HETA 92-157-2304
THE GENERAL CASTINGS CO.- DOMESTIC DIVISION
SHIPPENSBURG, PENNSYLVANIA
APRIL 1993

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I. SUMMARY

In February 1992, the National Institute for Occupational Safety and Health (NIOSH) received a management request to evaluate worker exposures throughout the General Castings-Domestic Division Facility, a gray and ductile iron foundry in Shippensburg, Pennsylvania.

On April 13-15, 1992, NIOSH representatives conducted an industrial hygiene survey. Personal breathing zone (PBZ) and area air samples were collected for respirable silica and cristobalite, metals, phenol, formaldehyde, carbon monoxide, ammonia, sulfur dioxide, and organic solvents. Work practices, engineering control measures, and noise exposures were also evaluated.

The PBZ air concentrations of respirable silica ranged from 14 (coremaker) to 319 micrograms per cubic meter [µg/m^3] (grinder), as time-weighted averages (TWAs). Six of the 11 sample concentrations (55%) exceeded the Occupational Safety and Health Administration (OSHA) Permissible Exposure Limit (PEL) of 100 µg/m^3 for respirable silica (as quartz), and 9 of the 11 sample concentrations (82%) exceeded the NIOSH Recommended Exposure Limit (REL) of 50 µg/m^3 for respirable crystalline silica (regardless of morphology). Cristobalite (30 µg/m^3) was detected in 2 samples collected for a shot blast operator and a grinder. Since grinders wore supplied air helmet respirators, the inside-respirator exposures of the employees were probably lower than the exposures measured. Three out of 5 noise exposures measured exceeded the OSHA PEL of 90 decibels, A-weighted levels, [dB(A)], as an 8-hour TWA. The lead concentration (79 µg/m^3) for one sample collected for the furnace operator exceeded the OSHA PEL of 50 µg/m^3. One area sample concentration for benzene (0.17 parts per million [ppm]) was collected in the pouring/shakeout area. This suggests employee exposures to benzene which NIOSH considers a potential occupational carcinogen. Using direct reading measurements, short-term carbon monoxide concentrations ranged in the pouring area from 130-170 ppm; all were below the NIOSH/OSHA ceiling value of 200 ppm. A fibrous board in the furnace operator's control area contained 30-<40% chyrsotile asbestos indicating that there is a potential for worker exposure. Concentrations of phenol (0.01-0.07 ppm), formaldehyde (0.002-0.008 ppm), ammonia (13 ppm), sulfur

dioxide (not detected), and the metals: aluminum, chromium, copper, iron, magnesium, manganese, nickel, and zinc (range: 0.5 to 4348 $\mu g/m^3$) did not exceed their respective occupational evaluation criteria.

The industrial hygiene sampling data indicate that workers were overexposed to respirable silica, lead, and noise; and that carbon monoxide, chrysotile, and benzene exposures constituted a potential health hazard to employees in the coremaking, molding, pouring, cleaning, 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 (Ferrous Foundries), respirable silica (quartz), cristobalite, lead, carbon monoxide, noise exposure, chrysotile, engineering controls.

II. INTRODUCTION

On April 13-15, 1992, National Institute for Occupational Safety and Health (NIOSH) representatives conducted a site visit to the General Castings-Domestic Division facility, a gray and ductile iron foundry, in Shippensburg, Pennsylvania. This visit was made in response to a management request to evaluate worker exposures in the coremaking, molding, pouring, melting, shakeout, sand handling, and cleaning areas of the facility. Since the company was under new management, there was a general interest in identifying potential occupational health hazards.

III. BACKGROUND

The General Castings-Domestic Division Facility is housed in a masonry building with several additions which were built between 1900-1925. There has been a foundry on the site since the 1890s. The facility operates three shifts with a total of 75 employees. The general layout of the foundry is presented in Figure 1.

To produce molten iron, the plant used an electric induction and two holding furnaces. There were no local exhaust hoods or air pollution control devices in place for the induction furnaces. Metal scrap yards were located both inside and outside the facility.

Four coremaking processes were used: hot shell, oil-baked, cold box (sulfur dioxide-SO_2), and no-bake. A core is used to define the internal hollows desired in the casting. Cores were made by hand and by machine. There were four hot shell molding machines: two had side-canopy exhaust hoods. A hot shell core is produced by dumping a resin-coated sand into a heated pattern, holding the coremaking materials in place long enough to produce curing on the surface, removing excess sand from the core, and then removing the hollow-cured shell from the pattern. Employees make oil-based cores, containing linseed oil and petroleum distillates, which are baked in one of 5 gas-fired ovens to make a solid core. Cold box coremaking uses a gaseous catalyst (SO_2) to cure the binder system and produce the hardened core. No-bake cores were made of a phenolic-formaldehyde binder [PEPSET I®, PEPSET II®, and PEPSET III®, Ashland Chemical Company, Columbus, Ohio] mixed with silica sand in an automatic mixer. A polymeric methylene phenylene diisocyanate (MDI) was used as the binder catalyst. According to the Material Safety Data Sheets (MSDSs), the decomposition products from these no-bake binders may include carbon dioxide, carbon monoxide, hydrocarbons, and phenols. There was local exhaust ventilation in place for the no-bake area.

There were three molding/pouring areas: the deck area, the floor area, and the Osborn area. A mold provides the cavity into which the metal is poured to produce a casting. A Hunter semi-automatic molding machine was used in the deck area. The molds are made in a press, then fed into a rotating circle for pouring. After pouring, the molds enter the lower conveyor and move toward shakeout. According to the operator, 10-20 ladles were poured at that location per shift. Squeeze jolt molding machines, which use green sand containing coal dust, were used in conjunction with the floor and deck pouring areas.

The Osborne molding machine is used to make larger castings. The molds are placed on a roller system and poured adjacent to where they were formed. Excess sand is removed in the coremaking and molding areas using compressed air. Crane hoists are used for lifting molds from the squeeze machines onto the conveyor systems. An overhead crane system, controlled from the ground, was used to position the ladles and move molds in the floor area. The metal pouring operations are performed during the day and night shifts. After pouring, the molds in the deck and floor areas move slowly on tracks and fall into a shakeout conveyor which vibrates the warm casting to remove the sand. The castings fall into a metal bin at the end of the conveyor and are taken by forklift to the blasting area. There are canopy hoods over the end of the shakeout conveyors where the castings are separated from the sand. The loose sand is automatically fed into the sand reclamation system. Some of the larger castings from the floor area are manually pulled off the conveyor into the metal bins. Bobcat® front-end loaders were used to both load the sand reclamation system and to shake out the larger castings which did not fit on the shakeout conveyor.

Two shotblast machines are located near the floor pouring area and are connected to a bag house dust collection system. The machines are emptied into a metal conveyor which dumps the castings into a metal container. The castings are then taken by forklift to the grinding areas. Brooms and shovels are used to clean up excess dry sand throughout the facility.

Grinders are located in three areas: two grinders in a separate building, one station in the main building, and four small grinding stations next to the blasting area. The first two locations have operational down-draft benches. The four small casting grinding stations have local exhaust ventilation in place. The castings requiring a primer coat are sprayed in an open area using a water reducible primer, which according to the MSDS, contains low volatile organic solvent concentrations and no chromate or lead. The spray paint booth, at the time of this evaluation, was being renovated.

Safety shoes, hard hats, and safety glasses are required throughout the facility. NIOSH/Mine Safety And Health Administration (MSHA) approved supplied air respirator helmets are used in the grinding areas. Hearing protection devices (disposable plugs) are required in the shakeout and grinding areas and available to other employees upon request. Flame retardant clothing and protective goggles are worn by the pourers. The MSDSs, hearing protection policy, and respiratory protection policy were reviewed.

General ventilation is supplied by propeller wall fans. At the time of the survey, the three wall fans over the deck pouring area were not in operation. Heat is provided by overhead electric heaters. Additional general ventilation is supplied by open doors and windows during the warmer months.

IV. METHODS

A. Respirable Silica and Cristobalite

Eleven personal breathing zone (PBZ) and 3 area 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 millimeter (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), limit of quantitation (LOQ), minimum detectable concentration (MDC), and minimum quantifiable concentration (MQC) for respirable silica (quartz) and cristobalite are presented in the following chart:

Analyte	LOD µg/sample	LOQ µg/sample	MDC µg/m³	MQC µg/m³	Minimum Volume (liters)
Quartz	10	30	18	55	544
Cristobalite	15	30	28	55	544

B. Metals

Twelve PBZ air samples were collected on mixed-cellulose ester filters (37 millimeter [mm] diameter, 0.8 micrometer [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 598 liters, for the selected metals are listed in Table 3.

C. Phenol

One PBZ and 5 area 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, LOQ, MDC, and MQC for phenol are presented in the following chart:

Analyte	LOD µg/sample	LOQ µg/sample	MDC ppm	MQC ppm	Minimum Volume (liters)
Phenol	1	3.3	0.006	0.021	40.5

D. Formaldehyde

Four area air samples were collected using impingers filled with 1% sodium bisulfite solution at a flowrate of 1 l/min. 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, LOQ, MDC, and MQC for formaldehyde are presented in the following chart:

Analyte	LOD µg/sample	LOQ µg/sample	MDC ppm	MQC ppm	Minimum Volume (liters)
Formaldehyde	0.5	1.7	0.001	0.003	411

E. Solvents

Four PBZ and 1 area air 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.[4] Total aromatic hydrocarbons were based on the presence of benzene. The analytical LOD, LOQ, MDC, and MQC for benzene are presented in the following chart:

Analyte	LOD µg/sample	LOQ µg/sample	MDC ppm	MQC ppm	Minimum Volume (liters)
Benzene	1	3.3	0.004	0.015	67

The analytical LOD, LOQ, MDC, and MQC for total aromatic hydrocarbons are presented in the following chart:

Analyte	LOD Mg/sample	LOQ Mg/sample	MDC mg/m^3	MQC mg/m^3	Minimum Volume (liters)
Aromatic Hydrocarbons	0.2	0.33	3	5	67

F. *Noise*

Area noise samples were measured with a Quest Electronics Model 2400 Sound Level Meter. Five noise dosimeters (Quest Electronics M-27 Noise Logging Dosimeters) were used during this survey. The dosimeter consists of a small noise recording device which is worn on the worker's collar or shoulder area. The device measures noise in decibels, A-weighted levels (dB[A]), integrates the data according to OSHA noise regulations, and stores it for later analysis.

G. Asbestos

A sample of fibrous board, located on the furnace operator's control platform, was collected and analyzed for percent and type of asbestos according to NIOSH Method 9002.[5] Microscope slides were prepared using refractive index liquid and scanned for the presence of asbestos utilizing polarized light microscopy and dispersion staining techniques.

H. Direct Reading Samples

Short-term (grab) air sample measurements were made in the coremaking and pouring areas for ammonia, carbon monoxide (CO), and sulfur dioxide (SO_2) using the Draeger® colorimetric gas detection system.

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 OSHA 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.[11-13]

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. *Benzene*

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. 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]

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 5 ppm as a TWA. All criteria include a skin notation, which indicates that skin absorption may be a significant route of exposure.

E. *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 ranging from 0.1 to 5 parts per million (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. 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.

F. *Noise/Hearing Loss*

Noise-induced loss of hearing is an irreversible, sensorineural condition that progresses with exposure. Although hearing ability declines with age (presbycusis) in all populations, exposure to noise produces hearing loss greater than that resulting from the natural aging process. This noise-induced loss is caused by damage to nerve cells of the inner ear (cochlea) and, unlike some conductive hearing disorders, cannot be treated medically.[26] While loss of hearing may result from a single exposure to a very brief impulse noise or explosion, such traumatic losses are rare. In most cases, noise-induced hearing loss is insidious. Typically, it begins to develop at 4000 or 6000 Hz (the hearing range is 20 Hz to 20000 Hz) and spreads to lower and higher frequencies. Often, material impairment has occurred before the condition is clearly recognized. Such impairment is usually severe enough to permanently affect a person's ability to hear and understand speech under everyday conditions. Although the primary frequencies of human speech range from 200 Hz to 2000 Hz, research has shown that the consonant sounds, which enable people to distinguish words such as "fish" from "fist", have still higher frequency components.[27]

The OSHA standard for occupational exposure to noise (29 CFR 1910.95)[28] specifies a maximum PEL of 90 dB(A)-slow response for a duration of 8 hours per day. The regulation, in calculating the PEL, uses a 5 dB time/intensity trading relationship. This means that in order for a person to be exposed to noise levels of 95 dB(A), the amount of time allowed at this exposure level must be cut in half in order to be within OSHA's PEL. Conversely, a person exposed to 85 dB(A) is allowed twice as much time at this level (16 hours) and is within his daily PEL. Both NIOSH, in its Criteria for a Recommended Standard,[29] and ACGIH, in their TLV®s,[7] propose an exposure limit of 85 dB(A) for 8 hours, 5 dB less than the OSHA standard. Both of these latter two criteria also use a 5 dB time/intensity trading relationship in calculating exposure limits.

Time-weighted average (TWA) noise limits as a function of exposure duration are shown as follows:

	Sound Level dB(A)	
Duration of Exposure (hrs/day)	NIOSH/ACGIH	OSHA
16	80	85
8	85	90

4	90	95
2	95	100
1	100	105
1/2	105	110
1/4	110	115*
1/8	115*	--- **

* No exposure to continuous or intermittent noise in excess of 115 dB(A).

** Exposure to impulsive or impact noise should not exceed 140 dB peak sound pressure level.

The OSHA regulation has an additional action level (AL) of 85 dB(A) which stipulates that an employer shall administer a continuing, effective hearing conservation program when the TWA value exceeds the AL. The program must include monitoring, employee notification, observation, an audiometric testing program, hearing protectors, training programs, and recordkeeping requirements. All of these stipulations are included in 29 CFR 1910.95, paragraphs (c) through (o).

The OSHA noise standard also states that when workers are exposed to noise levels in excess of the OSHA PEL of 90 dB(A), feasible engineering or administrative controls shall be implemented to reduce the workers' exposure levels. Also, a continuing, effective hearing conservation program shall be implemented.

G. *Asbestos*

NIOSH recommends as a goal the elimination of asbestos exposure in the workplace; where it cannot be eliminated, the occupational exposure should be limited to the lowest possible concentration.[30] This recommendation is based on the proven carcinogenicity of asbestos in humans and on the absence of a known safe threshold concentration.

NIOSH contends that there is no safe concentration for asbestos exposure. Virtually all studies of workers exposed to asbestos have demonstrated an excess of asbestos-related disease. NIOSH investigators therefore believe that any detectable concentration of asbestos in the workplace warrants further evaluation and, if necessary, the implementation of measures to reduce exposures. The OSHA PEL for asbestos limits exposure to 0.2 fibers per cubic centimeter (cc) as an 8-hour TWA.[8]

H. *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.

I. Sulfur Dioxide

Sulfur dioxide is intensely irritating to the eyes, mucous membranes, and respiratory tract. It can cause burning of the eyes and tearing coughing and chest tightness. Exposure may cause severe breathing difficulties. It forms sulfurous acid on contact with moist membranes.[31] NIOSH, OSHA, and ACGIH have set an exposure limit of 2 parts per million (ppm) for sulfur dioxide.

J. Ammonia

Ammonia is a severe irritant of the eyes, respiratory tract and skin. It may cause coughing, burning, and tearing of the eyes; runny nose; chest pain; cessation of respiration; and death. Symptoms may be delayed in onset. Exposure of the eyes to high gas concentrations may produce temporary blindness and severe eye damage. Exposure of the skin to high concentrations of the gas may cause burning and blistering of the skin. Repeated exposure to ammonia gas may cause chronic irritation of the eyes and upper respiratory tract.[14,32] The NIOSH REL for ammonia is 25 ppm as a 10-hour TWA. NIOSH and OSHA have set short-term exposure limits (STELs) of 35 ppm. ACGIH has set limits of 25 ppm or as an 8-hour TWA and a STEL of 35 ppm.

VI. RESULTS

A. Respirable Silica and Cristobalite

The results of the PBZ air sampling are presented in Table 2. The 11 PBZ sample concentrations ranged from 14 to 319 µg/m^3, as TWAs. Six of the 11 sample concentrations (55%) exceeded the OSHA PEL of 100 µg/m^3 for respirable silica and 9 of the 11 sample concentrations (82%) exceeded the NIOSH REL of 50 µg/m^3 for respirable silica. The samples collected for the grinders had the highest exposures (200 and 319 µg/m^3), followed by the forklift operator (224 µg/m^3), blast operators (51 and 255 µg/m^3), mixer operator (85 µg/m^3), coremakers (14 and 257 µg/m^3) and molders (29 and 55 µg/m^3). Cristobalite was detected for the rotoblast operator and the rough grinder at 30 µg/m^3. Grinders wore supplied air helmet respirators; therefore, the inside-respirator exposures to the employees were probably lower than the measured exposures. The three area air sample concentrations ranged from 38-119 µg/m^3 (geometric mean: 64 µg/m^3).

B. Metals

The 12 PBZ air sample concentrations are presented in Table 3. Concentrations of aluminum, chromium, copper, iron, magnesium, manganese, nickel, and zinc (range: 0.5 to 4348 µg/m^3) did not exceed the respective occupational evaluation criteria. The lead concentration (79 µg/m^3) for one sample collected for the furnace operator exceeded the OSHA PEL of 50 µg/m^3. The other lead sample concentration for the furnace operator was 14.6 µg/m^3.

C. Phenol

The results of the 1 PBZ and 5 area air samples are presented in Table 4. The PBZ concentration was 0.1 ppm and the area concentrations ranged from 0.01 to 0.07 ppm (geometric mean: 0.015 ppm). These levels were below the current occupational evaluation criteria of 5 ppm.

D. Formaldehyde

The results for the 4 area air samples in the coremaking department given in Table 5. The results ranged from 0.002 to 0.008 ppm and were below what are generally considered to be background concentrations.

E. Benzene

The 4 PBZ and 1 area sample results for benzene are given in Table 6. The PBZ benzene concentrations ranged from 0.01 ppm to 0.014 ppm (geometric mean: 0.011 ppm). The area concentration (0.17 ppm) collected in the vicinity of the floor shakeout conveyor exceeded the NIOSH REL of 0.1 ppm for benzene indicating a potential hazard.

F. Noise

To determine some of the potentially high noise activities in specific areas, a sound level meter, in the maximum hold position, was used to take readings in the slow dB[A] mode during a walk-through survey (Table 7). The noisiest activities in the squeeze molding area occurred during a process called " bumping" (the pieces of the metal mold were put together) and during the ramming process when sand was packed into the mold. The hot shell coremaking process generated high noise levels while compressed air was being released from the machine and when the core was hammered loose from the machine. The shotblasting area was noisiest when the metal parts fell on the metal conveyor and, subsequently, into a metal bin. The written hearing protection policy was reviewed and contained the appropriate components. Employees in the molding, pouring, shotblast, and cleaning areas were required to wear hearing protection.

Dosimeter measurements show how short-term noise levels affect an employee's noise exposure for an entire shift. A summary of the dosimeter readings is given in Table 8. Three of the 5 full-shift samples exceeded the OSHA PEL of 90 dB(A) for noise. All five full-shift samples exceeded the 85 dB(A) criteria used by NIOSH and ACGIH. Two of the samples (squeeze jolt molder and shot blast operator) had measurements over 115 dB(A) which current evaluation criteria state should not occur.

The dosimeter printouts are presented in Figures 2-6. The changes in the exposure patterns seem to be the result of break periods when the workers left the area and clean-up at the end of the day. The grinder (Figure 2) showed peaks when he was cleaning a casting and breaks when positioning a new piece. The laborer (Figure 3) showed the time at the end of the day when he left shakeout to move items around the facility on the forklift. The squeeze molder (Figure 4) and the hot shell coremaker (Figure 5) showed relative steady-state noise during the workday. The rotoblast operator (Figure 6) showed when the machine was emptied into the metal conveyor.

G. *Asbestos*

The bulk sample of fibrous board contained 30-<40% chrysotile based on polar light microscopy. There is a potential for the board to become friable where the furnace operator brushes against it.

H. Grab Sample Results

The results of short-term sampling for ammonia, CO, and SO_2 are listed in Table 9. In the vicinity of the hot shell coremaking machine, an ammonia concentration of 13 ppm was detected, compared to a NIOSH\OSHA STEL of 35 ppm. In the vicinity of the Hunter pouring operation, CO levels were between 130-170 ppm, which is less than the NIOSH\OSHA ceiling limit of 200 ppm. However since the pouring operation is relatively constant, these results indicate that workers are potentially overexposed to carbon monoxide in the pouring area of this facility. The most likely source of the carbon monoxide was the decomposition of the organic binders and coal additives used in the molds and cores. No SO_2 levels were detected in the area of the cold box coremaking machine at a LOD of 0.5 ppm.

I. Observations

It was observed that some individuals were not wearing hearing protection or safety glasses in the building where required. The written respiratory and hearing protection policies were appropriate. Employees were observed smoking and eating lunch in the general work area. The CO meter for the oil-lubricated compressor that supplied air for the grinders' helmets was not working. A chain guard across the railing opening leading to the lower conveyor system (about 16 feet below the deck) was not always in place. The material from the outside scrap yard created a large dust cloud in the area of the furnace when it was dumped in the interior scrap pile. Smoke powder showed that the three downdraft benches were working during the site visit. One coremaker was observed hand-dipping cores in a mixture containing solvents without using gloves. One shotblast unit was run accidently with the dust collection system off which created a dust cloud throughout the facility. Grinders were observed, after removing their respirators, cleaning their clothing at the end of the shift with compressed air. Workers were observed lifting and moving molds, weighing up to approximately 75 pounds by hand. This 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.[33] 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.[34] 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 workers were overexposed to respirable silica, lead, and noise; and that carbon monoxide, chrysotile, and benzene exposures constituted a potential health hazard to employees in the coremaking, molding, pouring, cleaning, and shakeout areas at this facility. During the walkthrough survey, some potential safety and health hazards were identified, such as the use of compressed air to clean loose sand from cores and molds, unenforced hearing and eye protection policies, and fall hazards.

VIII. RECOMMENDATIONS

The following recommendations are offered to reduce workers' exposures to respirable silica, carbon monoxide, lead, noise, asbestos, and benzene, 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, and shakeout departments should be provided respiratory protection for respirable silica exposures. Based on the concentrations of respirable silica detected, NIOSH recommends that workers should use an air-purifying respirator with a high-efficiency particulate filter.[35,36] The grinders should continue to use the supplied air helmets.

2. The current written hearing and eye protection policies should be strictly enforced. Based on the noise dosimeter survey, additional areas of the plant may require mandatory hearing protection. An in-depth noise evaluation should be conducted to determine if this is necessary. During the site visit, it was observed that some workers did not wear their hearing protection or safety glasses.

3. In accordance with the OSHA lead standard, the environmental lead monitoring should be repeated quarterly to see if the concentrations exceed the PEL.[37] Until the source of lead is removed, a half-mask air-purifying respirator with a high-efficiency particulate filter should be used, after determining if the employee is physically able to wear it. A biological monitoring program should be developed in accordance with the OSHA standard to determine blood lead levels and appropriate medical follow-up.

4. To reduce the noise emitted when metal parts are dumped into the metal conveyor and the portable metal bins, the conveyor and bins should be lined with damping compound.[38]

5. To reduce noise and minimize dust generation, regulators and low pressure nozzles, in conjunction with the compressed air lines, should be used.

6. To improve general ventilation, a make-up air system should be installed to supply fresh air and to replace existing space heaters. The air exhausted

from the building should be replaced with tempered air from an uncontaminated source. This air could be directed to operator work areas much as pouring and molding to provide a cleaner environment. A general ventilation system would also help with decomposition product control.

7. To determine if CO is a health hazard, additional full-shift and short-term monitoring of CO should be conducted. If overexposures to CO are found, the shakeout conveyor should be enclosed and exhausted to the outside.

8. 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).[39]

9. To reduce exposures to respirable silica, an industrial vacuum should be used on a regular basis to collect loose sand/dust on the floor instead of dry sweeping and shoveling. A collection bin could also be used to store excess sand until the end of the shift to aid in clean-up.

10. 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.

11. To prevent respirable silica exposure, a safety interlock should be installed to prevent the shotblast machines from operating without activating the bag house.

12. To prevent respirable silica exposure, a policy should be developed to prevent employees from removing dust from their clothing with compressed air.

13. Foundry returns should be cleaned of adhering sand by shot blasting prior to placing in scrap area. An annual housekeeping program to reduce the build up of dust in the scrap compartments should be implemented.

14. 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.

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

16. The carbon monoxide meter on the air compressor should be repaired. According to OSHA regulation 1910.134, an oil-lubricated compressor for supplying air should have a high temperature or carbon monoxide alarm or both.[40] If only a high temperature alarm is used, carbon monoxide levels

should be checked frequently to insure they are in accordance with Grade D breathing air.

17. To reduce emissions from the hot shell coremaking machines without local exhaust ventilation, a slotted side draft hood with a canopy hood (shown in Figure 7) should be installed.[41]

18. Following asbestos removal guidelines, the board containing chrysotile should be removed from the work environment and disposed of properly.

19. To prevent falls, the policy of replacing the protective chains across the deck conveyor should be strictly enforced.

20. To prevent unnecessary exposure to solvents in the coremaking department, according to the MSDS, gloves should be worn when hand-dipping cores in the Velavite material.

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Copies of this report have been sent to:

1. The General Castings Company - Domestic Division
2. Employee Representative
3. OSHA, Region III

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 2

Results of Personal Breathing Zone and Area Air Samples
for Respirable Silica and Cristobalite

General Castings Company
Domestic Division
Shippensburg, Pennsylvania
HETA 92-157

April 14-15, 1992

Job Title/ Location	Sampling Time	Sample Volume (liters)	Respirable Silica Concentration (TWA-µg/m^3)*	Cristobalite Concentration (TWA-µg/m^3)*
Personal:				
Rotoblast Operator	7:01-1:35	670	105	ND#
Mixer Operator	7:06-12:48	590	85	ND
Coremaker (Baked Cores)	7:36-2:19	695	14.4**	ND
Table Blast Operator	5:35-1:14	787	50.8	ND
Rotoblast Operator	7:13-1:40	666	255	30**
Grinder	5:28-1:11	799	200	ND
Squeeze Molder	7:36-2:14	685	29**	ND
Rough Grinder	6:52-1:12	658	319	30**
Squeeze Molder	6:05-11:20	544	55	ND
NIOSH Recommended Exposure Limit (REL):			50	50
OSHA Permissible Exposure Limit (PEL):			100	50
ACGIH Threshold Limit Value (TLV®):			100	50
Minimum Detectable Concentration (MDC):		544	18	28
Minimum Quantifiable Concentration (MQC):		544	55	55

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

Table 2 (continued)

Results of Personal Breathing Zone and Area Air Samples
for Respirable Silica and Cristobalite

General Castings Company
Domestic Division
Shippensburg, Pennsylvania
HETA 92-157

April 14-15, 1992

Job Title/ Location	Sampling Time	Sample Volume (liters)	Respirable Silica Concentration (TWA-µg/m^3)*	Cristobalite Concentration (TWA-µg/m^3)
Personal:				
Coremaker (Baked Cores)	6:21-1:57	777	257	ND#
Forklift Operator	5:54-12:57	716	224	ND
Area:				
Grinding-Single Station	5:52-1:30	789	38	ND
End of Deck Shakeout Conveyor	6:34-1:02	670	119	ND
Shakeout Table	6:30-1:03	677	59	ND
NIOSH Recommended Exposure Limit (REL):			50	50
OSHA Permissible Exposure Limit (PEL):			100	50
ACGIH Threshold Limit Value (TLV®):			100	50
Minimum Detectable Concentration (MDC):		544	18	28
Minimum Quantifiable Concentration (MQC):		544	55	55

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

Table 5

Results of Area Samples for Formaldehyde

General Castings Company
Domestic Division
Shippensburg, Pennsylvania
HETA 92-157

April 14-15, 1992

Location	Sampling Time	Sample Volume (liters)	Concentration (TWA-ppm)*
Coremaking/ No Bake Sand Mixer	7:22-2:18	417	0.006
Coremaking/ Hot Shell Machine	7:24-2:18	415	0.002**
Coremaking/ Baked Cores	7:26-2:17	411	0.008
Coremaking/ No Bake Sand Mixer	5:37-1:45	491	0.005
NIOSH Recommended Exposure Limit (REL):			LFC#
OSHA Permissible Exposure Limit (PEL):			0.75
ACGIH Threshold Limit Value (TLV®):			1
Minimum Detectable Concentration (MDC):		411	0.001 ppm
Minimum Quantifiable Concentration (MQC):		411	0.003 ppm

* - ppm - parts per million
** - Between MDC and MQC
\# - LFC - lowest feasible concentration

Table 4

Results of Personal Breathing Zone and Area Air Samples for Phenol

General Castings Company
Domestic Division
Shippensburg, Pennsylvania
HETA 92-157

April 14-15, 1992

Location/ Job Category	Sampling Time	Sample Volume (liters)	Concentration (TWA-ppm)*
Personal:			
Coremaker/Hot Shell	7:30-2:17	40.5	0.10
Area:			
West Side of Pouring Deck	6:02-1:42	46	0.02**
Coremaking/ Sand Mixer	7:20-2:17	41.8	0.07
Coremaking/ Sand Mixer	5:59-1:45	46.8	0.07
Deck Pouring Floor Near Shakeout Conveyor	6:38-1:24	40.8	0.01**
Large Pouring Floor/ Near Shakeout Conveyor	6:41-1:27	40.7	0.01**
NIOSH Recommended Exposure Limit (REL):			5
OSHA Permissible Exposure Limit (PEL):			5
ACGIH Threshold Limit Value (TLV®):			5
Minimum Detectable Concentration (MDC):		40.5	0.006 ppm
Minimum Quantifiable Concentration (MQC):		40.5	0.021 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
Domestic Division
Shippensburg, Pennsylvania
HETA 92-157

April 14-15, 1992

Job Title	Sampling Time	Sampling Volume (liters)	Metal Concentrations (TWA-µg/m³)*								
			Al	Cr	Cu	Fe	Mg	Mn	Ni	Pb	Zn
Rotoblast Operator	6:56-1:36	806	89	2	4.8	906	25	12	1	ND	2
Pourer-Floor/Osborne	6:14-1:20	864	75	0.7	1.3	174	21	5	ND	12	13
Pourer-Deck	5:51-1:19	906	276	0.8	1.4	298	70	5	ND	10	12
Grinder	5:24-10:14	598	30	3	12	4348	3	30	3	ND	2
Pourer-Deck	6:18-1:28	872	229	0.7	1.7	275	52	5	ND	8	8
Furnace Operator	6:25-2:14	952	44	0.5	1	336	18	21	ND	79	61
Pourer-Floor/Osborne	5:58-1:21	904	49	ND	1	133	14	3	ND	8	8
Hunter Operator	5:35-12:50	884	29	ND	1	78	10	1.5	ND	ND	2
Hunter Pourer	5:56-12:50	832	48	ND	1.2	132	18	3.5	ND	3.6	6
Grinder	5:47-1:40	960	8.3	0.7	1.5	740	2	9	0.8	ND	1
Furnace Operator	5:43-1:00	888	23	0.6	1.2	180	10	9	ND	14.6	21
Jolt Squeeze Molder	5:52-12:52	858	43	ND	1.5	112	16	2	ND	ND	2
Minimum Quantifiable Concentrations (Sampling Volume - 598 liters)			3.3	0.8	0.8	0.8	1.7	0.8	0.8	1.7	1.7

* - 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	1000
Fe - Iron	10000	5000	5000
Mg - Magnesium	10000	None	10000
Mn - Manganese	5000	1000	5000
Ni - Nickel	1000	15 (Carcinogen)	1000 (50 proposed)
Pb - Lead	50	<100	150
Zn - Zinc	10000	5000	10000

Table 6

Results of Personal Breathing Zone and Area Air Samples
for Benzene

General Castings Company
Domestic Division
Shippensburg, Pennsylvania
HETA 92-157

April 14-15, 1992

Job/Location	Sampling Time	Sample Volume (liters)	Benzene Concentration (TWA-ppm)*	Total Hygdrocarbons Concentration (TWA-mg/m^3)**
Personal:				
Hot-Shell Coremaker	6:54-2:12	87.9	0.01	38.7
Sulfur Dioxide Coremaker	7:02-2:13	87.1	0.01#	12.6
Hot Shell Coremaker	6:56-2:14	87.8	0.01#	4.8
Coremaker	7:11-12:51	67.2	0.014#	7.1
Area:				
Large Pouring Floor - Shakeout	6:41-1:27	79.3	0.17	2.52#
NIOSH Recommended Exposure Limit (REL):			0.1	
OSHA Permissible Exposure Limit (PEL):			1.0	
ACGIH Threshold Limit Value (TLV®):			10 (proposed-0.1)	
Minimum Detectable Concentration:		67	0.005	3
Minimum Quantifiable Concentration:		67	0.015	5

* - TWA-ppm - Time-weighted average - parts per million
** - TWA-mg/m^3 - Time-weighted average - milligrams per cubic meter
# - Between MDC and MQC

Table 1

Health Effects Summary for Metals

General Castings Company - Domestic Division
Shippensburg, Pennsylvania
HETA 92-157

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]
Nickel	Metallic nickel compounds cause sensitization dermatitis.[14] NIOSH considers nickel a potential carcinogen, as nickel refining has been associated with an increased risk of nasal and lung cancer.[22]
Zinc	Zinc has been associated with shortness of breath, minor lung function changes, and metal fume fever.[6,22]

Table 7

Sound Level Measurements

General Castings Company
Domestic Division
Shippensburg, Pennsylvania
HETA 92-157

April 14-15, 1992

Location/ Activity	Sound Level [dB(A)]
Hunter Molding Machine	89-94
Squeeze Molding	
- No machines operating	83
- Adding sand	90
- Using bumper to assemble mold	99
- Using rammer	94
Blasting Area	
- Parts falling into metal bin	103
- Emptying castings into metal conveyor	107
Shell Coremaking Operation	
- No vibrating	84-85
- Opening core mold	87-90
- Hammering core loose	97-102
- Using hand-held compressed air line to clean mold [meter about 3 feet away to avoid sand]	92-94
- Compressed air escaping during coremaking process (very short duration)	117-118

Table 9

Direct Reading Instrument Survey

General Castings Company
Domestic Division
Shippensburg, Pennsylvania
HETA 92-157

April 14-15, 1992

Compound	Location/ Activity	Concentration (ppm)*
Carbon Monoxide: [LOD**: 10 ppm]	Plant - General Vicinity of Furnace and Pouring Areas	10
	Hunter Machine/ Pouring	130-170 (4 samples)
Ammonia: [LOD: 5 ppm]	Hot Shell Coremaking Machine While Operating	13
Sulphur Dioxide [LOD 0.5 ppm]	Sulfur Dioxide Coremaking Machine While Operating	ND#

* - ppm - parts per million
** - LOD - Limit of Detection
\# - ND - None Detected, below the LOD

Table 8

Noise Dosimeter Survey

General Castings Company
Domestic Division
Shippensburg, Pennsylvania
HETA 92-157

April 14-15, 1992

Job Category	Sample Period [minutes]	Time-Weighted Average [dB(A)]
Grinder	425	99.6
Laborer (Shakeout)	471	87.9
Squeeze Jolt Molder (Deck Area)	460	93.1*
Hot Shell Coremaker	452	85.5
Shotblast Operator	436	97.7**

* - Exceeded ceiling limit of 115 dB(A) for 3 seconds.
** - Exceeded ceiling limit of 115 dB(A) for 6 minutes, 41 seconds.

Figure 7
General Castings Company-Domestic Division
Shippensburg, Pennsylvania
HETA 92-157

ACGIH [1988]. Industrial ventilation; a manual of recommended practice. Cincinnati, OH: American Conference of Governmental Industrial Hygienists.