity, 3 - 2,000 pound capacity, 1 - 2,500 pound capacity) are used to melt the scrap. In addition to the ferrous metals, approximately four heats per month

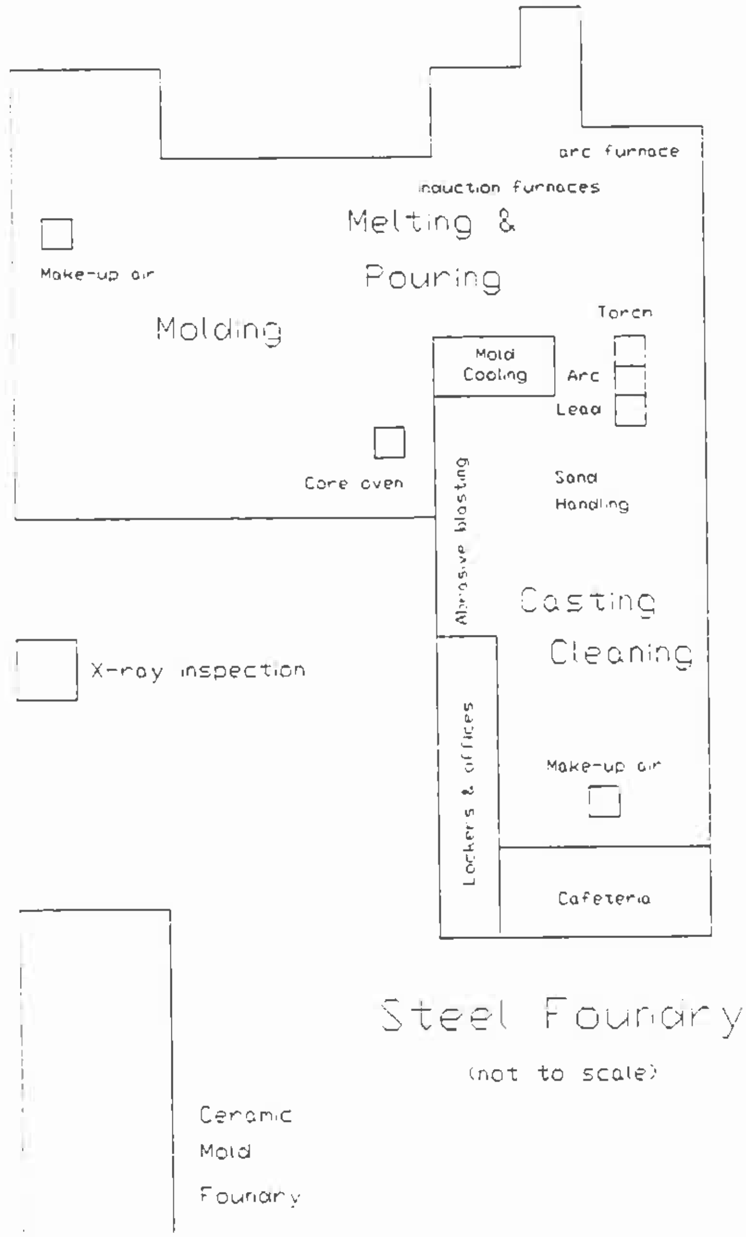

Figure 1. Schematic layout - Ingersoll-Rand steel foundry.

of leaded bronze are poured. Not all furnaces are in operation at any time. An annular-shaped exhaust hood surrounds the top of the melting vessel on the 2500 pound capacity furnace (used for the leaded bronze). A one ton electric arc furnace is also used. This furnace is equipped with a roof-mounted sidedraft hood to capture metal fumes escaping around electrode openings. None of the furnaces in the steel foundry were in operation during the walk-through. Furnace refractories (alumina) are replaced about every 90 days, by the furnace operator. Disposable ladle liners are used as both a labor saving and exposure reducing measure.

Molding and Coremaking--

The foundry produces molds using an alkyd-oil (drying oil/isocyanate) molding system. Sand, binder, and catalyst are combined in one of three screw mixers. Some small cores are made with silica sand using a drying oil binder. The oil polymerizes on heating in an oven. Zircon and silica-based washes are used on molds and cores. In general, patterns are waxed to facilitate mold removal, although some nonsilica parting compounds are used.

The plant was originally designed to produce small to medium size castings on a semiautomatic line. These molds are poured on the open floor, moved to roller conveyors located in ventilated cooling room, and mechanically dumped. This effectively isolates the workers from the cooling emissions. Larger molds (which represent the bulk of current production) will not fit on the conveyor. Shakeout and casting removal of the larger molds are performed manually. Sand from these molds is moved by front-end loader to a sand reclaimer connected to a baghouse. With the exception of limited use of the front-end loader, none of these operations were performed during the walk-through.

Casting Cleaning--

After shakeout and cooling, casting appendages are removed by means of either an air-arc or oxygen torch in one of two ventilated booths. Grinding of bronze castings is performed in an adjacent booth. Castings are cleaned automatically by steel shot in a Pangborn abrasive blasting machine or manually by sand blasting in a walk-in cabinet. Additional material is removed from castings primarily by hand-held chipping hammers or grinders on downdraft benches. These benches (manufactured by Wolverine), recirculated filtered air back into the foundry. Assorted swing grinders and cut-off saws were also used.

Inspection--

Castings were inspected using both x-ray and sealed-source radiation equipment in a separate building. This operation was not visited during the walk-through.

Ceramic Mold Foundry--

Certain high-value stainless steel castings are produced using a ceramic molding process in an adjacent, older building. The metal is melted in one of two induction furnaces and poured into heated ceramic molds. A wall fan removes heat and metal fumes from the furnace area. The molds are made by mixing (in a small unventilated cement mixer) zircon/fused silica and potassium and ethyl silicates. After pouring, a hot topping compound (mixture of sodium nitrate, sodium fluosilicate, wood dust, perlite, alumina, aluminum, graphite, and magnesium chromate) is used to retard cooling of the casting. Castings are trimmed/cleaned by a water-jet cutter, a stand grinder, an abrasive saw, an abrasive blasting machine (steel shot), or hand-held chippers/grinders (six downdraft benches).

Personal Protection and Hygiene--

Safety shoes, safety glasses, and hard hats are required in all areas of the plant. NIOSH-approved disposable dust/fume/mist respirators are required in certain casting cleaning areas. The sand blast operator wears a supplied-air respirator (carbon monoxide was reported to be monitored at the compressor). The corporate industrial hygienist is responsible for respirator selection. Work clothing is provided to the operator who grinds leaded bronze castings.

Medical--

The company provides annual physical examinations to all employees. Chest x-rays are provided to employees who fail a pulmonary function test.

Potential Hazards:

The main purpose of the SENSOR program is to follow up silicosis cases to prevent the development of new cases of this disease. Other major airborne hazards occurring in foundries are metal fumes and dusts, combustion and decomposition products of mold and core materials, and carbon monoxide. Information is also presented on these hazards, as attempts to control them may also cause a concomitant reduction in exposure to silica.

Crystalline Silica--

Crystalline silica is contained in molding and coremaking sands, in clays used as bonding agents, in parting compounds, in some refractory materials, and as surface contamination on castings. Exposure can occur almost anywhere within the foundry. In most operations, workers may have exposure to other contaminants as well. The crystalline forms of silica can cause severe tissue damage when inhaled. Silicosis is a form of pulmonary fibrosis caused by the deposition of fine particles of crystalline silica in the lungs. Symptoms usually develop insidiously, with cough, shortness of breath, chest pain, weakness, wheezing, and nonspecific chest illnesses. Silicosis usually occurs after years of exposure, but may appear in a shorter time if exposure concentrations are very high. This latter form is referred to as rapidly-developing silicosis, and its etiology and pathology are not as well understood. Silicosis is usually diagnosed through chest x-rays, occupational exposure histories, and pulmonary function tests. The manner in which silica affects pulmonary tissue is not fully understood, and theories have been proposed based on the physical shape of the crystals, their solubility, toxicity to macrophages in the lungs, or their crystalline structure. There is evidence that cristobalite and tridymite, which have a different crystalline form from that of quartz, have a greater capacity to produce silicosis.[1]

Metals--

The hazard of exposure to metals is dependent upon the type of metal cast. Some of the more hazardous metals used at this facility are lead, chromium, and nickel. Metal fumes can be encountered at melting, pouring, and various types of welding and brazing operations. Metal dusts produced during grinding operations are usually not as significant as the fume, because the dusts are of a larger particle size.[2]

Lead

Inhalation (breathing) of lead dust and fume is the major route of lead exposure. A secondary source of exposure may be from ingestion (swallowing) of lead dust deposited on food, cigarettes, or other objects. Once absorbed, lead is excreted from the body very slowly. Absorbed lead can damage the kidneys, peripheral and central nervous systems, and the blood forming organs (bone marrow). These effects may be felt as weakness, tiredness, irritability, digestive disturbances, high blood pressure, kidney damage, mental deficiency, or slowed reaction times. Chronic lead exposure is associated with infertility and with fetal damage in pregnant women.[3,4]

Nickel

Inorganic nickel compounds are suspected of causing lung and nasal cancer, based on the mortality experience of nickel refinery workers. Nickel metal and its compounds can also produce a contact dermatitis known as "nickel itch."[5]

Chromium

Chromium alloys can be oxidized to chromium trioxide fume, a soluble chromium (VI) compound. These compounds can produce health effects such as contact dermatitis, irritation and ulceration of the nasal mucosa, and perforation of the nasal septum. Certain insoluble chromium (VI) compounds are suspect carcinogens. Magnesium chromate, used as a component of the hot topping compound, is highly water soluble; however, it is not specifically identified by NIOSH as a non-carcinogenic chromium (VI) compound, requiring that it be handled as a carcinogen.[6]

Decomposition Products--

Epidemiological studies suggest that workers in ferrous foundries are at a greater risk of dying from lung cancer than persons in the general population. The risk is a function of the job performed, with molders, metal pourers, and cleaning room personnel having the greatest rate of mortality from lung cancer.[7] There are strong suspicions that the agents responsible may be formed during the thermal decomposition of a wide variety of organic additives and binders used in foundry mold and coremaking processes.[2] These materials undergo thermal decomposition from the intense heat produced when the molten metal is poured. These decomposition products may be released during pouring, mold cooling, and shakeout. They may also remain in the sand or adhere to the surface of the casting.

The major hazardous degradation products which are expected to be present in most pouring and cooling operations are: carbon monoxide, carbon dioxide, aliphatic and aromatic hydrocarbons (most likely benzene, toluene, and xylenes), and smoke. The smoke may contain various polynuclear aromatic hydrocarbons with suspected carcinogenic properties. Depending on the specific core and mold materials used, numerous other substances may be present. Formaldehyde, hydrogen cyanide, and methylene bisphenyl isocyanate are additional substances that may for from the decomposition of alkyd-oil binder systems.[8]

Carbon Monoxide

In the foundry, carbon monoxide is produced by melting processes based on combustion, from internal combustion engines, from other combustion sources, and from the decomposition of organic molding materials during pouring and cooling. Carbon monoxide has typically been used as an index of the hazard in mold pouring and cooling areas in gray iron foundries. Carbon monoxide combines with hemoglobin in the blood reducing the oxygen carrying capacity of the blood. Symptoms of CO poisoning are headache, dizziness, drowsiness, nausea, vomiting, collapse, coma, and death. Long term low level exposure to CO can increase the risk of heart attack for some people.[9]

Formaldehyde

Exposure to formaldehyde can occur in mold and coremaking processes using formaldehyde-based resins, and from the decomposition of other organic materials during pouring and cooling of castings. The primary health effects of exposure to formaldehyde are irritation of the respiratory tract, eyes, and skin. Eye and respiratory tract irritation has been reported in workers exposed to concentrations of less than 1 ppm.[10] Recent studies have found that formaldehyde induced nasal cancer in rats exposed to high levels (15 ppm) of formaldehyde over a long period of time.[11] These results have prompted NIOSH to recommend that formaldehyde be handled as a potential occupational carcinogen.

Hydrogen Cyanide

Exposure to hydrogen cyanide can occur in pouring and cooling of castings when nitrogen containing binders are used. Hydrogen cyanide is a chemical asphyxiant. It inactivates certain enzymes, the most important being cytochrome oxidase, which are used by the cells of the body for cellular respiration. Although the cells receive an adequate supply of oxygen through the blood stream, they are unable to use this oxygen because the metabolic process has been blocked by the presence of the -CN group. Inhalation, ingestion, or skin absorption of hydrogen cyanide may be rapidly fatal. Large doses may cause loss of consciousness, respiratory arrest, and death. Lower levels of exposure may cause weakness, headache, confusion, nausea, and vomiting.[9]

Isocyanates

Diisocyanates such as methylene bisphenyl isocyanate are strong irritants of the eyes, mucous membranes and skin, and also sensitizers of the respiratory tract. In sufficient concentrations they cause irritation of the eyes, nose, and throat, a choking sensation, and a productive cough. Depending on the length of exposure and concentration, respiratory symptoms will develop with a latent period of four to eight hours. Although the acute effects may be severe, a more important consideration is that respiratory sensitization can occur in susceptible individuals after repeated exposure to low levels of diisocyanates. Initial symptoms are often nighttime shortness of breath or cough with progression to asthmatic bronchitis. After symptoms subside, a return to work can cause an acute and severe asthmatic attack almost immediately or within a few hours.[(12)] A person who has become sensitized must avoid future exposure completely. Some decrease in lung function in the absence of symptoms has been observed in some workers exposed for long periods of time, even at low concentrations.[(13)] Exposures to diisocyanates (typically methylene bisphenyl isocyanate) are likely to occur in sand/resin mixing, in core/mold preparation, and at pouring and shakeout.

Environmental Criteria:

As a guide to the evaluation of the hazards posed by workplace exposures, NIOSH field staff employ environmental evaluation criteria for the assessment of a number of chemical and physical agents. These criteria are intended to suggest levels of exposure to which most workers may be exposed up to 10 hours per day, 40 hours per week for a working lifetime without experiencing adverse health effects. It is, however, important to note that not all workers will be protected from adverse health effects if their exposures are maintained below these levels. A small percentage may experience adverse health effects because of individual susceptibility, a pre-existing medical condition, and/or a hypersensitivity (allergy).

In addition, some hazardous substances may act in combination with other workplace exposures, the general environment, or with medications or personal habits of the worker to produce health effects even if the occupational exposures are controlled at the level set by the evaluation criterion. These combined effects are often not considered in the evaluation criteria. For example, in the foundry, gases such as the oxides of nitrogen and sulfur dioxide may adsorb on dust particles and produce health effects at levels normally considered safe. Also, some substances are absorbed by direct contact with the skin and mucous membranes, and thus potentially increase the overall exposure. Finally, evaluation criteria may change over the years as new information on the toxic effects of an agent become available.

The primary sources of environmental evaluation criteria for the workplace are: 1) NIOSH recommended exposure limits (RELs), 2) the American Conference of Governmental Industrial Hygienists' (ACGIH) Threshold Limit Values (TLVs®), and 3) the U.S. Department of Labor (OSHA) permissible exposure limits (PELs).[14,15,16] Often, the NIOSH RELs and ACGIH TLVs are lower than the corresponding OSHA PELs. Both NIOSH RELs and ACGIH TLVs usually are based on more recent information than are the OSHA PELs. The OSHA PELs also may be required to take into account the feasibility of controlling exposures in various industries where the agents are used; the NIOSH RELs, by contrast, are based primarily on concerns relating to the prevention of occupational disease. In evaluating the exposure levels and the recommendations for reducing these levels found in this report, it should be noted that industry is legally required to meet only those levels specified by an OSHA PEL.

The NIOSH Recommended Exposure Limit (REL): NIOSH recommends that occupational exposure be controlled so that no worker is exposed to a time-weighted average (TWA) exposure concentration of crystalline free silica greater than 50 micrograms per cubic meter of air (0.05 mg/m^3) as determined by full-shift respirable dust sample for up to a 10-hour work day, 40-hour work week.

The ACGIH Threshold Limit Value (TLV®): The ACGIH TLV® for respirable silica (quartz) is 0.1 mg/m^3 as a TWA for an 8-hour day.

The OSHA Permissible Exposure Limit (PEL): The OSHA PEL is now in a transitional period. The new PEL is 0.1 mg/m^3 as a TWA for an 8-hour day. This new standard is effective on March 1, 1989, and enforceable on September 1, 1989.

A time-weighted average (TWA) exposure refers to the average airborne concentration of a substance during a normal 8- to 10-hour workday. Some substances have recommended short-term exposure limits or ceiling values which are intended to supplement the TWA where there are recognized toxic effects from high short-term exposures.

III. METHODS

An initial meeting was conducted to familiarize the plant personnel with the purpose of the study, and to obtain a description of the processes and exposure controls employed in the operation. A walk-through of the plant was then conducted to further acquaint the survey team with the facility. After the walk-through, previous sampling data (if any) were reviewed, and spot measurements of airborne contaminants were made. At the conclusion of the survey, results of the direct reading measurements were presented and preliminary recommendations for control were discussed.

Aerosol measurements were made in the plant using a Hand-held Aerosol Monitor (HAM) (PPM, Inc., Knoxville, Tennessee) to identify and prioritize potential sources of exposure to dust in the foundry. These measurements were used to identify areas or operations causing potential exposure to silica; they may not reflect actual exposures measured by long-term sampling techniques.

This instrument samples the workroom air and instantaneously measures the concentration of airborne dusts and mists by measuring the amount of light scattered by these materials. Although the results of these measurements are reported in mg/m^3, these numbers should be considered as estimates of the true concentration, as the amount of light scattered depends on the characteristics of the specific aerosol in addition to its concentration. The optical characteristics of the HAM are such that it is most sensitive to respirable aerosols (dusts and mists well below about 10 micrometers in diameter). As a first approximation, the instrument responds roughly to particle volume, so the instrument readings can be corrected for particle density by multiplying by the ratio of the actual particle density to the density of the factory calibration aerosol (1.5 mg/m^3).

Analyses for selected chemical hazards were determined through the use of detector tubes (National Draeger, Inc., Pittsburgh, Pennsylvania). These devices consist of a glass tube containing an inert carrier impregnated with a reagent. The ends of the tube are broken and the tube connected to a hand operated air pump. Workplace air is pulled through the tube and the contaminant reacts with the reagent. The concentration is typically determined by the length of stain produced or by the number of pump strokes needed to produce a color change. Detector tubes are manufactured by several manufacturers and are available for a wide variety of airborne hazards. Detector tubes were used in this survey to identify the presence of potential chemical hazards. These measurements were used to identify areas or operations causing potential exposure; they may not reflect actual exposures measured by long-term sampling techniques.

Air velocity measurements were performed using a hot-wire anemometer. Measurements were made on the downdraft benches used in the cleaning department and the arc air and lead booths.

IV. RESULTS

Real Time Dust Measurements:

Concentrations of dusts measured in the casting cleaning area are presented in Table 1. Crude estimates of silica exposure are included in this table based on a density estimated to be about 2.6 mg/m^3[16] and an assumed average silica content of 10 percent (based on information developed by Wisconsin OSHA to estimate silica compliance using respirable mass).[18] These real-time results indicate that the casting cleaning operations represent potential over exposure to silica in this plant.

Measurable respirable dust concentrations exist in the exhaust of the downdraft grinding booths. This dust may originate from two sources: a) dust that settles in the horizontal exhaust openings, causing visible dust releases when the booth fans are started; b) penetration of dusts through or around the filter media. The results indicate the need for improved maintenance and monitoring of filter performance, or, as is later recommended, that the exhaust of the booth air be connected into a central duct system fitted with a dust collector exhausting to the outside of the plant.

Detector Tube Measurements:

Detector tube data are presented in Table 2 for various operations. Unfortunately, pouring took place several hours before these measurements were made. The same contaminants would be expected, but the concentrations would be higher and the relative proportions might be different at the time of pouring.

Table 1. Real-time aerosol measurements.

Location	Respirable Dust Concentration (mg/m3)*	Estimated Quartz Concentration (mg SiO2/m3)**
Outside of plant	0-0.1	NA
Molding area	0.1	< 0.05
Casting cleaning area		
grinding top of casting	0.4-0.5	0.05-0.1
booth exhaust (above activity)	0.3	< 0.05
alongside booth	2.0	0.3
booth exhaust	0.8	0.1-0.2
grinding small impeller	0.4	0.05-0.1
grinding large casting	0.5	0.05-0.1
grinding outside and inside of casting	0.9	0.1-0.2
grinding	0.4	0.05-0.1
booth exhaust (above activity)	0.2	< 0.05
OSHA PEL (8 hr. time weighted average)		0.1
NIOSH REL (10 hr. time weighted average)		0.05
ACGIH TLV (8 hr. time weighted average)		0.1

* based on factory calibration with an aerosol of density = 1.5 g/cm3;
** 0.17 times instrument reading; assuming quartz content of 10% and a particle density of 2.6 g/cm3
NA: not applicable
Note: these are short (about 1 minute) measurements used to identify areas or operations causing potential exposure; they may not reflect actual exposures measured by long term sampling techniques.

Table 2. Detector tube measurements.

Location	Concentration (ppm)		
	CO	HCHO	HCN
Cooling alkyd-oil molds, about 3 hours after pouring			
- alongside mold	10	-	-
- 6 inches above vent hole	100	1	< 2
OSHA PEL (8 hr. TWA)	50	1	10
NIOSH REL (10 hr. TWA)	35	(LF)	4.7
ACGIH TLV (8 hr. TWA)	50	1	10 (C)

LF: lowest feasible C: ceiling concentration

Note: these are grab samples used to identify areas or operations causing potential exposure; they may not reflect actual exposures measured by long term sampling techniques.

Key to Table 2

formula	detector tube*	chemical hazard
CO	Carbon monoxide 10/a	carbon monoxide
HCHO	Formaldehyde 0.2/a	formaldehyde
HCN	Hydrocyanic acid 2/a	hydrogen cyanide

*National Draeger, Inc. (Pittsburgh, Pennsylvania)

Ventilation Measurements:

Air velocity measurements were performed using a hot-wire anemometer. Measurements made on the downdraft benches used in the cleaning department and the arc air and lead booths are reported in Table 3. Flow rates were generally above those recommended in the ACGIH publication Industrial Ventilation.[19] Several booths were noted to be not operable.

V. RECOMMENDED EXPOSURE CONTROLS

Occupational exposures can be controlled by the application of a number of well-known principles, including engineering measures, ventilation, work practices, personal protection, and monitoring. By reducing workplace exposures, new cases of silicosis (and other occupational diseases) can be prevented.

Engineering Measures

The foundry was originally designed to produce small and medium size castings. The bulk of the current production is large castings which does not permit use of the semiautomatic mold handling system. Recommendations for improvements based on process or material substitution are discussed below for the operations observed:

1. A semiautomatic system to isolate small molds as they cool is already in place. This system should be modified/replaced so that all molds could be isolated once they are poured. In addition to increased exposure to decomposition products from the open floor cooling of large molds, high silica exposures are likely to occur during the front-end loader handling of the molding sands. Substitution of front-end loader sand handling with an automated mold handling system (exhausting through appropriate filters to the outdoors) should result in lower exposures.

2. Substitution of olivine sand has been shown to reduce the incidence of silicosis.[20] Silica sand is used in this foundry as their molding aggregate and in sand blasting. Olivine could be substituted with little or no change in operations, as it is compatible with the alkyd-oil binder system currently used. It would involve increased cost of molding aggregate when compared to silica sand, but may reduce dust control costs.

3. The hand grinding operators are potentially exposed to excessive levels of silica. The castings should be as clean as possible before grinding. The exhaust from the compressed air tool should be ducted away from the tool via a hose to avoid blowing dust from the casting. Mufflers should be installed at the end of this hose for noise reduction. The metal grates of the grinding benches can amplify the noise from grinding. Replacing the metal grates with a wooden lattice can reduce noise levels at a relatively low cost.

Table 3. Ventilation measurements.

Equipment	Existing flow rate (cfm/sqft)	Recommended minimum flow (cfm/sqft)	Reference[27]
Hand grinders -			
downdraft grinding bench	100	150-250	VS-412
downdraft grinding bench	115	150-250	"
downdraft grinding bench	300	150-250	"
downdraft grinding bench	300	150-250	"
downdraft grinding bench	180	150-250	"
downdraft grinding bench	360	150-250	"
downdraft grinding bench	300	150-250	"
downdraft grinding bench	420	150-250	"
downdraft grinding bench	180	150-250	"
downdraft grinding bench	180	150-250	"
downdraft grinding bench	180	150-250	"
Arc air booth	190	200	VS-415*
Lead grinding booth	300	200	VS-415*

*No specific recommendation exists in Industrial Ventilation; operation is judged by the authors to be similar to metal spraying, therefore VS-415 is referenced.

Local Exhaust Ventilation

Recommendations for improvements in local exhaust ventilation are discussed below for the operations observed:

1. The plant uses downdraft tables to control dust exposure to the hand grinding operators. These benches recirculate filtered air back into the foundry. The filters should be inspected for physical integrity and dust loading, and airflow measured. Detailed recommendations for air recirculation and downdraft bench airflow requirements are contained in the ACGIH publication Industrial Ventilation.[19] Preliminary measurements indicate that the air from the downdraft benches may not be suitable for recirculation back into the plant. Rather than a continuous monitoring program and maintenance of the present equipment, it may prove to be more economical to remove the filters and fans and then connect the benches into a duct system discharging out-of-doors through a single, larger dust collection unit. The removal of the individual fans should result in a significant noise reduction.

2. The cleaning of the large castings presents difficult problems. The size of the casting precludes work at a distance near enough to the grates of the downdraft booths for efficient capture. Perhaps a sidedraft booth could be used, with the castings set on a rotating table so that the grinding swarf could be directed into the hood. A better approach for the cleaning of large castings would be the installation of high-velocity, low-volume (HVLV) exhaust hoods to supplement the downdraft benches. Detailed recommendations are contained in the ACGIH publication Industrial Ventilation VS-801 through VS-807.

3. Ventilation rates on other equipment not observed in operation should be measured and be upgraded to those recommended in Industrial Ventilation. A standard pitot tube and inclined tube manometer should be obtained for measuring volumetric flow rates. An inexpensive swinging vane anemometer is also suggested for purchase to measure air velocities into hoods. A log of these measurements should be maintained.

4. Smoke was observed to be escaping around openings in the back of the arc air booth. While the volumetric total flow into the booth appeared to be adequate, the exhaust take-off was not in a position to "receive" the high velocity contaminant stream. The operation is judged to be similar to metal spraying, therefore a hood like that depicted in VS-415 is recommended for this, the torch, and the lead operations. Unless the company has exposure data to indicate otherwise, these operators should be furnished with supplied-air respirators, due to the toxicity of the metals with which they work.

6. Consideration should be given to melting stainless steels only in designated furnaces and equipping those furnaces with hoods like that used on the leaded bronze furnace, or with hoods similar to that shown in VS-106. These hoods should also be installed in the ceramic mold foundry.

7. A pouring station hood, similar to that shown in VS-109, should be installed in the ceramic mold foundry to contain magnesium chromate fumes from the hot topping compounds used.

8. A hood similar to that used for barrel filling (VS-303) could be used for the filling and operation of the mixer used for mold materials in the ceramic mold foundry.

General Ventilation

For the open floor pouring of ferrous castings, the AFS Foundry Ventilation Manual[21] recommends general ventilation rates of 20 to 50 cfm per square foot of floor area. During mold cooling this can be reduced to 10 to 20 cfm per square foot of floor area. An audit should be performed to determine if the present rate meets these suggested minimums.

Fresh make-up air is introduced into the foundry through two make-up air units. One is located at the molding end of the molding/melting department; the other is located at the cafeteria end of the casting cleaning department. Ideally, all air exhausted from the building should be replaced by tempered air from an uncontaminated location. By providing a slight excess of make-up air in relatively clean areas, and a slight deficit of make-up air in dirty areas (e.g. around abrasive blasting and sand handling areas), cross contamination can be reduced. Unfortunately, the make-up air units discharge directly into the plant, mixing with contaminated plant air before arriving at individual work stations. It is recommended that the tempered air be ducted directly to operator work areas, providing the cleanest possible work environment. For those individuals working at relatively fixed work stations (e.g., grinders), this fresh air could be supplied in the form of a low velocity air shower (<100 fpm to prevent interference with the exhaust hoods), located directly above the worker.

Crane operators may be at increased risk of exposure to decomposition products because of the tendency of the heated air to collect below the roof of the building. It is recommended that the crane cab(s) be enclosed and fresh air be introduced into the cab from outside of the plant through a "zipper" duct system running parallel to crane rails.

Work Practices:

When general ventilation is used to minimize the exposure to metal fumes and mold gases, the AFS Foundry Ventilation Manual[21] recommends that the progression of mold pouring should progress towards the make-up air source so that the air contaminants are moving in the opposite direction. However, no predominant flow pattern was observed in this facility.

Use of the front-end loader to process large volumes of sand into the reclamation unit should be performed after the normal work shift, to limit exposure to only the loader operator.

Recommended Publications:

It is important that responsibility for health and safety be assigned to one individual within the plant management. In order to develop the in-house expertise needed to implement a strong health and safety program, it is strongly recommended that <u>all</u> of the following publications be purchased and read:

American Conference of Governmental Industrial Hygienists (513) 661-7881

Industrial Ventilation, A Manual of Recommended Practice, 20th edition (1988).
Industrial Ventilation Workbook, (1989)
"Threshold Limit Values for Chemical Substances and Physical Agents in the Workroom Environment with Intended Changes for 1988-1989"

American Foundrymen's Society (800) 537-4237

Health and Safety Guides, 1985.
Foundry Ventilation Manual, 1985.

National Institute for Occupational Safety and Health (513) 533-8287

NIOSH Publications Catalog

An Evaluation of Occupational Health Hazard Control Technology for the Foundry Industry, 1978. DHEW Publication no. (NIOSH) 79-114
Recommendations for Control of Occupational Safety and Health Hazards... Foundries DHHS (NIOSH) Publication No. 85-116
NIOSH/OSHA Occupational Health Guidelines for Chemical Hazards, DHHS (NIOSH) Publication No. 81-123

VI. FOLLOW-UP STUDY

A follow-up study of this plant is strongly recommended. The company appears to be economically viable and the plant management stated an intention to upgrading the make-up air system. A plan could be developed for this foundry that might well serve as a guide to other foundries.

The follow-up study would involve the following elements:

1. A quantitative assessment should be made of the potential of a continuing silicosis hazard through the determination of the silica exposure of random sampling of all categories of the production workers.

2. An evaluation of the suggested AFS ventilation requirements in the open floor pouring of molds would be performed through a comprehensive detector tube work-up and conventional sampling.

3. A quantitative evaluation of the hazard of chromium exposure to melters and pourers using hot topping compounds in the ceramic mold foundry would be performed using conventional sampling techniques.

4. Bulk samples of the ceramic mold constituents would be performed to determine the possibility of exposure to crystalline silica.

5. A quantitative evaluation of the hazard of lead exposure to melters, pourers, and cleaners of the leaded bronze alloys would be performed using conventional sampling techniques.

6. Work practices used in cleaning castings on the downdraft benches would be examined, using a combination of video recording and real-time dust measurement. This examination would attempt to identify activities associated with high dust exposures, with the hope of elimination of those activities, where possible. Measured flow rates on the grinding benches and the size of the castings would be compared with the exposure of the operators to crystalline silica.

7. Dust exposure during sand loading and reclamation would be determined using conventional and real-time instrumentation. A safe "re-entry" time would be determined if it is feasible to perform this operation off-shift.

8. The advisability of the current use of recirculation would be studied. A portable particle counter would be used to determine the dust removal efficiency of the grinding benches.

9. A ventilation audit would be conducted and recommendations for upgrades will be made. A conceptual design of a make-up air system would be performed.

10. Other evaluations would be performed as the situation permitted.

Ideally, the foundry could adopt the recommendations generated in this study, and a second study could be conducted to determine the exposure reductions achieved.

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