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GENERAL CASTINGS - TOLEDO STREET FACILITY
DELAWARE, OHIO

NIOSH INVESTIGATORS:
NANCY CLARK BURTON, MPH, MS
RONALD HALL
GREGORY KINNES, MS, CIH
WILLIAM TODD, MS

I. SUMMARY

In November 1991, the National Institute for Occupational Safety and Health (NIOSH) received a management request to evaluate worker exposures throughout the General Castings-Toledo Street Facility, a gray and ductile iron foundry in Delaware, Ohio.

On February 4-6, 1992, NIOSH representatives, with field assistance from the Ohio Department of Health, conducted an industrial hygiene survey. Personal breathing zone (PBZ) and area air samples were collected for respirable silica and cristobalite, metals, phenol, formaldehyde, isopropanol, carbon monoxide, and organic solvents. Work practices and engineering control measures were also evaluated.

The PBZ air concentrations of respirable silica ranged from 31 (shakeout) to 284 (crane operator) micrograms per cubic meter [$\mu g/m^3$], as time-weighted averages (TWAs). Six of the 16 nearly full-shift sample concentrations (38%) exceeded the Occupational Safety and Health Administration (OSHA) Permissible Exposure Limit (PEL) of 100 $\mu g/m^3$ for respirable silica (as quartz), and 11 of the 16 sample concentrations (69%) exceeded the NIOSH Recommended Exposure Limit (REL) of 50 $\mu g/m^3$ for respirable crystalline silica (regardless of morphology). Cristobalite was not detected in any of the samples. One PBZ sample concentration for benzene collected for a molder was equal to the NIOSH REL of 0.1 ppm for benzene, which is considered a potential occupational carcinogen. Area formaldehyde concentrations ranged from 0.012 to 0.026 ppm. Two of these samples exceeded the NIOSH REL of 0.016 ppm for formaldehyde which is considered a potential human carcinogen. NIOSH recommends that benzene and formaldehyde exposures be reduced to the lowest feasible limit (LFL). Carbon monoxide (CO) concentrations ranged from 2-30 ppm. Five out of 10 PBZ samples for CO exceeded the American Conference of Governmental Industrial Hygienists Threshold Limit Value (TLV®) of 25 ppm for carbon monoxide. Six out of 10 PBZ samples had peak exposures (218 to 542 ppm) over the NIOSH and OSHA ceiling limit [never to be exceeded] of 200 ppm. Concentrations of phenol (0.07-0.54 ppm), isopropanol (1-38 ppm), toluene (<0.062-0.066 ppm), and the metals: aluminum, chromium, copper, iron, magnesium, manganese, lead, and zinc (range: 0.4 to 714 $\mu g/m^3$) did not exceed the respective occupational evaluation criteria.

The industrial hygiene sampling data indicate that respirable silica, carbon monoxide, formaldehyde, and benzene exposures constitute a potential health hazard to employees in the coremaking, molding, and shakeout areas at this facility. Recommendations for engineering controls, an improved respiratory protection program, and improved work practices can be found in Section VIII of this report.

KEYWORDS: SIC 3321 (Gray and Ductile Iron Foundries), foundry industry, respirable silica, engineering controls, metals, benzene, formaldehyde, phenol, isopropanol, carbon monoxide.

II. INTRODUCTION

On February 4-6, 1992, National Institute for Occupational Safety and Health (NIOSH) representatives, with field assistance from the Ohio Department of Health, conducted a site visit at the General Castings-Toledo Street Facility, a gray and ductile iron foundry, in Delaware, Ohio. This visit was made in response to a management request to evaluate worker exposures in the coremaking, molding, pouring, melting, shakeout, and sand handling areas of the facility. Since the company was under new management and had recently changed the process flow, there was a general interest in identifying potential occupational health hazards.

III. BACKGROUND

The General Castings-Toledo Street Facility is housed in a 55,000 square foot masonry building which was built in the 1940s. The facility operated three shifts: there were 44 production workers on the day shift, 3 employees on the afternoon shift, and 8 workers on the night shift. The general layout of the facility is presented in Figure 1.

To produce molten iron, the plant used two coreless electric channel furnaces which operated at 1500 kilowatts with a melt rate of 60 tons per day. There were no local exhaust hoods or air pollution control devices in place for the induction furnaces. The furnace operators spent the majority of their time in a climate-controlled control booth. At the time of the site visit, the company was producing gray iron from one furnace while the other furnace was being repaired. The furnaces were totally relined with a silica refractory each year. Metal scrap yards were located both inside and outside the facility.

The metal pouring operation was performed on the day shift in two open areas inside the facility using stationary molds (large mold and small mold pouring). The metal was manually poured using the ladle fly-wheel. Overhead crane systems were used to position the ladles for pouring in both the small and large mold pouring areas. The two crane operators worked in open cabs. For some of the large molds, the pourer was required to climb a ladder to assist the crane operator with positioning the ladle before and while pouring. The molds were allowed to cool in the location where they were poured.

A mold provides the cavity into which the metal is poured to produce a casting; a core is used to define the internal hollows desired in the casting. There were two coremaking areas: the small core room and the large coremaking area. Cores were made by hand and by machine. In the small core room, employees made oil-based cores which were baked in a gas-fired oven. In the large coremaking area, cores and molds were made of a phenolic-formaldehyde binder mixed with silica sand in an automatic mixer. A polymeric methylene phenylene diisocyanate (MDI) was used as the binder catalyst. The no-bake binders used were PEPSET I®, PEPSET II®, and PEPSET III® manufactured by the Ashland Chemical Company, Columbus, Ohio. According to the Material Safety Data Sheets, the decomposition products from these binders may include carbon dioxide, carbon monoxide, hydrocarbons, and phenols. Crane hoists were used for lifting small molds. A "blue dip primer" containing isopropanol, magnesium silicate, titanium oxide, and xylenes was utilized to seal the cores and molds after forming. The molds and cores were set afire to burn off the residual isopropanol in the primer to form a smooth surface. Compressed air was used to remove excess sand in the coremaking and molding departments.

The metal castings were shaken out of the molds while still hot (referred to as "shakeout") on second and third shifts. A large shaker table was moved into the center of the large pouring area. Castings were lifted to the top of the shaker table using the overhead cranes and shaken out. For certain castings, workers used compressed air to remove excess sand from internal cavities. Sledge hammers were also used to manually remove sand from the castings. A sand reclamation system with a side draft exhaust hood was used. Two Bobcat® front-end loaders were used to load the sand reclamation system and shake out some of the castings. The castings were loaded unto flat bed trucks, using cranes and chain hoists, and transported to another facility owned by the company for cleaning. Brooms were used to clean up excess dry sand throughout the facility.

Safety shoes, hard hats, and safety glasses were required throughout the facility. NIOSH/Mine Safety And Health Administration (MSHA) approved half mask respirators with dust/fume/mist cartridges were available upon request. Hearing protection devices (disposable plugs) were required in the shakeout area. Flame retardant clothing was worn by the pourers. The Material Safety Data Sheets, hearing protection policy, and respiratory protection policy were reviewed.

General ventilation was supplied by propeller fans: two wall fans and two ceiling fans. At the time of the survey, the two ceiling fans over the large mold pouring area were in operation. Heat was provided by direct-fired gas space heaters. Additional general ventilation was supplied by open doors and windows during the warmer months.

IV. METHODS

A. Respirable Silica and Cristobalite

Sixteen personal breathing zone (PBZ) air samples for respirable dust (aerodynamic diameter less than 10 micrometers [µm]) were collected at a flowrate of 1.7 liters per minute (l/min) using 10 millimeters (mm) nylon cyclones mounted in series with pre-weighed polyvinyl chloride (PVC) filters (37 mm diameter, 5 µm pore size). They were analyzed for quartz and cristobalite content with X-ray diffraction. Samples were analyzed according to NIOSH Method 7500[1] with the following modifications: a) the filters were dissolved in tetrahydrofuran rather than being ashed in a furnace, and, b) standards and samples were run concurrently and an external calibration curve was prepared from the integrated intensities rather than the suggested normalization procedure. The analytical limit of detection (LOD) was 15 micrograms (µg) per filter, which equates to a minimum detectable concentration (MDC) of 22 micrograms per cubic meter (µg/m^3), assuming an average sampling volume of 698 liters. The limit of quantitation (LOQ) was 30 µg per filter, which equates to a minimum quantifiable concentration (MQC) of 43 µg/m^3, assuming an average sampling volume of 698 liters.

B. Metals

Thirteen PBZ air samples were collected on mixed-cellulose ester filters (37 mm diameter, 0.8 µm pore size) using a flowrate of 2.0 l/min. The samples were analyzed for metals according to NIOSH Method 7300.[2] In the laboratory, the samples were wet-ashed with concentrated nitric and perchloric acids and the residues were dissolved in a dilute solution of the same acids. The resulting sample solutions were analyzed by inductively coupled plasma atomic emission spectrometry. The MQCs, using a sample volume of 262 liters, for the selected metals are listed in Table 3.

C. Phenol

Eight PBZ air samples were collected on XAD-7 silica gel tubes using a flowrate of 0.1 l/min. The samples were desorbed in methanol and analyzed by high performance liquid chromatography according to OSHA Method 32 for phenol. The analytical LOD was 1 µg per sample, which equates to a MDC of 0.01 parts per million (ppm), assuming a sample volume of 22 liters. The LOQ was 3.3 µg per sample, which equates to a MQC of 0.04 ppm, assuming a sample volume of 22 liters.

D. Carbon Monoxide

Ten PBZ and 2 area direct reading continuous measurements were collected for carbon monoxide over the entire workshift with Draeger CO Dataloggers (Model 190, National Draeger Inc.). These instruments used an electrochemical sensor and were calibrated prior to use with calibration span gas at 800 ppm. The LOD for these instruments is 1 ppm.

E. Formaldehyde

Five area air samples were collected using impingers with 1% sodium bisulfite solution at a flowrate of 1 l/min. For analysis, color was developed by adding chromotopic acid and concentrated sulfuric acid to each sample. Samples were heated in a 95°C water bath for 15 minutes and allowed to cool 2 to 3 hours. The samples were read by visible spectroscopy according to NIOSH Method 3500.[3] The analytical LOD for formaldehyde was 0.6 µg per sample, which equates to a MDC of 0.004 ppm, assuming a sampling volume of 117 liters. The LOQ for formaldehyde was 1.8 µg per filter, which equates to a MQC of 0.013 ppm, assuming a sampling volume of 117 liters.

F. Isopropyl Alcohol

Eight PBZ air samples were collected on charcoal tubes at a flowrate of 0.2 l/min. The charcoal tubes were desorbed with carbon disulfide (with 1% 2-butanol as a desorbing aid) and screened by GC-FID according to NIOSH Method 1400.[4] The analytical LOD was 0.02 mg/sample, which equates to a MDC of 0.19 ppm, assuming a sampling volume of 43 liters. The LOQ was 0.042 mg/sample, which equates to a MQC of 0.40 ppm, assuming a sampling volume of 43 liters.

G. Solvents

Four PBZ samples were collected on charcoal tubes at a flowrate of 0.2 l/min. The charcoal tubes were desorbed with carbon disulfide and screened by gas chromatography/flame ionization detector (GC-FID), according to NIOSH Method 1501.[5] Total aromatic hydrocarbons were based on the presence of n-hexane. The analytical LODs, the LOQs, the MDCs, and the MDQs for the major constituents are presented in the following chart:

Analyte	LOD µg/sample	LOQ µg/sample	MDC ppm	MQC ppm	Minimum Volume (liters)
Benzene	1	3.3	0.01	0.02	43
Toluene	10	33	0.06	0.20	43

The analytical LOD for total aromatic hydrocarbons was 100 µg per sample, which equates to a MDC of 2.3 mg/m^3, assuming a sampling volume of 43 liters. The LOQ for total aromatic hydrocarbons was 330 µg per filter, which equates to a MQC of 7.7 mg/m^3, assuming a sampling volume of 43 liters.

V. EVALUATION CRITERIA

To assess the hazards posed by workplace exposures, industrial hygienists use a variety of environmental evaluation criteria. These criteria propose exposure levels to which most employees may be exposed for a normal working lifetime without adverse health effects. These levels do not take into consideration individual susceptibility, such as pre-exiting medical conditions, or possible interactions with other agents or environmental conditions. Evaluation criteria change over time with the availability of new toxicologic data.

There are three primary sources of environmental evaluation criteria for the workplace: 1) NIOSH Recommended Exposure Limits (RELs)[6], 2) the American Conference of Governmental Industrial Hygienists' (ACGIH) Threshold Limit Values (TLVs®)[7], and 3) the U.S. Department of Labor Occupational Safety and Health Agency (OSHA) Permissible Exposure Limits (PELs).[8] The OSHA PELs may reflect the feasibility of controlling exposures in various industries where the agents are used; whereas the NIOSH RELs are based primarily on concerns relating to the prevention of occupational disease. It should be noted when reviewing this report that employers are legally required to meet those levels specified by an OSHA standard.

A. Respirable Silica and Cristobalite

Crystalline silica (quartz) and cristobalite have been associated with silicosis, a fibrotic disease of the lung 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 non-specific chest illnesses. Silicosis usually occurs after years of exposure, but may appear in a shorter period of time if exposure concentrations are very high.[9] The NIOSH RELs for respirable quartz and cristobalite, published in 1974, are 50 µg/m^3, as TWAs, for up to 10 hours per day during a 40-hour work week.[10] These RELs are intended to prevent silicosis. However, evidence indicates that crystalline silica is a potential occupational carcinogen and NIOSH is currently reviewing the data on carcinogenicity.[11,12,13] The OSHA PELs and the ACGIH TLV®s for respirable quartz and cristobalite are 100 and 50 µg/m^3, as 8-hour TWAs, respectively.[7,8]

B. Metals

A list of selected metals along with a brief summary of their primary health effects are presented in Table 1. The evaluation criteria for occupational exposures to these contaminants are included in Table 3.

C. Organic Solvents

Acute benzene overexposure can cause central nervous system depression with symptoms such as headache, nausea, and drowsiness. Chronic exposure to benzene has been associated with the depression of the hematopoietic system and is associated with an increased incidence of leukemia and possibly multiple myeloma.[6,20] The NIOSH REL is 0.1 ppm. NIOSH classifies benzene as a human carcinogen and recommends that exposures be reduced to the lowest feasible level (LFL). The OSHA PEL is 1 ppm. The current ACGIH TLV® is 10 ppm as a suspected human carcinogen. ACGIH has proposed to lower the TLV® to 0.1 ppm and classify it as a proven human carcinogen.[7]

Toluene exposure has been associated with central nervous system depression. Symptoms may include headache, dizziness, fatigue, confusion, and drowsiness. Exposure may also cause irritation of the eyes, respiratory tract, and skin.[14,20] The NIOSH REL, ACGIH TLV®, and OSHA PEL for toluene are 100 ppm as a TWA. ACGIH has proposed a TLV® of 50 ppm in their notice of intended changes.

D. Phenol

Phenol is an irritant of the eyes, mucous membranes, and skin. Systemic absorption can cause convulsions as well as liver and kidney disease. The skin is a route of entry for the vapor and liquid phases. Phenol has a marked corrosive effect on any tissue. Symptoms of chronic phenol poisoning may include difficulty in swallowing, diarrhea, vomiting, lack of appetite, headache, fainting, dizziness, dark urine, mental disturbances, and possibly a skin rash.[14] The NIOSH REL, ACGIH TLV®, and OSHA PEL for phenol are 25 ppm as a TWA. NIOSH has set a ceiling limit of 15.6 ppm. All criteria include a skin notation, which indicates that skin absorption may be a significant route of exposure.

E. Carbon Monoxide

Carbon monoxide (CO) is a colorless, odorless, tasteless gas which can be a product of the incomplete combustion of organic compounds. CO combines with hemoglobin and interferes with the oxygen carrying capacity of blood. Symptoms include headache, drowsiness, dizziness, nausea, vomiting, collapse, myocardial ischemia, and death.[14] The NIOSH REL and OSHA PEL for carbon monoxide are 35 ppm as a TWA. NIOSH and OSHA have established a ceiling level (not to be exceeded at any time during the workday) of 200 ppm. The ACGIH TLV® for carbon monoxide is 25 ppm as an 8-hour TWA.

F. Formaldehyde

Formaldehyde is a colorless gas with a strong odor. Exposure can occur through inhalation and skin absorption. The acute effects associated with formaldehyde are irritation of the eyes and respiratory tract and sensitization of the skin. The first symptoms associated with formaldehyde exposure, at concentrations of 0.1 to 5 ppm, are burning of the eyes, tearing, and general irritation of the upper respiratory tract. There is variation among individuals, in terms of their tolerance and susceptibility to acute exposures of the compound.[23] In two separate studies, formaldehyde has induced a rare form of nasal cancer in rodents. Formaldehyde exposure has been identified as a possible causative factor in cancer of the upper respiratory tract in a proportionate mortality study of workers in the garment industry.[24] NIOSH has identified formaldehyde as a suspected human carcinogen and recommends that exposures be reduced to the lowest feasible concentration (0.016 ppm based on LOD). The OSHA PEL is 0.75 ppm as an 8-hour TWA and 2 ppm as a STEL.[25] ACGIH has designated formaldehyde to be a suspected human carcinogen and therefore, recommends that worker exposure by all routes should be carefully controlled to levels "as low as reasonably achievable" below the TLV.[7] ACGIH has set a ceiling limit of 0.3 ppm.

G. Isopropyl Alcohol

Isopropyl alcohol is an irritant of the eyes and mucous membranes. High exposures can cause central nervous system depression.[14] The NIOSH REL, ACGIH TLV®, and OSHA PEL for isopropyl alcohol are 400 ppm as a TWA.

VI. RESULTS

A. Respirable Silica and Cristobalite

The results of the PBZ air samples are presented in Table 2. The 16 PBZ approximately full-shift sample concentrations ranged from 31 to 284 $\mu g/m^3$, as TWAs. Six of the 16 sample concentrations (38%) exceeded the OSHA PEL of 100 $\mu g/m^3$ for respirable silica and 11 of the 16 sample concentrations (69%) exceeded the NIOSH REL of 50 $\mu g/m^3$ for respirable silica. The samples collected for the crane operators had the highest exposures (80 to 284 $\mu g/m^3$; geometric mean: 153 $\mu g/m^3$), followed by the molders (38 to 184 $\mu g/m^3$, geometric mean: 118 $\mu g/m^3$), shakeout and front-end loader operators (31 to 118 $\mu g/m^3$, geometric mean: 67 $\mu g/m^3$), and coremakers (38 to 79 $\mu g/m^3$; geometric mean: 52 $\mu g/m^3$). Cristobalite was not detected in any of the samples.

B. Metals

The 13 PBZ air sample concentrations are presented in Table 3. Concentrations of aluminum, chromium, copper, iron, magnesium, manganese, lead, and zinc (range: 0.4 to 714 $\mu g/m^3$) did not exceed the respective occupational evaluation criteria. However, since the valence state of chromium was not determined, worker exposures to the more toxic Chromium VI was unknown.

C. Phenol

The results of the 8 PBZ samples are presented in Table 4. The concentrations ranged from 0.07 to 0.54 ppm (geometric mean: 0.14 ppm) which were below the current occupational evaluation criteria of 5 ppm.

D. Carbon Monoxide

The results for the 10 PBZ and 2 area air samples are listed in Table 5. The PBZ concentrations ranged from 2 to 30 ppm. Five out of the 10 samples collected (two pourers, two crane operators, and a small area coremaker/pourer) exceeded the ACGIH TLV® of 25 ppm. Six of the 10 PBZ samples had peak exposures (218 to 542 ppm) that exceeded the NIOSH and OSHA ceiling limit of 200 ppm, which should not be exceeded at any time. The area CO concentrations ranged from 10 to 19 ppm.

These results indicate that workers were overexposed to carbon monoxide at this facility. The most likely source of the carbon monoxide was the decomposition of the organic binders used in the molds and cores.

E. Formaldehyde

The results for the five area air samples in the coremaking, molding, and pouring areas are given in Table 6. The results ranged from 0.012 to 0.026 ppm. Two samples (large coremaking area and small pouring area) exceeded the NIOSH REL of 0.016 ppm for occupational exposure.

F. Isopropyl Alcohol

The results for the 8 PBZ air samples are presented in Table 7. The PBZ concentrations ranged from 0.94 to 37.8 ppm (geometric mean: 4.1 ppm); all were below the current occupational evaluation criteria of 400 ppm.

G. Organic Solvents

The four PBZ sample results for benzene and toluene are given in Table 8. Benzene concentrations ranged from 0.003 ppm to 0.1 ppm (geometric mean: 0.03 ppm). The highest concentration was collected for a molder which equaled the NIOSH REL of 0.1 ppm for benzene. Toluene concentrations ranged from less than 0.062 ppm to 0.066 ppm which were below the current evaluation criteria of 100 ppm.

H. Observations of Work Practices

Hearing and eye protection was required in the facility, but not everyone wore hearing protection or safety glasses in the building. Employees were observed smoking and eating lunch in the general work area. Workers were observed lifting and moving molds by hand, weighing up to approximately 75 pounds, which could result in back and other injuries.

VII. DISCUSSION AND CONCLUSIONS

The foundry industry has been identified as a complex process with numerous associated health hazards.[26] Little information is available about the long-term health effects of emissions from molds composed of synthetic chemical molding materials. Mortality studies have indicated that a two- to three-fold excess risk of lung cancer has been identified for molders, pourers, and cleaning room operators when compared to a standard population.[27] Smoking history was not available for these studies. Additional investigations are needed to determine if chronic health effects do result from exposures to current mold emissions. The industrial hygiene sampling data indicate that respirable silica, carbon monoxide, formaldehyde, and benzene exposures in the coremaking, molding, and shakeout areas at this facility constitute a potential health hazard to workers. During the walkthrough survey, some potential safety and health hazards were identified, such as the use of compressed air to clean molds, and unenforced hearing and eye protection policies.

VIII. RECOMMENDATIONS

The following recommendations are offered to reduce workers' exposures to respirable silica, benzene and other solvents, formaldehyde, carbon monoxide, and to correct safety and health issues that were identified at this facility. NIOSH and OSHA recommend that engineering controls should be used to control hazards to the extent feasible, followed by work practices, and, if necessary, personal protective equipment.

1) Until appropriate engineering controls are implemented to reduce exposures to within OSHA and NIOSH recommended criteria, employees in the coremaking, molding, and shakeout departments should be provided respiratory protection for organic vapors and respirable silica exposures. Based on the concentrations of organic solvents and respirable silica detected, NIOSH recommends that workers should use an organic vapor cartridge in conjunction with an air-purifying respirator with a high-efficiency particulate filter.[28,29]

2) To reduce CO and other exposures to the crane operators, a fresh air supply system should be installed to ventilate the cab with uncontaminated air from the outside, and the cab should be enclosed and maintained under positive pressure with respect to the work environment. The crane operators are exposed to emissions that rise from the channel furnaces, emissions generated during pouring operations, and decomposition products and respirable silica during shakeout operations.

3) A permanent location should be created for the shaker table (shake-out area). The shaker table should be enclosed with movable sides to enable ease of movement for large castings. The enclosure should be ventilated to help contain emissions of dust containing respirable silica and thermal decomposition products. To reduce exposures, the molds should be dropped directly onto the semi-enclosed shaker table, instead of breaking the molds on the open floor using the front-end loader. In place of the front end loaders, molds could be dumped into containers that could be dumped by forklifts into the shakeout. To reduce exposures to decomposition products, the molds should be shaken out cold.

4) To reduce exposures to respirable silica during the cleaning of the core and mold surfaces, the compressed air hoses should be eliminated and replaced with a central vacuum system. As an interim measure, the existing air lines should be regulated to reduce air to less than 30 pounds per square inch (psi) to lessen dust levels currently being generated.[30] An industrial vacuum should be used on a regular basis to collect loose sand/dust on the floor instead of dry sweeping. A collection bin should be used to store excess sand until the end of the shift to aid in clean-up.

5) To reduce exposures to respirable silica and solvents in the molding and coremaking departments, uncontaminated, tempered air should be supplied directly to the operator work areas. This fresh air could be supplied in the form of a low velocity air shower located directly over the workers. If this would interfere with the use of overhead cranes when moving the molds, the fresh air could be introduced behind the worker.

6) To reduce CO and decomposition product exposures and improve general ventilation, a make-up air system should be installed to supply fresh air and heat, therefore, replacing the existing direct-fired gas space heaters. Air exhausted from the building should be replaced with tempered air from an uncontaminated source. This air could be directed to operator work areas such as pouring and molding to provide a cleaner environment. The American Foundrymen's Society "Foundry Ventilation Manual" recommends that general ventilation rates of 20-50 cubic feet per minute (cfm) per square foot (ft^2) of floor area be used to control emissions in pouring areas.[31] In the small and large mold pouring areas, approximately 297,000 cfm (floor area: 14,580 ft^2) and 423,000 cfm (floor area: 21,150 ft^2) of air would be needed to meet the minimum general ventilation requirement, respectively. The progression of mold pouring should be toward the make-up air source so that air contaminants are moved in the opposite direction.[31]

7) To reduce exposures to respirable silica, all chutes transporting dry sand in the coremaking/molding departments should be enclosed and ventilated. At a minimum, the hinged lids on the chutes should be gasketed to help reduce dust emissions. Transfer points, particularly where valves activate, should also be enclosed with sheet metal and ventilated to reduce dust emissions. The sand free fall distance from the machine to the core box should be reduced or enclosed.

8) To reduce employee exposures to benzene, carbon monoxide, and other decomposition products, the molds should be poured on a conveyor that then enters an enclosed and ventilated tunnel. The tunnel could lead to a smokehouse where the molds can off-gas safely until ready for the shakeout operation.

9) To prevent accidents from the pourer using a ladder to reach the molds, the overhead cranes in the large mold pouring area should be modified for pouring activities to eliminate this unsafe practice.

10) To avoid ingestion or inhalation of contaminants such as heavy metals and hydrocarbons, employees should not be allowed to eat, drink, or smoke in the production area.

11) The current written hearing and eye protection policies should be strictly enforced. During the site visit, it was observed that some workers did not wear their hearing protection or safety glasses.

12) Employees should use the available crane hoists instead of manually lifting and moving cores and small molds.

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X. AUTHORSHIP AND ACKNOWLEDGEMENTS

Report Prepared by:	Nancy Clark Burton, M.P.H., M.S. Industrial Hygienist
	Gregory Kinnes, M.S., C.I.H. Industrial Hygienist Industrial Hygiene Section Hazard Evaluation and Technical Assistance Branch
	Ronald Hall Industrial Hygienist
	William A. Todd, M.S. Industrial Engineer Engineering Control Technology Branch Division of Physical Sciences and Engineering
Field Support:	Richard Liston Ohio Department of Health Bureau of Occupational Health
Analytical Support:	Data Chem, Inc. 960 West Leroy Drive

	Salt Lake City, Utah
Originating Office:	Hazard Evaluations and Technical Assistance Branch Division of Surveillance, Hazard Evaluations and Field Studies
Report Formatted By:	Donna M. Humphries Office Automation Assistant Industrial Hygiene Section

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1. The General Castings Company - Toledo Street Facility
2. Employee Representative
3. OSHA, Region V

For the purpose of informing affected employees, copies of this report shall be posted by the employer in a prominent place accessible to the employees for a period of 30 calendar days.

Table 1

Health Effects Summary for Metals

General Castings Company - Toledo Street Facility
Delaware, Ohio
HETA 92-090

Substance	Primary Health Effects
Aluminum	Metallic aluminum dust is considered a relatively benign "inert dust".[14]
Chromium	Chromium (Cr) exists in a variety of chemical forms and toxicity varies among the different forms. For example, elemental chromium is relatively non-toxic.[14] Other chromium compounds may cause skin irritation, sensitization, and allergic dermatitis. In the hexavalent form (Cr(VI)), Cr compounds are corrosive, and possibly carcinogenic. Until recently, the less water-soluble Cr(VI) forms were considered carcinogenic while the water-soluble forms were not considered carcinogenic. Recent epidemiological evidence indicates carcinogenicity among workers exposed to soluble Cr(VI) compounds.[15-19] Based on this new evidence, NIOSH recommends that all Cr(VI) compounds be considered as potential carcinogens.
Copper	Inhalation of copper fume has resulted in irritation of the upper respiratory tract, metallic taste in the mouth, and nausea.[14] Exposure has been associated with the development of metal fume fever.[6]
Iron	Inhalation of iron oxide dust may cause a benign pneumoconiosis called siderosis.[20]
Lead	Chronic lead exposure has resulted in nephropathy (kidney damage), gastrointestinal disturbances, anemia, and neurologic effects.[14] These effects may be felt as weakness, fatigue, irritability, high blood pressure, mental deficiency, or slowed reaction times. Exposure also has been associated with infertility in both sexes and fetal damage.[21]
Magnesium	Magnesium can cause eye and nasal irritation.[22] Exposure has been associated with the development of metal fume fever.[6]
Manganese	Manganese fume exposure has been associated with chemical pneumonitis and central nervous system effects.[14,20]
Zinc	Zinc has been associated with shortness of breath, minor lung function changes, and metal fume fever.[6,22]

Table 2

Results of Personal Breathing Zone Samples
for Respirable Silica

General Castings Company
Toledo Street Facility
Delaware, Ohio
HETA 92-090

February 5-6, 1992

Job Title/ Location	Sampling Time	Sample Volume (liters)	Respirable Silica Concentration (TWA-µg/m³)*
Bobcat Operator	9:23-12:44	340	118
Shakeout/Coreout Operator	9:25-12:39	328.1	31
Coremaker	6:21-2:25	799	37.5
Small Hand Coremaker	6:45-2:20	758.2	79.1
Molder/Coremaker/ Small Molding Area	6:19-2:20	816	159.3
Crane Operator	6:44-2:25	766.7	156.5
Molder\Large Molding Area	6:32-2:25	804.1	174.1
Molder/Coremaker/ Small Molding Area	6:19-2:18	814.3	184.2
Coremaker/Large Molding Area	6:26-2:35	831.3	48.1
Shakeout/Large Molding Area	6:29-2:25	807.5	99.1
NIOSH Recommended Exposure Limit (REL):		50	
OSHA Permissible Exposure Limit (PEL):			100
ACGIH Threshold Limit Value (TLV®):			100

Minimum Detectable Concentration (MDC) [Avg. Volume: 698 l] 22
Minimum Quantifiable Concentration (MQC) [Avg. Volume: 698 l] 43

* - TWA-µg/m³ - Time-weighted average micrograms per cubic meter

Table 2 (continued)

Results of Personal Breathing Zone Samples
for Respirable Silica

General Castings Company
Toledo Street Facility
Delaware, Ohio
HETA 92-090

February 5-6, 1992

Job Title/ Location	Sampling Time	Sample Volume (liters)	Respirable Silica Concentration (TWA-µg/m³)*
Molder\Large Molding Area	6:34-2:18	794	38
Shakeout/Hookers	5:34-12:40	724	55
Bobcat Operator/ Shakeout	5:29-12:46	740	54
Foreman/Crane Operator	5:28-12:47	746	80
Shakeout/Hookers	5:32-12:46	738	81
Crane Operator	9:14-12:41	352	284
NIOSH Recommended Exposure Limit (REL):		50	
OSHA Permissible Exposure Limit (PEL):			100
ACGIH Threshold Limit Value (TLV®):			100

Minimum Detectable Concentration (MDC) [Avg. Volume: 698 l] 22

Minimum Quantifiable Concentration (MQC) [Avg. Volume: 698 l] 43

* - TWA-µg/m³ - Time-weighted average micrograms per cubic meter

Table 6

Results of Area Samples for Formaldehyde

General Castings Company
Toledo Street Facility
Delaware, Ohio
HETA 92-090

February 5-6, 1992

Location	Sampling Time	Sample Volume (liters)	Concentration (TWA-ppm)*
Large Coremaking Department	12:10-2:07		1170.026
Small Pouring Line	12:12-2:13		1210.012
Small Molding Line	12:13-2:13		1190.013
Large Molding Area	12:02-2:13		1310.012
Small Pouring Line	12:07-2:13		1260.021

NIOSH Recommended Exposure Limit (REL):	0.016
OSHA Permissible Exposure Limit (PEL):	0.75
ACGIH Threshold Limit Value (TLV®):	1
Minimum Detectable Concentration (MDC): (Sample Volume - 117 liters)	0.004 ppm
Minimum Quantifiable Concentration (MQC): (Sample Volume - 117 liters)	0.013 ppm

* - ppm - parts per million

Table 4

Results of Personal Breathing Zone Air Samples for Phenol

General Castings Company
Toledo Street Facility
Delaware, Ohio
HETA 92-090

February 5-6, 1992

Location/ Job Category	Sampling Time	Sample Volume (liters)	Concentration (TWA-ppm)*
Crane Operator	6:49-2:13	44	0.20
Large Molding/ Molder	6:16-2:14	48	0.07
Small Molding/ Coremaker	6:38-2:25	47	0.11
Small Pouring Floor/ Supervisor	6:25-2:17	46	0.09
Small Pouring Floor/ Pourer	6:26-2:26	48	0.08
Small Molding/ Molder	10:41-2:16	22	0.54
Large Molding/ Molder	10:46-2:25	22	0.11
Crane Operator	10:52-2:52	23.5	0.18
NIOSH Recommended Exposure Limit (REL):			5
OSHA Permissible Exposure Limit (PEL):		5	
ACGIH Threshold Limit Value (TLV®):			5
Minimum Detectable Concentration (MDC) (Sample Volume: 22 liters)			0.01 ppm
Minimum Quantifiable Concentration (MQC) (Sample Volume: 22 liters)			0.04 ppm

* - ppm - parts per million

Table 7

Results of Personal Breathing Zone Air Samples for Isopropyl Alcohol

General Castings Company
Toledo Street Facility
Delaware, Ohio
HETA 92-090

February 5-6, 1992

Location/ Job Category	Sampling Time	Sample Volume (liters)	Concentration (TWA-ppm)*
Coremaker	6:12-2:09	95	8.2
Crane Operator	6:49-2:26	91	4.9
Supervisor	6:40-2:10	82	19.5
Large Molding Area/ Molder	10:47-2:20	43	2.0
Small Molding Area/ Molder	6:22-2:25	98	1.1
Mold Preparation	6:20-2:12	48	37.8
Small Molding Area/ Molder	10:49-2:25	43	1.4
Small Molding Area/ Molder	10:36-2:16	44	0.94
NIOSH Recommended Exposure Limit (REL):			400
OSHA Permissible Exposure Limit (PEL):		400	
ACGIH Threshold Limit Value (TLV®):			400
Minimum Detectable Concentration (MDC) (Volume: 43 liters)		0.19 ppm	
Minimum Quantifiable Concentration (MQC) (Volume: 43 liters)			0.40 ppm

* - ppm - Parts per million

Table 3

Results of Personal Breathing Zone Air Samples for Metals
Using Inductively Coupled Plasma Emission Spectroscopy (ICP)

General Castings Company
Toledo Street Facility
Delaware, Ohio
HETA 92-090

February 5-6, 1992

Job Title	Sampling Time	Sample Volume	Metal Concentrations (TWA-µg/m³)* Al	Cr	Cu	Fe	Mg	Mn	Pb	Zn
Pourer/Small Line	6:31-2:25	950	36	ND**	ND	116	10	2	ND	1
Crane Operator/ Small Line	6:33-2:25	946	32	ND	ND	106	9	2	ND	1
Pourer/Large Line	7:07-2:21	866	23	0.4	ND	76	8	3	ND	3
Coresetter/Pourer/ Large Line	7:13-2:16	846	50	0.8	0.5	189	18	5	ND	3
Coresetter/Pourer/ Large Line	12:09-2:26	264	34	ND	ND	167	11	5	ND	5
Furnace Operator	7:03-2:17	868	50	2	4	714	28	38	2	12
Coremaker/Pourer/ Large Line	10:39-2:14	428	26	ND	ND	105	9	4	ND	3
Minimum Quantifiable Concentration (MQC) 7.6 (Volume: 262 liters)			1.1	1.1	1.9	1.9	0.8	3.8	1.9	

* - TWA-µg/m³ - Time-weighted average micrograms per cubic meter
** - ND - None Detected, below the MQC

Metals	OSHA PELs (µg/m³)	NIOSH RELs (µg/m³)	ACGIH TLVs (µg/m³)
Al - Aluminum	15000	10000	10000
Cr - Chromium	1000	500	500
Cu - Copper	1000	1000 (fume-100)	1000
Fe - Iron	10000	5000	5000
Mg - Magnesium	10000	None#	10000
Mn - Manganese	5000	1000	5000
Pb - Lead	50	<100	150
Zn - Zinc	10000	5000	10000

NIOSH contends that health effects can occur at the PEL.

Table 3 (continued)

Results of Personal Breathing Zone Air Samples for Metals
Using Inductively Coupled Plasma Emission Spectroscopy (ICP)

General Castings Company
Toledo Street Facility
Delaware, Ohio
HETA 92-090

February 5-6, 1992

Job Title	Sampling Time	Sample Volume	Metal Concentrations (TWA-µg/m³)*							
			Al	Cr	Cu	Fe	Mg	Mn	Pb	Zn
Coremaker/Pourer/ Large Line	10:41-2:26	450	18	ND**	ND	76	9	5	ND	4
Coremaker/Pourer/ Small Line	10:45-2:22	434	30	ND	ND	157	8	2	ND	2
Coremaker/Pourer/ Small Line	10:49-2:20	422	28	ND	ND	81	8	1	ND	1
Coremaker/Pourer/ Large Line	12:02-2:17	262	19	ND	ND	107	6	5	ND	5
Furnace Operator	9:08-12:34	412	12	ND	ND	51	8	3	7	14
Furnace Operator	9:07-12:34	416	7	ND	ND	43	6	2	7	13
Minimum Quantifiable Concentration (MQC) (Volume: 262 liters)			7.6	1.1	1.1	1.9	1.9	0.8	3.8	1.9

* - TWA-µg/m³ - Time-weighted average micrograms per cubic meter
** - ND - None Detected, below the MQC

Metals	OSHA PELs (µg/m³)	NIOSH RELs (µg/m³)	ACGIH TLVs (µg/m³)
Al - Aluminum	15000	10000	10000
Cr - Chromium	1000	500	500
Cu - Copper	1000	1000 (fume-100)	1000
Fe - Iron	10000	5000	5000
Mg - Magnesium	10000	None#	10000
Mn - Manganese	5000	1000	5000
Pb - Lead	50	<100	150
Zn - Zinc	10000	5000	10000

NIOSH contends that health effects can occur at the PEL.

Table 8

Results of Personal Breathing Zone Air Samples
for Volatile Organic Compounds

General Castings Company
Toledo Street Facility
Delaware, Ohio
HETA 92-090

February 5-6, 1992

Job/ Location	Sampling Time	Sample Volume (liters)	Benzene Concentration (TWA-ppm)*	Toluene Concentration (TWA-ppm)	Total Hydrocarbons Concentration (TWA-mg/m^3)**
Molder/ Small Floor	6:22-2:25	98	0.08	0.013##	47.8
Mold Preparation	6:20-2:12	95	0.04	0.066##	74.8
Molder/ Small Floor	10:49-2:25	43	0.003##	ND#	18.2
Molder/ Small Area	10:36-2:16	44	0.1	ND	436
NIOSH Recommended Exposure Limit (REL):			0.1	100	
OSHA Permissible Exposure Limit (PEL):			1.0	100	
ACGIH Threshold Limit Value (TLV®):			10 (proposed-0.1)	100 (proposed-50)	
Minimum Detectable Concentration (MDC): (Sample Volume: 43 liters)			0.007	0.062	2.33
Minimum Quantifiable Concentration (MQC): (Sample Volume: 43 liters)			0.024	0.204	7.67

* - TWA-ppm - Time-weighted average - parts per million

** - TWA-mg/m^3 - Time-weighted average milligrams per cubic meter

- Between MDC and MQC

#- ND - None Detected, below the MDC

Table 5

Results of Personal Breathing Zone and Area Air Samples
for Carbon Monoxide

General Castings Company
Toledo Street Facility
Delaware, Ohio
HETA 92-090

February 5-6, 1992

Job Category	Average Concentration (ppm)*	Peak Concentration (ppm)*
Personal:		
Furnace Operator	11	140
Crane Operator	30	239
Crane Operator	29	218
Metal Pourer	24	221
Metal Pourer Assistant	9	110
Metal Pourer	30	328
Metal Pourer Assistant	27	542
Metal Pourer Assistant	2	124
Small Coremaker/Pourer	26	453
Small Coremaker/Pourer	17	145
Area:		
Furnace Area	19	101
Furnace Area	10	87
NIOSH Recommended Exposure Limit (REL):	35	200
OSHA Permissible Exposure Limit (PEL):	35	200
ACGIH Threshold Limit Value (TLV®):	25	

Limit of Detection: 1 ppm

* - ppm - parts per million