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GENERAL CASTINGS CO.
LIBERTY ROAD FACILITY
DELAWARE, OHIO

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I. SUMMARY

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

On January 13-16, 1992, NIOSH representatives, with field assist from the Ohio Department of Health, conducted an industrial hygi 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 practices and engineering control measures were also evaluated.

The PBZ air concentrations of respirable silica ranged from less 22 (coremaking department) to 1120 micrograms per cubic meter [µ (cleaning department), as time-weighted averages (TWAs). Seven 33 sample concentrations (21%) exceeded the Occupational Safety Health Administration (OSHA) Permissible Exposure Limit (PEL) of 100 µg/m³ for respirable silica (as quartz), and 28 of the 33 sar concentrations (85%) exceeded the NIOSH Recommended Exposure Limit (REL) of 50 µg/m³ for respirable crystalline silica (regar of morphology). Cristobalite (177 µg/m³) was detected in one sar collected for a grinder which exceeded the NIOSH REL and OSHA PE 50 µg/m³. NIOSH recommends that crystalline silica be treated as potential human carcinogen. Workers in the cleaning department powered air-purifying helmet respirators. The samples were coll outside of the respirators, therefore, the actual exposures to t employees were probably lower than those measured.

One PBZ sample concentration for iron (8004 µg/m³) collected for grinder exceeded the NIOSH REL for iron of 5000 µg/m³. Area and benzene concentrations ranged from 0.11 to 0.97 parts per millio in the cooling, coremaking, and molding departments. These concentrations suggest that PBZ exposures may have exceeded the REL of 0.1 ppm for benzene, which is considered a potential occupational carcinogen. Area formaldehyde concentrations range 0.02-0.04 ppm which exceeded the NIOSH REL of 0.016 ppm. Carbon monoxide concentrations ranged from 7-50 ppm. Three of the area samples and four PBZ samples exceeded the American Conference of Governmental Industrial Hygienists Threshold Limit Value (TLV®) 25 ppm for carbon monoxide. Ranges for phenol (0.2-1.2 ppm), isopropanol (7-67 ppm), toluene (0.6-21 ppm), and xylene (0.4-1. concentrations were below current evaluation criteria for occupa exposure.

The industrial hygiene sampling data indicate that respirable s cristobalite, iron, and benzene exposures constitute a potentia health hazard to employees in the cleaning, coremaking, molding shakeout areas. Employees are potentially overexposed to carbo monoxide in the pouring area. Recommendations for engineering controls, an improved respiratory protection program, and impro work practices can be found in Section IX (please see pages 14 of this report.

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

II. INTRODUCTION

On January 13-16, 1992, National Institute for Occupational Safe Health (NIOSH) representatives, with field assistance from the O Department of Health, conducted a site visit to the General Cast Liberty Road Facility, a gray and ductile iron foundry, in Delaw Ohio. This visit was made in response to a management request t evaluate worker exposures in the coremaking, molding, pouring, m shakeout, sand handling, and cleaning areas of the facility. Si company was under new management and had recently changed the pr flow, there was a general interest in identifying potential occupational health hazards.

III. BACKGROUND

The General Castings-Liberty Road Facility is housed in a 120,00 square foot concrete block building, which was built in 1967 and expanded in the 1970s. The facility operated three shifts: the 59 production workers on the day shift, 8 employees on the after shift, and 13 workers on the night shift.

To produce molten iron, the plant used three coreless electric induction furnaces which operated at 2000 kilowatts with a melt 50 tons per day. There were no exhaust hoods or air pollution c devices in place for the induction furnaces. At the time of the visit, the company was producing gray and ductile iron. Ductile is formed by the addition of magnesium to the molten metal immed before pouring. The furnaces were totally relined with a silica refractory each year. Scrap yards were located both inside and the facility.

The metal pouring operation was performed on the night shift in open areas inside the facility using stationary molds. An overh crane system with electronic controls was used to position the l for pouring in the large mold pouring area. An overhead monorai system was used for the small mold pouring area. 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 pro casting. A core is used to define the internal hollows desired casting. Cores and molds were made of a phenolic-formaldehyde b mixed with silica sand in an automatic mixer. A polymeric methy phenylene diisocyanate (MDI) was used as the binder catalyst. T 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. Cores were made by hand an machine. Crane hoists were used for lifting molds. A "blue dip primer" containing isopropanol, magnesium silicate, titanium oxi xylenes was utilized to seal the molds after forming. The isopr was burned off with matches to form a smooth surface. Excess sa removed using compressed air in the coremaking, molding, and cle departments.

The metal castings were shaken out of the molds while still hot (referred to as shakeout) on all three shifts. There were three shotblast machines, in which steel shot was utilized to remove e sand from the castings. Each machine had its own dust collector certain castings, it was necessary for workers to manually use compressed air to remove excess sand from internal cavities. Br were used to clean up excess sand throughout the facility. A sa reclamation system with a fluidized bed cooler-heat exchange sys used. A Bobcat® front-end loader was used to load the sand recl system and shakeout some of the castings. The majority of casti cleaning recently was moved to another facility owned by the com Two employees worked on large castings at this facility. Cutoff grinders, and chippers were used to clean and trim the castings. welders worked on repairs during the first shift and also ran he treating ovens.

The grinders and shotblast machine operators used NIOSH/Mine Saf Health Administration (MSHA) approved air-purifying respirator h which had high efficiency particulate air (HEPA) filters and a b face shield. Safety shoes, hard hats and safety glasses were re throughout the facility. Hearing protection devices (disposable were required in the grinding area. Flame retardant clothing wa by the pourers. The material safety data sheets, hearing protec policy, and respiratory protection policy were reviewed.

A direct-fired (gas) makeup-air unit was used in the winter mont supply general ventilation to work areas. Overhead infrared ele heaters provided additional heat. General ventilation during th warmer months was supplied by open doors and windows.

A previous walkthrough industrial hygiene survey was conducted a facility by the Ohio Department of Health (ODH) in June 1989 und NIOSH cooperative agreement SENSOR (Sentinel Event Notification for Occupational Risk) program. In December 1989, ODH and the O Bureau of Worker's Compensation, Industrial Hygiene Section, con a follow-up survey to evaluate worker exposures to respirable si and cristobalite, carbon monoxide, phenol, toluene, 1,1,1-trichloroethylene, formaldehyde, MDI, coal tar pitch volatiles, lead.[1] In the cleaning department, the majority of 8-hr TWA expo for respirable silica [quartz] (irrespective of respiratory prot exceeded the OSHA PEL of 100 $\mu g/m^3$ (range: <40 to 580 $\mu g/m^3$).[2] A the other exposures were below the respective current occupation evaluation criteria. Phenol exposures in the coremaking and mol departments ranged from 0.32 to 0.50 parts per million (ppm) as

Carbon monoxide levels ranged from 15 to 28 ppm as TWAs. Two di reading measurements for carbon monoxide did exceed the ceiling (a 15-minute exposure never to be exceeded) of 200 ppm in the sh area. Cristobalite was detected in two samples. MDI concentrat ranged from below the analytical limit of detection (LOD) to 0.0008 ppm. Formaldehyde ranged from 0.2 to 0.5 ppm. Coal tar volatiles ranged from 0.05 to 0.11 mg/m^3. The painters had expos TWAs of lead at 4-5 µg/m^3, 1,1,1-trichloroethylene at 140 ppm, to at 2 ppm, and xylene at 8 ppm.

IV. METHODS

A. Respirable Silica and Cristobalite

Thirty-three personal breathing zone (PBZ) and three area air samples for respirable dust (aerodynamic diameter less than 1 were collected at a flowrate of 1.7 l/min using 10 mm nylon cyclones mounted in series with pre-weighed polyvinyl chloride (PVC) filters (37 mm diameter, 5 µm pore size). The analyzed for quartz and cristobalite content with X-ray diffraction. Samples were analyzed according to NIOSH Method with the following modifications: a) the filters were dissol 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 intensitie rather than the suggested normalization procedure. The analy LOD was 15 micrograms (µg) per filter, which equates to a min detectable concentration (MDC) of 22 µg/m^3, assuming a sampling volume of 695 liters. The limit of quantitation (LO 30 µg per filter, which equates to a minimum quantifiable concentration (MQC) of 43 µg/m^3, assuming a sampling volume o 695 liters.

B. Metals

Ten PBZ air samples and five area air samples were collected mixed-cellulose ester filters (37 millimeter (mm) diameter, 0.8 micrometer (µm) pore size) using a flowrate of 2.0 l/min. Samples were collected for periods as near as possible to ent workshifts (6 to 7 hours). The samples were analyzed for met according to NIOSH Method 7300.[4] In the laboratory, the samp were wet-ashed with concentrated nitric and perchloric acids the residues were dissolved in a dilute solution of the same The resulting sample solutions were analyzed by inductively c plasma atomic emission spectrometry. The MQCs, using a sampl volume of 852 liters, for the selected metals are listed in Table 3.

C. Volatile Organic Compounds

Matched pairs of area air samples were collected in five area qualitative and quantitation analyses of volatile organic compounds. Samples were collected on charcoal tubes at a flo of 0.2 l/min. The charcoal tubes were desorbed with carbon disulfide and screened by gas chromatography (GC)-flame ioniz detector (FID), using a 30 meter DB-1 fused silica capillary (splitless mode). One set of samples was used for qualitativ analysis to identify major constituents by gas chromatography spectroscopy (GC/MS) analysis. Major constituents identified then subsequently quantitatively analyzed in the paired sampl (NIOSH Method 1501).[5] Total aromatic hydrocarbons were deter based on the presence of 1,2,4-trimethyl benzene. The analyt LODs, the MDCs, the LOQs, and the MDQs for the major constitu are presented in the following chart.

Analyte	LOD µg/sample	LOQ µg/sample	MDC ppm	MQC ppm	Minimum Volume (liters)
Benzene	2	8	0.01	0.03	86.4
Toluene	2	8	0.01	0.03	86.4

The analytical LOD for total aromatic hydrocarbons was 3 µg p sample, which equates to a MDC of 0.04 mg/m^3, assuming a samp volume of 86.4 liters. The LOQ for total aromatic hydrocarbo 9 µg per sample, which equates to a MQC of 0.10 mg/m^3, assumi sampling volume of 86.4 liters.

D. Phenol

Eight PBZ samples were collected on XAD-7 silica gel tubes us flowrate of 0.1 l/min. The samples were desorbed in methanol analyzed by high performance liquid chromatography according OSHA Method 32 for phenol. The analytical LOD was 1 µg per s which equates to a MDC of 0.006 ppm, assuming a sample volume 43.4 liters. The LOQ was 3.3 µg per sample, which equates to of 0.02 ppm, assuming a sample volume of 43.4 liters.

E. Carbon Monoxide

Carbon monoxide was measured using Draeger® passive diffusion which utilize a colormetric method (carbon monoxide reacts wi palladium salts, resulting in a color change or stain). The diffusion tubes were fastened to the employee's collar in the breathing zone for the duration of the shift. The length of resulting stain was determined and the time-weighted average calculated. The MDC for an 8-hour sample was 6.25 ppm.

F. Formaldehyde

Five area air samples were collected using impingers with 1% bisulfite solution at a flowrate of 1 l/min. Color was devel by adding chromotopic acid and concentrated sulfuric acid to sample. Samples were heated in a 95°C water bath for 15 minu and allowed to cool 2 to 3 hours. The samples were read by v spectroscopy according to NIOSH Method 3500.[6] The analytical for formaldehyde was 1 µg per sample, which equates to a MDC 0.01 ppm, assuming a sampling volume of 82 liters. The LOQ f formaldehyde was 3.2 µg per filter, which equates to a MQC of 0.03 ppm, assuming a sampling volume of 82 liters.

G. Gases and Vapors

Short-term area (grab) air sample measurements were collected alcohols, carbon monoxide, and phenol as a screening device t if additional sampling was necessary. The Draeger® gas detec system with colormetric tubes was used. The LODs for alcohol carbon monoxide, and phenol were 1000 ppm, 5 ppm, and 5 ppm, respectively.

H. Alcohols

Ten PBZ air samples and five area air samples were collected charcoal tubes at a flowrate of 0.2 l/min. The charcoal tube desorbed with carbon disulfide (with 1% 2-butanol as a desorb aid) and screened by GC-FID according to NIOSH Method 1400.[7] analytical LOD was 0.01 mg/sample, which equates to a MDC of 0.04 ppm, assuming a sampling volume of 81.4 liters. The LOQ 0.03 mg/sample, which equates to a MQC of 0.13 ppm, assuming sampling volume of 81.4 liters.

I. Solvents

Eight PBZ samples were collected on charcoal tubes at a flowr 0.2 l/min. The charcoal tubes were desorbed with carbon disu and screened by GC-FID, according to NIOSH Method 1501.[5] Tota aromatic hydrocarbons were based on the presence of mesitylen The analytical LODs, the LOQs, the MDCs, and the MDQs for the 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	58.8
Toluene	10	33	0.05	0.15	58.8
Xylene	10	33	0.04	0.13	58.8

The analytical LOD for total aromatic hydrocarbons was 100 µg sample, which equates to a MDC of 1.7 mg/m^3, assuming a sampl volume of 58.8 liters. The LOQ for total aromatic hydrocarbo 330 µg per filter, which equates to a MQC of 5.6 mg/m^3, assum sampling volume of 58.8 liters.

V. EVALUATION CRITERIA

To assess the hazards posed by workplace exposures, industrial hygienists use a variety of environmental evaluation criteria. criteria propose exposure levels to which most employees may be for a normal working lifetime without adverse health effects. T levels do not take into consideration individual susceptibility, as pre-exiting medical conditions, or possible interactions with agents or environmental conditions. Evaluation criteria change 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)[8], 2) the American Conference of Governmental Indus Hygienists' (ACGIH) Threshold Limit Values (TLVs®)[9], and 3) the U Department of Labor OSHA PELs.[2] The OSHA PELs may reflect the feasibility of controlling exposures in various industries where agents are used; whereas the NIOSH RELs are based primarily on c relating to the prevention of occupational disease. It should b when reviewing this report that employers are legally required t those levels specified by an OSHA standard.

A. Respirable Silica and Cristobalite

Crystalline silica (quartz) and cristobalite have been associ with silicosis, a fibrotic disease of the lung caused by the deposition of fine particles of crystalline silica in the lun Symptoms usually develop insidiously, with cough, shortness o breath, chest pain, weakness, wheezing, and non-specific ches illnesses. Silicosis usually occurs after years of exposure, may appear in a shorter period of time if exposure concentrat are very high.[10] The NIOSH RELs for respirable quartz and cristobalite, published in 1974, are 50 µg/m^3, as 10-hour TWA: Based on data available more recently, NIOSH considers quartz cristobalite to be potential human carcinogens and recommends exposures be reduced to the lowest feasible levels.[8] The OSH and the ACGIH TLV®s for respirable quartz and cristobalite ar 100 and 50 µg/m^3, as 8-hour TWAs, respectively.[2,9]

B. Metals

A list of selected metals along with a brief summary of their primary health effects are presented in Table 1. The evaluat 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 drowsi Chronic exposure to benzene has been associated with the depr of the hematopoietic system and is associated with an increas incidence of leukemia and possibly multiple myeloma.[8,18] The N REL is 0.1 ppm. NIOSH classifies benzene as a human carcinog The OSHA PEL is 1 ppm. The current ACGIH TLV® is 10 ppm as a suspected human carcinogen. ACGIH has proposed to lower the to 0.1 ppm and classify it as a proven human carcinogen.[9]

Toluene exposure has been associated with central nervous sys depression. Symptoms may include headache, dizziness, fatigu confusion, and drowsiness. Exposure may also cause irritatio the eyes, respiratory tract, and skin.[12,18] The NIOSH REL, ACG TLV®, and OSHA PEL for toluene are 100 ppm as a TWA. ACGIH h proposed a TLV® of 50 ppm in their notice of intended changes

Xylene exposure may cause irritation of the eyes, mucous memb skin, and respiratory tract.[12,18] The NIOSH REL, ACGIH TLV®, a OSHA PEL for xylene are 100 ppm as a TWA.

D. Phenol

Phenol is an irritant of the eyes, mucous membranes, and skin Systemic absorption can cause convulsions as well as liver an kidney disease. The skin is a route of entry for the vapor a liquid phases. Phenol has a marked corrosive effect on any t Symptoms of chronic phenol poisoning may include difficulty i swallowing, diarrhea, vomiting, lack of appetite, headache, fainting, dizziness, dark urine, mental disturbances, and pos a skin rash.[12] The NIOSH REL, ACGIH TLV®, and OSHA PEL for ph are 25 ppm as a TWA. NIOSH has set a ceiling limit of 15.6 p

All criteria include a skin notation, which indicates that sk absorption may be a significant route of exposure.

E. Carbon Monoxide

Carbon monoxide (CO) is a colorless, odorless, tasteless gas can be a product of the incomplete combustion of organic comp CO combines with hemoglobin and interferes with the oxygen ca capacity of blood. Symptoms include headache, drowsiness, dizziness, nausea, vomiting, collapse, and death.[12] The NIOSH and OSHA PEL for carbon monoxide are 35 ppm as a TWA. The AC TLV® for carbon monoxide is 25 ppm as an 8-hour TWA.

F. Formaldehyde

Formaldehyde is a colorless gas with a strong odor. Exposure occur through inhalation and skin absorption. The acute effe associated with formaldehyde are irritation of the eyes and respiratory tract and sensitization of the skin. The first symptoms associated with formaldehyde exposure, at concentrat of 0.1 to 5 parts per million (ppm), are burning of the eyes, tearing, and general irritation of the upper respiratory trac There is variation among individuals, in terms of their toler and susceptibility to acute exposures of the compound.[21] In t separate studies, formaldehyde has induced a rare form of nas cancer in rodents. Formaldehyde exposure has been identified possible causative factor in cancer of the upper respiratory in a proportionate mortality study of workers in the garment industry.[22] NIOSH has identified formaldehyde as a suspected carcinogen and recommends that exposures be reduced to the lo feasible concentration (0.016 ppm). The OSHA PEL is 0.75 ppm 8-hour TWA and 2 ppm as a STEL.[23] ACGIH has designated formaldehyde to be a suspected human carcinogen and therefore recommends that worker exposure by all routes should be caref controlled to levels "as low as reasonably achievable" below TLV.[9] ACGIH has set a ceiling limit of 0.3 ppm.

G. Isopropyl Alcohol

Isopropyl alcohol is an irritant of the eyes and mucous membr High exposures can cause central nervous system depression.[12] 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 and area air sampling are presented in Table 2. The 33 PBZ sample concentrations ranged from less t 22 µg/m^3 to 1120 µg/m^3, as TWAs. Seven of the 33 sample concentrations (21%) exceeded the OSHA PEL of 100 µg/m^3 for respirable silica and 28 of the 33 sample concentrations (85% exceeded the NIOSH REL of 50 µg/m^3 for respirable silica. Th sample collected for a grinder had the highest exposure (1120 µg/m^3), followed by the shotblast operators (37 to 1002 µg/m^3, average: 272 µg/m^3), and front-end loader/shakeout operators to 99 µg/m^3, average: 88 µg/m^3). One PBZ sample collected fo shotblast operator contained 177 µg/m^3 of cristobalite which w over the NIOSH REL and OSHA PEL of 50 µg/m^3. These samples we collected outside the workers' NIOSH/MSHA approved airhats, therefore the employees' exposures were probably less than th reported.

The employees in the coremaking department were overexposed t respirable silica; the average exposure was 66 µg/m^3 (range: <22 to 119 µg/m^3). Workers in the molding department were al overexposed; the average exposure was 80 µg/m^3 (range: 51 to 138 µg/m^3). Employees in these two departments were not requ to wear respiratory protection. The area air samples in the shakeout and grinding areas ranged from 26-51 µg/m^3.

B. Metals

The 10 PBZ and 5 area air sample concentrations are presented Tables 3 and 4, respectively. Concentrations of aluminum, chromium, copper, magnesium, nickel, lead, and zinc (range: 0 134 µg/m^3) did not exceed the respective occupational evaluat criteria. However, since the valence state of chromium was n determined, worker exposures to the more toxic Chromium VI wa unknown. PBZ concentrations for iron ranged from 81 to 8004 One PBZ sample collected for a grinder (8004 µg/m^3) exceed th NIOSH REL of 5000 µg/m^3. This sample was collected outside t NIOSH/MSHA approved airhats, therefore the actual exposure to employee was probably less. The area concentrations of the a metals (<0.6 to 352 µg/m^3) were relatively low, none of the f samples' concentrations exceeded the respective evaluation criteria.

C. Organic Decomposition Products

The five area air samples collected in the cleaning and mold cooling areas for organic decomposition products had similar chromatographs. A copy of the chromatograph with identified is included as Figure 1. The major compounds identified incl isopropanol and alkyl benzenes, aromatics in the C_9 - C_{12} rang which include such isomers as trimethyl-methyl ethyl benzenes (Molecular Weight [MW] 120), tetramethyl- and diethyl-benzene (MW 134), and pentamethyl- and diethylmethyl benzenes (MW 148 Other compounds detected included benzene, toluene, fatty aci esters, C_6 - C_9 alkanes, and naphthalene.

The results of the quantitative analyses are shown in Table 5 Area benzene concentrations ranged from 0.31 to 0.5 ppm. The results indicate that personal exposures in these areas may e the NIOSH REL of 0.1 ppm. Area toluene concentrations ranged 0.05 to 0.18 ppm, which were below current evaluation criter occupational exposures.

D. Phenol

The results of the 8 personal breathing zone samples are pres in Table 6. The concentrations ranged from 0.18 to 1.16 ppm (average: 0.48 ppm) which is below the current occupational evaluation criteria of 5 ppm.

E. Carbon Monoxide

The results for the 15 personal breathing zone and 5 area air samples are listed in Table 7. The PBZ concentrations ranged 7 to 35 ppm. The four samples collected for two pourers, a forklift driver, and a shakeout operator exceeded the ACGIH T 25 ppm. The area air sample concentrations ranged from 8 to 50 ppm. The large and small pouring lines were 43 ppm and 50 respectively. These results indicate that workers were poten overexposed to carbon monoxide in these areas. The most like source of the carbon monoxide was the decomposition of the or binders used in the molds and cores.

F. Formaldehyde

The results for the five area air samples in the coremaking department are given in Table 8. The results ranged from 0.0 0.04 ppm, above the NIOSH REL of 0.016 ppm for occupational exposure.

G. Gases and Vapors - Grab Sampling

The results of the short-term (grab) sampling for total alcoh carbon monoxide, and phenol are listed in Table 9. Alcohols not detected at the LOD of 1000 ppm. Carbon monoxide levels from 8 ppm to 20 ppm. Trace phenol concentrations were detec the coremaking and pouring areas.

H. Isopropyl Alcohol

The results of the PBZ and area air sampling are presented in Table 10. The PBZ concentrations ranged from 2.9 to 67.4 ppm (average: 17 ppm); all were below the current occupational evaluation criteria of 400 ppm. The area air concentrations from 0.4 ppm to 11 ppm.

I. Organic Solvents

The eight PBZ sample results for benzene, toluene, and xylene given in Table 11. Benzene concentrations ranged from 0.11 p 0.97 ppm (average: 0.39 ppm). The highest concentration was collected for a molder. All eight of the PBZ samples exceede NIOSH REL of 0.1 ppm for benzene. Toluene concentrations ran from 0.56 to 2.12 ppm (average: 1.1 ppm) which was below the current evaluation criteria of 100 ppm. Xylene concentration ranged from 0.44 to 1.22 ppm (average: 0.76 ppm) which was b the evaluation criteria of 100 ppm.

J. Observations of Work Practices

Hearing and eye protection was required in the facility, but everyone wore hearing protection or safety glasses in the bui Employees were observed smoking and eating lunch in the gener work area. During the walkthrough, it was noted that employe were exposed to high noise levels as metal casting scraps wer being dropped into metal bins before being returned to the sc yard. Workers were observed lifting and moving molds, weighi to approximately 75 pounds, by hand which could result in bac other injuries.

VIII. DISCUSSION AND CONCLUSIONS

The foundry industry has been identified as a complex process wi numerous associated health hazards.[24] Little information is avai about the long-term health effects of emissions from molds compo synthetic chemical molding materials. Mortality studies have in that a two- to three-fold excess risk of lung cancer has been identified for molders, pourers, and cleaning room operators whe compared to a standard population.[25] Smoking history was not ava for these studies. Additional investigations are needed to dete if chronic health effects do result from exposures to current mo emissions. The industrial hygiene sampling data indicate that respirable silica, cristobalite, iron, formaldehyde, and benzene exposures in the cleaning, coremaking, molding, and shakeout are this facility constitute a potential health hazard to workers. Additionally, results indicated that employees are potentially overexposed to carbon monoxide. The concentrations found during survey are similar to a study conducted at the same site by the Bureau of Workers' Compensation and the Ohio Department of Healt 1989. The majority of employees in the cleaning department duri these two visits had been moved to a different facility prior to survey. During the walkthrough survey, some potential safety an health hazards were identified, such as the use of compressed ai clean molds, and unenforced hearing and eye protection policies.

IX. RECOMMENDATIONS

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

1) Until appropriate engineering controls are implemented to red exposures to within OSHA and NIOSH recommended criteria, empl in the cleaning, coremaking, molding, and shakeout department should be provided respiratory protection for organic vapors (coremaking and molding) and respirable silica exposures.[26] considers respirable silica to be an occupational carcinogen, as such, recommends that exposures be reduced to the lowest feasible level. Based on this recommendation, workers in the cleaning and shakeout areas should use supplied air respirato

2) To reduce employee exposures to benzene and other decompositi products, the molds should be poured on a conveyor and then e an enclosed and ventilated tunnel. The tunnel could lead to smokehouse where they could off gas safely until ready for th shakeout operation.

3) The shaker table (shakeout area) should be enclosed on three and ventilated to help contain emissions of dust containing respirable silica and thermal decomposition products. To red exposures, the molds should be dropped directly onto the semi enclosed shaker table, instead of breaking the molds on the o floor using the front-end loader. To reduce exposures to decomposition products, the molds should be shaken out cold.

4) To reduce exposures to respirable silica during the cleaning 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 t reduce air to less than 30 pounds per square inch (psi) to re the dust levels currently being generated.[27] An industrial va should be used on a regular basis to collect loose sand/dust floor instead of dry sweeping.

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

6) To reduce exposures to respirable silica, all chutes transpor sand in the coremaking department should be enclosed and ventilated. At a minimum, the hinged lids on the chutes shou securely fastened shut to help reduce dust emissions. Transf points, particularly where valves activate, should also be en with sheet metal and ventilated to reduce dust emissions (see Figure 2). The sand free fall distance from the machine to t core box should be reduced or enclosed.

7) A remote pendant is used by the crane operator during the thi shift to operate the overhead crane from the floor. This pen should be used during the first and second shifts as well to protect the crane operator from the high exposures to decompo products he would otherwise encounter while in the cab. If t crane operator continues to operate the controls from inside cab, a fresh air supply system should be installed to ventila cab with uncontaminated air from the outside, and the cab sho maintained under positive pressure with respect to the work environment.

8) Certain castings, due to their shape, cannot be completely cl of sand by the shotblast machine, and the sand is removed fro inside castings by compressed air hoses which generate visibl quantities of dust. To reduce employee exposures to respirab silica during this process, the following procedure is recomm Plug up all but two holes in the casting, attach a vacuum or exhaust duct to one open hole, and then blow the sand out of casting using a compressed air hose attached to the other ope hole.

9) To reduce respirable silica exposure, bins which collect wast the shotblast machines should be enclosed and ventilated. Th could be accomplished by either installing a rubber cover fro waste line to the bin or by completely enclosing the waste li bin in sheet metal, and then connecting an exhaust duct to re the dust from the enclosed area.

10) To reduce employee exposures to respirable silica when the pa be cleaned are too large to put in the shotblast machine, a shotblast room could be installed and the castings manually a prior to the grinding operation. Also, for large castings, h

velocity, low volume (HVLV) tool hoods could be used for the grinders.

11) To reduce employee exposure to carbon monoxide, the natural g flame used to preheat the ladles should be adjusted until it appears blue to minimize the formation of carbon monoxide due incomplete combustion.

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

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

14) The current written hearing and eye protection policies shoul continued and enforced. During the site visit, it was observ that some workers did not wear their hearing protection or sa glasses.

15) Employees should use the available crane hoists instead of ma lifting and moving cores and small molds as observed.

16) To reduce the noise emitted when metal parts are thrown into portable scrap bins, located around the shakeout area, the bi should be lined with damping compound.[28]

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2. Employee Representative
3. OSHA, Region V

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

Table 2

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

General Castings Company
Liberty Road Facility
Delaware, Ohio
HETA 92-044

January 14-16, 1992

Location/ Job Title	Sampling Time	Sample Volume (liters)	Respirable Silica Concentration (TWA-µg/m³)*	Cr Concentratio
Personal:				
Shakeout Operator	6:45-11:50 12:31-2:26	525 182	99	ND**
Shotblast Operator	6:52-11:51 12:36-2:25	525 189	238	ND
Shotblast Operator	7:00-2:26	768	91	ND
Grinder	7:02-2:30	765	1120	ND
Shakeout/Bobcat Operator	7:10-12:30 12:34-2:21	495 185	88	ND
Shakeout Operator	3:49-11:36	796	214	ND
Shakeout Operator	3:48-11:37	806	37	ND
Shakeout Operator	3:59-11:38	787	51	ND
Coremaker	3:49-11:44	813	86	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) [Volume: 695 liters]			22	22
Minimum Quantifiable Concentration (MQC) [Volume: 695 liters]			43	43

* - 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 Samples
for Respirable Silica and Cristobalite

General Castings Company
Liberty Road Facility
Delaware, Ohio
HETA 92-044

January 14-16, 1992

Location/ Job Title	Sampling Time	Sample Volume (liters)	Respirable Silica Concentratio (TWA-µg/m³)*	Cr Concentratio
Personal:				
Bobcat Operator	4:04-11:34	777	77	ND**
Pouring/Shakeout Operator	3:50-11:36	784	89	ND
Shotblast Operator	3:50-11:40	789	1002	177
Coremaker	3:56-11:41	782	90	ND
Core finisher	7:02-2:37	774	ND	ND
Molder	7:41-2:30	695	72	ND
Mold Finisher	7:32-2:25	702	57	ND
Molder	7:24-2:21	709	71	ND
Coremaker	7:06-2:32	758	92	ND
Coremaking/ Mill Operator	7:18-2:34	741	40#	ND
Coremaker	7:15-2:31	741	40	ND
Core Finisher	7:13-2:38	757	119	ND
Core Setter	7:51-2:22	772	78	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) [Volume: 695 liters] 22 22
Minimum Quantifiable Concentration (MQC) [Volume: 695 liters] 43 43
* - 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 Samples
for Respirable Silica and Cristobalite

General Castings Company
Liberty Road Facility
Delaware, Ohio
HETA 92-044

January 14-16, 1992

Location/ Job Title	Sampling Time	Sample Volume (liters)	Respirable Silica Concentration (TWA-µg/m³)*	Cristobalite Concentration
Personal:				
Crane Operator	6:46-2:35	804	75	ND
Chain Operator	6:42-2:23	791	114	ND
Crane Operator	7:02-2:40	785	89	ND
Chain Operator	6:39-2:23	799	138	ND
Coremaker	7:00-2:31	768	65	ND
Molder	6:57-2:25	768	65	ND
Molding-Rollover Machine Operator	7:03-2:30	763	66	ND
Molder	7:00-2:32	774	52	ND
Core Finisher	6:46-2:22	775	ND	ND
Coremaker	6:41-2:22	782	76	ND
Molder/Coremaker	6:50-2:25	782	64	ND
Area:				
Shakeout Area	6:52-2:31	782	51	ND
Grinding Area	6:56-2:28	775	26#	ND
Shakeout Area	7:13-2:35	755	40#	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) [Volume: 695 liters]			22	22
Minimum Quantifiable Concentration (MQC) [Volume: 695 liters]			43	43

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

Table 3

Results of Personal Breathing Zone Samples for Metals

General Castings Company
Liberty Road Facility
Delaware, Ohio
HETA 92-044

January 14-16, 1992

Job Title	Sampling Time	Sample Volume	Metal Concentrations (TWA-µg/m							
			Al	Cr	Cu	Fe	Mg	Ni	P	
Grinder	6:55-2:20	912	76	13	15	8004	30	14	ND**	3
Grinder	6:59-2:27	902	63	23	9	4102	44	9	ND	23
Grinder	7:06-2:32	896	87	104	12	3125	134	9	ND	4
Shakeout/Overhead Crane Operator	7:20-2:35	880	9	0.6	2	81	15	ND	ND	1
Forklift Operator	7:17-2:24	858	16	0.9	3	175	28	ND	ND	2
Furnace Operator	9:30-5:45	866	25	2	3	381	35	2	8	16
Ladle Preparer	9:28-5:09	926	57	6	2	497	54	ND	6	13
Pourer	9:40-5:07	902	10	1	3	288	26	ND	3	8
Crane Operator For Ladle	10:00-5:06	852	6	0.8	3	176	25	ND	2	5
Furnace Charger	10:05-5:10	868	16	3	2	426	23	ND	6	13
Minimum Quantifiable Concentration (MQC) (Volume: 852 liters)			0.6	2.3	0.6	1.2	1.2	0.6	1.2	0.6

* - 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 (
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
Ni - Nickel	1000	15 (carcinogen)	1000
Pb - Lead	50	<100	150
Zn - Zinc	10000	5000	10000

- NIOSH contends that health effects can occur at the PEL.

Table 4

Results of Area Air Samples for Metals

General Castings Company
Liberty Road Facility
Delaware, Ohio
HETA 92-044

January 14-16, 1992

Job Title	Sampling Time	Sample Volume	Metal Concentrations (TWA-µg/m							
			Al	Cr	Cu	Fe	Mg	Ni	P	
Grinding	6:59-2:30	906	11	0.7	ND	143	13	ND	ND	1
Grinding	7:23-2:32	864	2	0.9	4	162	14	ND	ND	1
Shakeout	7:12-2:35	884	16	0.9	3	136	25	ND	ND	2
Furnace Platform	10:05-5:10	852	12	1	1	352	16	ND	8	16
Large Pouring	10:09-5:02	886	6	1	1	124	24	ND	2	6
Minimum Quantifiable Concentration (MQC) (Volume: 852 liters)			0.6	2.3	0.6	1.2	1.2	0.6	1.2	0.6

* - 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 (
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
Ni - Nickel	1000	15 (carcinogen)	1000
Pb - Lead	50	<100	150
Zn - Zinc	10000	5000	10000

- NIOSH contends that health effects can occur at the PEL.

Table 8

Results of Area Samples for Formaldehyde

General Castings Company
Liberty Road Facility
Delaware, Ohio
HETA 92-044

January 14-15, 1992

Location	Sampling Time	Sample Volume (liters)	Concentration (TWA-ppm)*
Coremaking Area- Small Hand Work	9:49-11:16	87	0.03**
Coremaking Area- Center of Large Assembly Line	9:50-11:16	86	0.03**
Coremaking Area- Between Large and Small Assembly Lines	9:54-11:16	82	0.04
Coremaking Area- Small Hand Work	9:01-10:26	85	0.02**
Coremaking Area- Between Large and Small Assembly Lines	9:00-10:27	87	0.02**
NIOSH Recommended Exposure Limit (REL):			0.016
OSHA Permissible Exposure Limit (PEL):			0.75
ACGIH Threshold Limit Value (TLV®):			1

Minimum Detectable Concentration (MDC): 0.01 ppm
(Sample Volume - 82 liters)

Minimum Quantifiable Concentration (MQC): 0.032 ppm
(Sample Volume - 82 liters)

* - ppm - parts per million

** - Between MDC and MQC

Table 7

Results of Passive Dosimeter Monitors for Carbon Monoxide

General Castings Company
Liberty Road Facility
Delaware, Ohio
HETA 92-044
January 14-16, 1992

Location	Sampling Time	Concentration (TWA-ppm)*
Personal:		
Ladle Repair	10:14-5:20	7
Pourer	10:10-5:20	28
Pourer	10:10-5:20	35
Furnace Charger	10:16-5:20	10
Furnace Charger	10:15-5:20	14
Shakeout	6:45-2:45	25
Forklift Driver	7:04-2:45	15
Forklift Driver	7:04-2:45	29
Shotblast Operator	7:00-2:26	9
Shakeout	7:10-2:30	14
Forklift Operator	7:16-2:25	14
Grinder	7:06-2:31	7
Molder/Coremaker	7:26-2:30	10
Superintendent	7:28-2:30	7
Shakeout (2 hrs Overhead Crane)	7:20-2:35	8
Area:		
Small Pouring Line	10:20-5:20	50
Large Pouring Line	10:20-5:20	43
Pouring/Cooling Area	10:19-5:20	21
Sand Handler and Shakeout	9:56-5:20	27
Furnace Platform	10:15-5:20	8
NIOSH Recommended Exposure Limit (REL):		35
OSHA Permissible Exposure Limit (PEL):		35
ACGIH Threshold Limit Value (TLV®):		25

* - TWA-ppm - time-weighted average - parts per million. MDC for 8-hr shi

Table 6

Results of Personal Breathing Zone Air Samples for Phenol

General Castings Company
Liberty Road Facility
Delaware, Ohio
HETA 92-044

January 14-16, 1992

Location/ Job Category	Sampling Time	Sample Volume (liters)	Concentr (TWA-p
Coremaking/ Coremaker	7:11-2:41	45	0.63
Molding/Wash Applicator	7:03-2:27	44.4	0.49
Molding/ Molder	6:57-2:25	44.8	1.16
Coremaking/ Coremaker	7:06-2:33	44.7	0.43
Coremaking/ Corefinisher	7:02-2:23	45.5	0.21
Coremaking/ Corefinisher	7:13-2:38	43.7	0.18
Coremaking/ Mill Operator	7:18-2:34	43.6	0.37
Coremaking/ Coremaker	7:15-2:31	43.4	0.33

NIOSH Recommended Exposure Limit (REL):	5
OSHA Permissible Exposure Limit (PEL):	5
ACGIH Threshold Limit Value (TLV®):	5

Minimum Detectable Concentration (MDC) (Sample Volume: 43.4 liters)	0.006 ppm
Minimum Quantifiable Concentration (MQC) (Sample Volume: 43.4 liters)	0.02 ppm

* - ppm - parts per million

Table 10

Results of Personal Breathing Zone and Area Air Samples
for Isopropyl Alcohol

General Castings Company
Liberty Road Facility
Delaware, Ohio
HETA 92-044

January 14-16, 1992

Location/ Job Category	Sampling Time	Sample Volume (liters)	Concentr (TWA-p
<u>Personal:</u>			
Molding/Molder	7:24-2:21	81	10
Molding/Rollover Machine Operator	7:39-2:27	82	9
Molding/Machine Operator	7:46-2:29	82	7
Molding/Mold Finisher	7:32-2:25	82	67
Molding/Crane Operator	6:46-2:35	93	5
Coremaking/Rollover Machine Operator	7:05-2:20	87	10
Molding/Molder	7:22-2:25	85	3
Coremaking/Coremaker	6:50-2:25	90	13
Coremaking/Corefinisher	6:46-2:20	92	31
Molding/Coremaker	6:41-2:24	93	16
<u>Area:</u>			
Shakeout	6:46-2:45	96	2
Molding	6:49-2:45	94	11
Mold Cooling Floor	7:08-2:45	91	7
Sandhandler	9:54-5:20	86	0.6
Vacuum Cleaner	9:52-5:20	87	0.4

NIOSH Recommended Exposure Limit (REL): 400
OSHA Permissible Exposure Limit (PEL): 400
ACGIH Threshold Limit Value (TLV®): 400

Minimum Detectable Concentration (MDC) (Volume: 81.4 liters) 0.04 ppm
Minimum Quantifiable Concentration (MQC) (Volume: 81.4 liters) 0.13 ppm
* - ppm - parts per million

Table 1

Health Effects Summary for Metals

General Castings Company - Liberty Road Facility
Delaware, Ohio
HETA 92-044

Substance	Primary Health Effects
Aluminum	Metallic aluminum dust is considered a relatively benign dust".[12]
Chromium	Chromium (Cr) exists in a variety of chemical forms and t varies among the different forms. For example, elemental is relatively non-toxic.[12] Other chromium compounds may c irritation, sensitization, and allergic dermatitis. In t hexavalent form (Cr(VI)), Cr compounds are corrosive, and carcinogenic. Until recently, the less water-soluble Cr(V were considered carcinogenic while the water-soluble form considered carcinogenic. Recent epidemiological evidence indicates carcinogenicity among workers exposed to solubl compounds.[13-17] Based on this new evidence, NIOSH recommen all Cr(VI) compounds be considered as potential carcinoge
Copper	Inhalation of copper fume has resulted in irritation of t respiratory tract, metallic taste in the mouth, and nause Exposure has been associated with the development of meta fever.[8]
Iron	Inhalation of iron oxide dust may cause a benign pneumoco called siderosis.[18]
Lead	Chronic lead exposure has resulted in nephropathy (kidney gastrointestinal disturbances, anemia, and neurologic eff These effects may be felt as weakness, fatigue, irritabil blood pressure, mental deficiency, or slowed reaction tim Exposure also has been associated with infertility in bot fetal damage.[19]
Nickel	Metallic nickel compounds cause sensitization dermatitis. considers nickel a potential carcinogen, as nickel refini associated with an increased risk of nasal and lung cance
Magnesium	Magnesium can cause eye and nasal irritation.[20] Exposure associated with the development of metal fume fever.[8]
Zinc	Zinc has been associated with shortness of breath, minor function changes, and metal fume fever.[8,20]

Table 11

Results of Personal Breathing Zone Samples
for Volatile Organic Compounds

General Castings Company
Liberty Road Facility
Delaware, Ohio
HETA 92-044

January 14-16, 1992

Job Title	Sampling Time	Sample Volume (liters)	Benzene Concentration (TWA-ppm)*	Toluene Concentration (TWA-ppm)	Xylenes Concentration (TWA-ppm)	Hydrocar Concentrat (TWA-ppm)
Molder	7:43-2:37	83.5	0.97	1.85	0.44	191.6
Molder	7:41-2:29	81.6	0.11	0.59	1.22	171.6
Coremaker	7:13-12:09	58.8	0.23	2.12	0.63	105.4
Molder	7:00-2:33	90.5	0.22	0.56	1.17	154.7
Molder/ Chain Operator	6:39-2:23	92.9	0.40	0.63	0.52	71.0
Coresetter	7:51-2:22	88.8	0.42	1.14	0.75	112.6
Molder	6:42-2:23	92.5	0.51	0.89	0.62	118.9
Crane Operator	7:09-2:28	87.8	0.24	1.00	0.68	86.6
NIOSH Recommended Exposure Limit (REL):			0.1	100	100	
OSHA Permissible Exposure Limit (PEL):			1.0	100	100	
ACGIH Threshold Limit Value (TLV®):			10 (proposed-0.1)	100	100 (proposed-50)	
Minimum Detectable Concentration (MDC) (Sample Volume: 58.8 liters)			0.006	0.018	0.039	1.7
Minimum Quantifiable Concentration (MQC) (Sample Volume: 58.8 liters)			0.018	0.049	0.129	5.6

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

** - TWA-mg/m³ - Time-weighted average - milligrams per cubic meter

Table 9

Results of Direct Reading Survey for Carbon Monoxide,
Alcohols and Phenol

General Castings Company
Liberty Road Facility
Delaware, Ohio
HETA 92-044

January 15, 1992

Location	Concentration (ppm)*		
	Carbon Monoxide	Alcohols	Phen
Coremaking	10	ND**	Trace
Pouring (Large Molds)	20	--	Trace
Ladle Preparation	10	--	--
Pouring (Small Molds)	20	ND	Trace
Shakeout Area	5 10	--	--
Sand Reclamation System Control Room	8	--	--
Limit of Quantitation (LOQ)	5	1000	5

* - ppm - parts per million
** - ND - none detected

Table 5

Results of Quantitative Area Samples
for Volatile Organic Compounds

General Castings Company
Liberty Road Facility
Delaware, Ohio
HETA 92-044

January 14-16, 1992

Location	Sampling Time	Sample Volume (liters)	Benzene Concentration (TWA-ppm)*	Toluene Concentration (TWA-ppm)	Total Hydrocarbo Concentrat (TWA-mg/m³
Shakeout	6:46-2:45	95.6	0.43	0.10	29.2
Molding	6:49-2:45	94.3	0.50	0.14	61.6
Mold Cooling Floor	7:08-2:45	91	0.45	0.18	60
Sandhandler	9:54-5:20	86.4	0.48	0.10	15.1
Vacuum Cleaner	9:52-5:20	87	0.31	0.05	6.2
Minimum Detectable Concentration (Sample Volume: 86.4 liters)			0.007	0.006	0.03
Minimum Quantifiable Concentration (Sample Volume: 86.4 liters)			0.029	0.025	0.104
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)	

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

** - TWA-mg/m³ - Time-weighted average - milligrams per cubic meter