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WILLIAM POWELL COMPANY
CINCINNATI, OHIO

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I. SUMMARY

In January 1991, the National Institute for Occupational Safety and Health (NIOSH) received a request from the Ohio Department of Health (ODH) for technical assistance in evaluating employee lead exposures at the William Powell Company, a brass foundry, in Cincinnati, Ohio.

On August 15 and 18, 1991, NIOSH representatives conducted industrial hygiene surveys. Personal breathing zone samples for lead, other metals, and respirable silica were collected for twelve employees at the foundry; direct reading measurements using a Realtime Aerosol Monitor (RAM-1) were made throughout the facility; general work practices and conditions were observed; and biological monitoring results for lead were reviewed. On the second site visit, a study of the current engineering controls for the pouring operation was conducted.

Biological monitoring for lead was routinely performed by the company every six months. The most recent blood lead levels (BLLs) ranged from 10 to 39 micrograms per deciliter (µg/dl). The average BLL was 21 µg/dl. The individual with the highest BLL was retested and the second BLL was 28 µg/dl. These test results were below the levels set by the Occupational Safety and Health Administration (OSHA) standard which requires that an employee whose BLL is 40 µg/dl or greater be tested every two months and be removed from a lead exposure job if his/her average BLL is 50 µg/dl or more on three occasions over a 6-month period.

Workplace lead concentrations ranged from nondetectable to 172 micrograms per cubic meter (µg/m^3), as time-weighted averages (TWAs). Three (two metal pourers and one cut-off saw operator) of the seven personal breathing zone samples collected for metals exceeded the OSHA Permissible Exposure Limit (PEL) for workplace exposure to airborne lead of 50 µg/m^3 as an 8-hour TWA. All employees that worked as metal pourers were required to wear NIOSH/Mine Safety and Health Administrion (MSHA) approved powered air-purifying helmet respirators while working with hot metal. Samples were collected outside of the metal pourers' respirators, therefore, the actual exposures to the individuals were probably lower than those measured. Personal breathing zone air concentrations for metals (copper, iron, magnesium, nickel, phosphorus, and zinc) were below existing guidelines and standards established by NIOSH, OSHA, and the American Conference of Governmental Industrial Hygienists (ACGIH). One personal breathing zone sample for a pourer exceeded the NIOSH Recommended Exposure Limit (REL) of lowest feasible concentration for cadmium, which has been classified as a suspected human carcinogen. Nickel, which has also been classified by NIOSH as a suspected human carcinogen, was detected in two personal breathing zone samples but did not exceed the current NIOSH REL of 15 µg/m^3, as a TWA.

The personal breathing zone samples for respirable silica for the shakeout/grinding operator, the core machine operator, and the shotblast/shakeout operator were below the limit of detection (LOD) of 15 µg per filter. The jolt squeeze operator and the core setter had exposures of approximately 30 µg/m^3 as a TWA, which should be considered an estimate as the value was between the LOD and the limit of quantitation (LOQ). The area concentration

measured for the knock-out area was 47 $\mu g/m^3$ as a TWA, which was also between the LOD and LOQ. No cristobalite was detected in any of the samples.

The results for the real-time respirable aerosol monitoring from the first industrial hygiene survey using the RAM showed that, during pouring, the movement of the full ladle from the furnace to the pouring line had the highest concentration of fume (range: 0.48-0.78 mg/m^3). In the molding area, the use of the automatic muller produced the highest level of dust (range: 1.5-2.0 mg/m^3). These short-term measurements should be considered estimates of exposure and, therefore, are not comparable to evaluation criteria.

Video exposure monitoring techniques were employed to identify exposure sources during the pouring operations. A direct reading instrument monitored personal aerosol exposures of one worker who performed both the stationary and continuous operations. Also a video recording of the work activity was made for a detailed task analysis. The average flow rate for the side draft hood used during continuous pouring measured 700 cubic feet per minute/linear foot (cfm/linear ft) which was more than double the flow rate recommended (200 - 300 cfm/linear ft of hood) in the ACGIH publication Industrial Ventilation. The close-capture system used at the electric induction furnace appeared to contain visible smoke and fumes and the concentration measured was the lowest of the tasks for both the continuous and stationary operations. The study of engineering controls found that the largest portions of aerosol exposure to the pourer came from the transport of the ladle, the pouring of ingots, and the scraping of the ladle.

The industrial hygiene sampling data indicate that lead levels at this facility constitute a potential health hazard to employees in the pouring and cut-off saw areas. Biological monitoring results indicated that employee blood lead levels were below the current OSHA standard which shows that engineering and administrative controls in place were reducing exposures. Several recommendations are offered to reduce exposures, such as providing additional local exhaust ventilation during ladle transport, addition of a side draft hood ventilation system to the ingot pouring and ladle scraping area, and the use of a vacuum cleaner with high efficiency particulate air (HEPA) filters for cleaning up dust.

KEYWORDS: SIC 3366 (copper foundries), lead, respirable silica, engineering controls, real time monitoring, cadmium, nickel.

II. INTRODUCTION

On August 15 and 18, 1991, National Institute for Occupational Safety and Health (NIOSH) representatives, along with a representative from the Ohio Department of Health, conducted site visits to the William Powell Company, a brass foundry, in Cincinnati, Ohio. These visits were made in response to a request for technical assistance from the Ohio Department of Health to evaluate worker exposure to lead at the facility. The facility was identified through the physician occupational disease reporting system for the State of Ohio as having potential worker over-exposure to lead.

III. BACKGROUND

The William Powell Company manufactures brass valves for internal use and for retail sale. The company was founded in 1846. The two-story building housing the foundry was built between 1930-1935. At the time of the site visit, the company used two different alloys, with lead content ranging from 1.6-5%. The facility used electric induction furnaces, which were equipped with close-capture ventilation hoods (Hawley Mob-L-Vent, Vulcan Engineering, Birmingham, AL) to control employee exposure to metal fumes while melting and pouring the molten metal into ladles. Two different pouring operations were used at this facility: a stationary pouring line and a continuous pouring line (see Figure 1). For the stationary operation, sand molds were placed on a stationary roller conveyor.

A mobile hood and zipper duct system (Hawley Trav-L-Vent, Vulcan Engineering, Birmingham, AL) was used to capture and remove aerosol emissions when the worker poured the molds and transported the ladle along the stationary roller conveyor. For the continuous operation, the sand molds were placed on a slow-moving conveyor. The continuous operation used a side draft hood located along the continuous conveyor where the worker poured the molds to capture and remove emissions. A ladle used during both operations was suspended from an overhead monorail system and was manually maneuvered into position.

The facility also contained coremaking, molding, and casting cleaning areas. Cores were made of a phenolic-urethane or phenolic-formaldehyde resin with silica sand. Coremaking was done by hand and by machine. Some of the hot shell molding machines did not have local ventilation controls. Molds were made with green sand. An automatic muller was used to mix the resin with the sand in the molding area. Some trimming of the castings was done using dies. A shot blast machine which utilized steel shot was used to remove excess sand and clean the castings. Cut-off saws and grinders were also used to clean and trim the castings. A canopy hood-type exhaust system was used to collect and remove dust over the shakeout table. A bag-house was used in conjunction with the local exhaust ventilation systems to collect dust.

At the time of the site visit, there were forty-four workers at the foundry who worked one shift. According to company officials, there was a low employee turnover rate; the majority of the employees retired from the facility. NIOSH/Mine Safety and Health Administration (MSHA) approved powered air-purifying respirator helmets and flame retardant clothing were worn in the pouring area. Safety glasses and safety shoes were required throughout the facility. Each employee was issued their own respirator and was responsible for cleaning it. Biological monitoring for lead was done on a routine basis. A lunch area and locker/shower area were provided for employees. Employees were required to shower and change before leaving the facility.

IV. EVALUATION CRITERIA AND TOXICOLOGY

In order 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),[1] 2) the American Conference of Governmental Industrial Hygienists' (ACGIH) Threshold Limit Values (TLVs®),[2] and 3) the U.S. Department of Labor Occupational Safety and Health Administration (OSHA) Permissible Exposure Limits (PELs).[3] The OSHA PELs may include the feasibility of controlling exposure 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. Lead

Inhalation of lead dust and fumes is the major route of exposure for this industrial environment. A secondary source of exposure may be from ingestion of lead deposited on food, cigarettes, or other objects. Absorbed lead interferes with red blood cell production and can damage the kidneys, peripheral and central nervous systems, and bone marrow. Effects that have been associated with high lead exposures include fatigue, weakness, irritability, digestive disturbances, high blood pressure, kidney damage, and slow reaction times. Chronic lead exposures have been associated with infertility among both sexes and with fetal damage in pregnant women.[4,5] The developing central nervous systems of young children may be damaged by blood lead levels (BLLs) as low as 10 micrograms per deciliter (µg/dl).[6]

The OSHA PEL for lead in air is 50 micrograms per cubic meter (µg/m^3) of air calculated as an 8-hour time-weighted average (TWA) for daily exposure (29 CFR 1910.1025).[7] The OSHA lead standard for general industry also requires semi-annual blood lead monitoring of workers exposed to lead air concentrations of 30 µg/m^3 or greater for more than 30 days per year. Employees whose BLL is 40 µg/dl or greater must be retested every two months, and removed from a lead-exposed job if his/her average BLL is 50 µg/dl or more over a 6 month period.
A BLL of 60 µg/dl or greater, confirmed by retesting within two weeks, requires immediate medical removal. A worker on medical removal should not be returned to a lead-exposed job until his/her BLL is confirmed to be below 40 µg/dl. Under the

OSHA standard, a medically removed worker has protection for wage, benefits, and seniority for up to 18 months until the BLL is below 40 µg/dl and he/she can be returned to lead exposure areas.[7] The zinc protoporphyrin (ZPP) tests are not required by the OSHA standard, but they are suggested. The ZPP test measures an adverse metabolic effect of lead on the synthesis of heme (a component of hemoglobin, the oxygen carrying substance in the red blood cells) and thus serves as an indicator of lead body burden.[7]

B. Silica

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.[8] The NIOSH RELs for respirable quartz and cristobalite, published in 1974, are 50 µg/m^3, as 10-hour TWAs.[1] Based on data available more recently, NIOSH considers quartz and cristobalite to be potential human carcinogens.[1] The OSHA PELs and the ACGIH TLVs are 100 and 50 µg/m^3 for respirable quartz and cristobalite, as 8-hour TWAs, respectively.

C. Other Metals

The potential health effects associated with the other metals of major toxicologic importance detected in the samples are shown in Table 1. These elements include cadmium, copper, iron, magnesium, nickel, phosphorus, tin, and zinc. The NIOSH REL, the OSHA PEL, and the ACGIH TLV are presented for each element.[1,2,3,8]

V. STUDY DESIGN

A. Industrial Hygiene

1. Metals

Seven personal breathing zone 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 liters per minute (l/min). Samples were collected for periods as near as possible to entire workshifts (6 to 7 hours). The samples were analyzed for metals according to NIOSH Method 7300.[9] 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 (ICP) atomic emission spectrometry.

2. Respirable Silica and Cristobalite

One area air sample and five personal breathing zone samples for respirable dust (aerodynamic diameter less than 10 µm) were collected at a flow rate of 1.7 l/min using 10 mm nylon cyclones mounted in series with pre-weighed 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[10] 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 limit of detection (LOD) was 15 µg per filter and the limit of quantitation (LOQ) was 30 µg per filter.

3. Real-time Respirable Particulate Measurements

Initial real-time total aerosol measurements were made at the facility using a direct-reading instrument (Realtime Aerosol Monitor [RAM-1, MIE, Inc., Bedford, MA]) to identify the most significant sources of exposure to foundry dusts. The instrument sampled the workplace air and measured the concentration of airborne dusts by analyzing the amount of light scattered by these materials. The characteristics of the RAM are such that it is most sensitive to respirable aerosols (dusts below 10 µm in diameter). The instrument is factory-calibrated using Arizona road dust at an estimated density of 2.4 grams per cubic centimeter (g/cm^3).

B. <u>Engineering Control Study</u>

1. Real-time Measurements

Video exposure monitoring techniques were employed to identify exposure sources during the pouring operations.[11] A direct reading instrument monitored personal aerosol exposures of one worker who performed both the stationary and continuous operations. Also a video recording of the work activity was made for a detailed task analysis.

A Hand-held Aerosol Monitor (HAM) (PPM, Inc., Knoxville, Tennessee) measured the aerosol concentrations during the pouring operations. The response of this light-scattering instrument was dependent upon the optical characteristics of the aerosol being measured. The HAM responded to respirable aerosols, but did not differentiate between lead and other aerosols.[12] For this reason, relative concentrations were reported rather than absolute levels. The HAM was attached to the worker using a belt and harness with the sensor monitor positioned on the chest near the worker's breathing zone. The analog output of the HAM was recorded by a data logger (Rustrak Ranger, Gulton, Inc., East Greenwich, Rhode Island) attached to the belt of the worker. Data were collected for two sampling periods of approximately thirty minutes each. After each sampling period, the data logger was downloaded to an IBM compatible computer for storage and future analysis.

2. Side Draft Hood Evaluation

The side draft ventilation system was characterized for air velocity. The side draft ventilation system for the continuous pouring line consisted of a slot hood approximately 40 feet (ft) in length, with four exhaust take-offs separated by a distance of about 5 ft. The face velocity of the side draft hood was measured using a hot wire anemometer (Kurz Digital Air Velocity Meter 1440-4, Carmel Valley, CA). Velocity readings were made at 22 points along the face of the hood.

VI. RESULTS

A. Industrial Hygiene

1. Metals

Employee exposures to metals were monitored throughout the production area. Table 2 presents the results for metals with potential health hazards, including lead. Workplace lead concentrations ranged from nondetectable to 172 µg/m^3, as TWAs. The cut-off saw operator and the two pourers had personal breathing zone exposures to airborne lead that exceeded the OSHA PEL of 50 µg/m^3. The two pourers were required to wear NIOSH/MSHA approved powered air-purifying helmet respirators while working with hot metal. Samples were collected outside of the respirators, therefore, the actual exposures to the individuals were probably lower than those measured.

All of the personal breathing zone air concentrations for copper, iron, magnesium, nickel, phosphorus, and zinc were below existing guidelines and standards established by NIOSH, OSHA, and ACGIH.

Cadmium and nickel have been classified by NIOSH as suspected human carcinogens. One personal breathing zone sample for a pourer exceeded the NIOSH REL for cadmium of the lowest feasible concentration. Nickel was detected in two personal breathing zone samples but did not exceed the current NIOSH REL of 15 µg/m^3, as a TWA.

2. Respirable Silica and Cristobalite

The results for the personal breathing zone and area samples for respirable silica are listed in Table 3. The personal breathing zone samples for the shakeout/grinding operator, the core machine operator, and the shotblast/shakeout operator were below the LOD of 15 µg per filter. The jolt squeeze operator and the core setter had exposures of approximately 30 µg/m^3 as a TWA, which should be considered an estimate as the value was between the LOQ and LOD. The area concentration measured for the knock-out area was 47 µg/m^3 as a TWA, which was also between the LOD and LOQ. No cristobalite was detected in any of the samples.

3. Real-time Respirable Particulate Measurements

The results for the real-time respirable aerosol monitoring from the first industrial hygiene survey using the RAM are shown in Table 4. During pouring, the movement of the full ladle from the furnace to the pouring line had the highest concentration of fume (range: 0-48-0.78 mg/m^3). In the molding area, the use of the automatic muller produced the highest level of dust (range: 1.5-2.0 mg/m^3). These short-term measurements should be considered estimates of exposure and, therefore, are not comparable to evaluation criteria.

B. Engineering Control Study

1. Real-time Measurements

By reviewing the real-time video recordings, the individual tasks of the stationary and continuous pouring operations were identified and coded into a data set so that each task's contribution to the worker's cumulative aerosol exposure could be calculated. The stationary operation was divided into six tasks: working at the furnace (ventilated), transporting a full ladle without the zipper duct attached (unventilated), transporting a full ladle with the zipper duct attached (ventilated), pouring with the zipper duct attached (ventilated), transporting an empty ladle with the zipper duct attached (ventilated), and transporting an empty ladle without the zipper duct attached (unventilated).

The continuous operation was broken into five tasks: working at the furnace (ventilated), transporting a full ladle (unventilated), pouring along the continuous conveyor (ventilated), scraping the ladle at the designated area (unventilated), and transporting an empty ladle (unventilated).

To find how each task affected the cumulative exposure, the real-time data were assembled into a spreadsheet format (Lotus 1-2-3, Release 2.d, Lotus Development Corp., Cambridge, MA). The data set consisted of total aerosol concentration measurements and the time the measurements were taken. The interval between measurements was one second. Codes were added to identify the specific task being performed at the time of the measurement. The average concentration, cumulative time, and cumulative exposure (the product of the average concentration and cumulative time) were calculated for each of the tasks of the stationary and continuous pouring operations as follows:

$$\text{Cumulative Exposure} = \frac{\Sigma\ \text{Concentration}}{\text{Number of Measurements}} \times \Sigma\ \text{Task Length}$$

It was determined that transporting a full ladle without the zipper duct attached (unventilated) resulted in the highest concentration. This concentration was arbitrarily assigned a relative concentration index of 100. The relative concentration indices for all other concentration measurements were calculated as follows:

$$\text{Relative Concentration} = \frac{\text{Average Concentration}}{\text{Highest Average Concentration}} \times 100$$

Figure 3A shows the relative aerosol concentrations of each of the six stationary operation tasks. Figures 3B and 3C summarize the contribution of the individual tasks of the stationary operation to the total activity time and cumulative exposure. While it accounted for less than a tenth of the total activity time, transporting a full ladle without the zipper duct attached (unventilated) was responsible for almost half the cumulative exposure for the stationary operation.

Figure 4A shows the relative aerosol concentrations for each of the five continuous operation tasks. Transporting a full ladle (unventilated) resulted in the highest concentration for the continuous line with a concentration index of 41. Figures 4B and 4C summarize the contribution of the individual tasks of the continuous operation to the total activity time and cumulative exposure, respectively. Transporting a full ladle (unventilated) contributed to more than one third of the cumulative exposure during the continuous operation, while accounting for one tenth of the total activity time.

2. Side Draft Hood

The face velocity readings obtained along the length of the side draft hood indicated that the highest velocities were found at the mid-point of each exhaust take-off, between 2 and 8 meters per second (m/s) or 4450 - 1400 feet per minute (fpm). Figure 2 shows all the measured velocities at the respective positions along the hood, with a smooth curve fitted to the data points. The average flow rate for the side draft hood measured 700 cubic feet per minute/linear foot (cfm/linear ft) or 1.1 cubic meter per second per meter ($m^3/s/m$) of hood which was more than double the flow rate recommended (200 - 300 cfm/linear ft or 0.3-0.5 $m^3/s/m$ of hood) in the ACGIH publication Industrial Ventilation.[13]

C. Biological Monitoring

Biological monitoring for lead was routinely performed by the company every six months. The latest biological monitoring had been performed by the company approximately two weeks prior to the site visit. These results were evaluated at the time of the site visit. The blood lead levels (BLLs) ranged from 10 to 39 µg/dl for the ten employees who participated in the screening. The average BLL for all persons tested was 21 µg/dl. The individual with the highest BLL was retested and the second BLL was 28 µg/dl. These test results were below the levels set by the OSHA standard.[7] The OSHA standard requires that an employee whose BLL is 40 µg/dl or greater be tested every two months and be removed from a lead exposure job if his/her average BLL is
50 µg/dl or more on three occasions over a 6-month period.

VII. ENGINEERING CONTROL ALTERNATIVES

A. Ladle Transport

The aerosol concentrations for the ladle transport tasks (empty and full) of the stationary operation were well controlled when using the mobile hood and zipper duct system. However, when a ladle was transported without the zipper duct attached, the exposure to the worker increased substantially. The mobile hood and zipper duct system was able to reduce the aerosol concentration by about a factor of ten during full ladle transport and a factor of four during empty ladle transport.

The effectiveness of the mobile hood and zipper duct system on the stationary operation led to an initial conclusion that the use of additional ventilation such as a mobile hood and zipper duct system on the continuous operation could result in reduced concentrations during the unventilated ladle transport tasks. By substituting the concentration data of the stationary operation's ventilated ladle transport tasks for the concentration data of the continuous operation's unventilated ladle transport tasks, potential exposure reductions could be calculated for the ladle transport tasks (full and empty) of the continuous operation. Figure 5 contrasts the current exposure data for the continuous ladle transport tasks with theoretical values for the same tasks using controls. The data show that by using the mobile hood and zipper duct system during the ladle transport tasks of the continuous operation, the worker's cumulative exposure to aerosols could theoretically be reduced by up to 76% for the full ladle transport task, and up to 25% for the empty ladle transport task.

B. Pouring

Since the pouring task of the stationary operation was performed with the mobile hood and zipper duct system attached at all times, the task could not be compared to a completely uncontrolled situation. It was assumed that without the control of the mobile hood and zipper duct system, the concentration during the pouring task of the stationary operation would have been greater, as was true in the ladle transport tasks.

Three alternatives for reducing the exposure from the pouring task of the continuous operation were considered. The first was to substitute a mobile hood and zipper duct system for the existing side draft hood located along the continuous conveyor. The second was to modify the existing side draft hood to improve the efficiency of aerosol capture during the pouring task. The third was to use a mobile hood and zipper duct system in addition to the side draft hood.

For the first alternative, Figure 5 shows the theoretical exposure when using a mobile hood and zipper duct system contrasted with the current exposure for the continuous pouring task. The data show that by using the mobile hood and zipper duct system during the pouring task of the continuous operation, the worker's cumulative exposure to aerosols could be reduced by up to 20%.

For the second alternative, the side draft hood was analyzed to find where the ventilation was least efficient. It appeared that the fluctuations in the measured face velocities were caused by a shallow plenum. To determine the effect the pouring location had on the cumulative exposure, the pouring task was divided into two categories: pouring within the length of the take-off and pouring in-between the take-offs (data collected when pouring only partly within the exhaust take-off were not included in this analysis). The aerosol concentration index, cumulative time, and cumulative exposure were calculated for both pouring locations (within and between the take-offs). If the hood was modified so that a uniform face velocity was obtained, the worker's cumulative aerosol exposure from the pouring task could be reduced about 12%.

The third alternative was to implement a mobile hood and zipper duct system while continuing to use the side draft hood during the continuous pouring task. Although no data were available for analysis of this proposed control measure, it was expected that the combined effectiveness of the mobile hood and zipper duct system and the side draft hood would be greater than the effectiveness of either of the control components individually. Fumes given off during the actual pouring would immediately be captured by the mobile hood and zipper duct system, and any further fumes would be captured by the side draft hood as the molds continued along the continuous conveyor.

C. Scraping

The scraping task was the third highest cumulative exposure source of the continuous operation. A side-draft hood similar to the one used during the pouring task of the continuous operation was proposed to control this operation. A conservative estimate expected for the scraping task exposure could be derived by substituting the concentration index obtained when using limited ventilation (pouring in-between the exhaust take-offs of the side draft hood during the pouring task of the continuous operation) for the current concentration index of the scraping task. Figure 5 contrasts the current exposure data for the scraping task with the expected exposure for the same task using controls. The theoretical data show that the implementation of a side-draft hood could conservatively be expected to reduce the cumulative exposure from the scraping task by up to 30%.

D. Furnace

The close-capture system used at the electric induction furnace appeared to contain visible smoke and fumes and the concentration measured was the lowest of the tasks for both the continuous and stationary operations. Therefore, no further controls were suggested for work at the furnace.

VIII. DISCUSSION AND CONCLUSIONS

Airborne lead concentrations exceeding the OSHA PEL were measured for three personal breathing zone samples, thus constituting a potential health hazard to the employees of this foundry working in the pouring and cut-off saw areas. Samples were collected outside of the respirators worn by the employees, therefore, the actual exposures to the individuals were probably lower than those measured. Low concentrations of respirable quartz and no cristobalite were detected in personal and area air samples collected in the foundry. Cadmium, a suspected human carcinogen, was detected in one of the air samples analyzed for metals.

The highest concentrations for both the stationary and continuous pouring operations occurred during the transport of the unventilated full ladle. The cumulative aerosol exposures from the continuous operation's tasks were far greater than those from the stationary operation due to the greater amount of time the worker spent doing continuous pouring. Also, the controls on the stationary operation were more effective than the controls on the continuous operation.

Recent studies suggest that significant health risks exist for workers with BLLs below 50 µg/dl. Such risks include neurologic impairment, hypertension, and adverse reproductive effects in both men and women.

A positive relationship between BLLs and both elevated systolic and diastolic blood pressures have been found. No evidence of a threshold level for this effect has been found.

Maternal lead exposure has been associated with reduced birth weight, gestational age, and neurobehavioral development up to 2 years of age. Maternal lead exposures below 25 µg/dl can lead to lower child IQ, slower reaction time, inadequate Vitamin D metabolism, reduced size up to 8 years of age, and other neurotoxic effects. The precise level of lead exposure that can cause adverse health effects has yet to be determined.[14]

IX. RECOMMENDATIONS

1. A local exhaust ventilation system, such as mobile hood and zipper duct, should be installed to reduce the fumes generated when moving the ladles to and from the continuous pouring line and during pouring operations.

2. A side draft hood ventilation system should be installed to remove the fumes generated during ingot pouring and ladle scraping.

3. The side-draft hood which serviced the continuous pouring line had higher air flow rates at the take off points. The plenum should be deepened to attain a uniform distribution.

4. The hot shell molding machines were emitting smoke and fumes into the breathing zones of the workers. As shown in Figure 6, a slotted side draft hood with a canopy hood would help remove this hazard.[11]

5. A plastic liner in the large storage bin of the cutoff saw area would muffle the noise as parts were added and keep it from ringing.

6. Workers were observed sweeping dust with a broom which could increase potential exposures to contaminants. A vacuum cleaner, with high efficiency particulate air filters should be used as a less hazardous method of dust clean up.

7. A local exhaust hood on the automatic sand muller should be installed reduce dust exposure in the molding area.

8. Blood lead levels of workers exposed to lead should continue to be monitored every six months and the results reviewed by a qualified physician, with training in occupational medicine, as long as employees may be exposed to air concentrations above the action level of 30 µg/m^3, as a TWA.[7]

9. Quartz and cristobalite air monitoring should be conducted on a regular basis to make sure there are no excessive exposures, and that controls continue to be effective.

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1. The William Powell Company
2. United Steel Workers Union
3. The Ohio Department of Health
4. OSHA, Region V

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

Table 1

Possible Health Effects and Evaluation
Criteria for Detected Metals

William Powell Company
Cincinnati, Ohio
HETA 91-092

Metal	Health Effects	NIOSH REL (µg/m^3)*	OSHA PEL (µg/m^3)	ACGIH TLV (µg/m^3)
Cadmium	pulmonary edema; cough; emphysema; renal involvement; mild anemia; respiratory cancer	LFC**	200	50 (10#)
Copper	irritation of upper respiratory tract; metallic taste; nausea; metal fume fever	1000	1000	1000
Iron	siderosis; scarring of the lung with increased quartz content	10000	10000	5000
Magnesium	Eye and nasal irritation; metal fume fever	None	10000	10000
Nickel	Lung and nasal cancer	15***	1000	1000 (50#)
Phosphorus	Eye and respiratory tract irritation; skin burns; necrosis of facial bones	100	100	100
Zinc	Metal fume fever	5000	10000	10000

* - µg/m^3 - microgram per cubic meter as time-weighted average (NIOSH-10 hour TWA; OSHA and ACGIH-8 hour TWA).

** - NIOSH considers cadmium to be a potential human carcinogen; therefore, exposure should be reduced to the lowest feasible concentration (LFC).

*** - NIOSH considers nickel to be a potential human carcinogen.

- TLV proposed in ACGIH Notice of Intended Changes 1991-92.

Table 2

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

William Powell Company
Cincinnati, Ohio
HETA 91-092

August 15, 1991

Job Title	Sampling Time	Sample Volume	Metal Concentrations (TWA-µg/m³)*							
			Cd	Cu	Fe	Mg	Ni	Pb	P	Zn
Snag Grinder	7:45-2:00	750	ND	6.7	4	ND	ND	ND	ND	4
Furnace Charger	7:17-2:00	806	ND	64.5	48.4	3.7	1.2	21.1	ND	732
Shotblast Operator/ Shakeout	7:37-2:02	770	ND	93.5	32.5	2.6	ND	14.3	ND	36.4
Pour-off Operator	7:14-2:05	822	ND	10.9	9.7	ND	ND	77.9	ND	365
Core Setter	7:18-1:59	802	ND	10	24.9	3.7	ND	7.5	ND	38.7
Cut-off Saw Operator	7:39-2:01	764	ND	693.7	13.1	ND	6.5	61.5	26.2	57.6
Pour-off Operator	7:16-2:02	812	2.46	14.8	12.3	2.5	ND	172.4	ND	665
Limits of Detection (µg/filter)		1	1	1	2	1	2	10	1	

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

Metals	OSHA PELs (µg/m³)	NIOSH RELs (µg/m³)	ACGIH TLVs (µg/m³)
Cd - Cadmium	200	LFC***	50
Cu - Copper	1000	1000	1000
Fe - Iron	10000	5000	5000
Mg - Magnesium	10000	None	10000
Ni - Nickel	1000	15	1000
Pb - Lead	50	<100	150
P - Phosphorus	100	100	100
Zn - Zinc	10000	5000	10000

*** - Lowest Feasible Concentration

Table 3

Results of Personal Breathing Zone and Area Samples
for Respirable Silica

William Powell Company
Cincinnati, Ohio
HETA 91-092

August 15, 1991

Job Title/ Location	Sample Sampling Time	Respirable Silica Volume (liters)	Concentration (TWA-µg/m^3)*
Personal:			
Jolt Squeeze Operator	7:23-2:09	690.2	29#
Shakeout Operator/ Grinding Operator	7:46-2:07	647.7	ND**
Core Setter	7:21-1:56	654.5	31#
Core Machine Operator	7:24-2:10	673.2	ND
Shotblast Operator/ Shakeout Operator	7:24-2:10	673.2	ND
Area:			
Knock-out Area	7:50-2:06	639.2	47#

NIOSH Recommended Exposure Limit (REL): 50 µg/m^3

OSHA Permissible Exposure Limit (PEL): 100 µg/m^3

Limit of Detection (LOD): 15 µg/filter
Limit of Quantitation (LOQ): 30 µg/filter

* - TWA-µg/m^3 - Time-weighted average micrograms per cubic meter
** - ND - None Detected, below the LOD
# - Between LOD and LOQ

Table 4

Respirable Aerosol Monitoring Results

William Powell Company
Cincinnati, Ohio
HETA 91-092

August 15, 1991
(Measurements Taken Between 10:00 am and 11:00 am)

Location	Range of Concentration (mg/m^3)*
<u>Pouring:</u>	
Filling the Ladle From the Furnace	0.15 - 0.35
Traveling to Pouring Line	0.48 - 0.78
Pouring with Slot Hood Local Exhaust Ventilation	0.3 - 0.6
Pouring into an Ingot	0.4 - 0.45
<u>Molding/Coremaking:</u>	
Staking Finished Molds	0.5 - 0.7
Filling the Molds Using Automatic Filler	1.5 - 2.0
Match Plateline/Manual Molds	0.1 - 0.2
Core Sand Muller	0.17 - 0.24
Sand Mixer	0.2 - 0.31
Coremakers	0.18 - 0.21
Shell Core Machine	0.4 - 0.8
<u>Shakeout:</u>	0.1 - 0.2
<u>Grinding:</u>	0.1 - 0.2
<u>Cutoff Saw:</u>	0.08

* - mg/m^3 - Milligrams per cubic meter

Figure Captions
Figure 1--Process layout of the continuous and stationary pouring operations.

Figure 2--Velocity readings along the side draft hood of the continuous pouring operation.

Figure 3--Contribution of the individual tasks of the stationary pouring operation to the (A) total aerosol concentration, (B) activity time, and (C) cumulative exposure.

Figure 4--Contribution of the individual tasks of the continuous pouring operation to the (A) total aerosol concentration, (B) activity time, and (C) cumulative exposure.

Figure 5--Theoretical exposure reductions for the individual tasks of the continuous pouring operation with the implementation of engineering controls.

Figure 1

Process layout of the continuous and stationary pouring operations.

William Powell Company
Cincinnati, Ohio
HETA 91-092

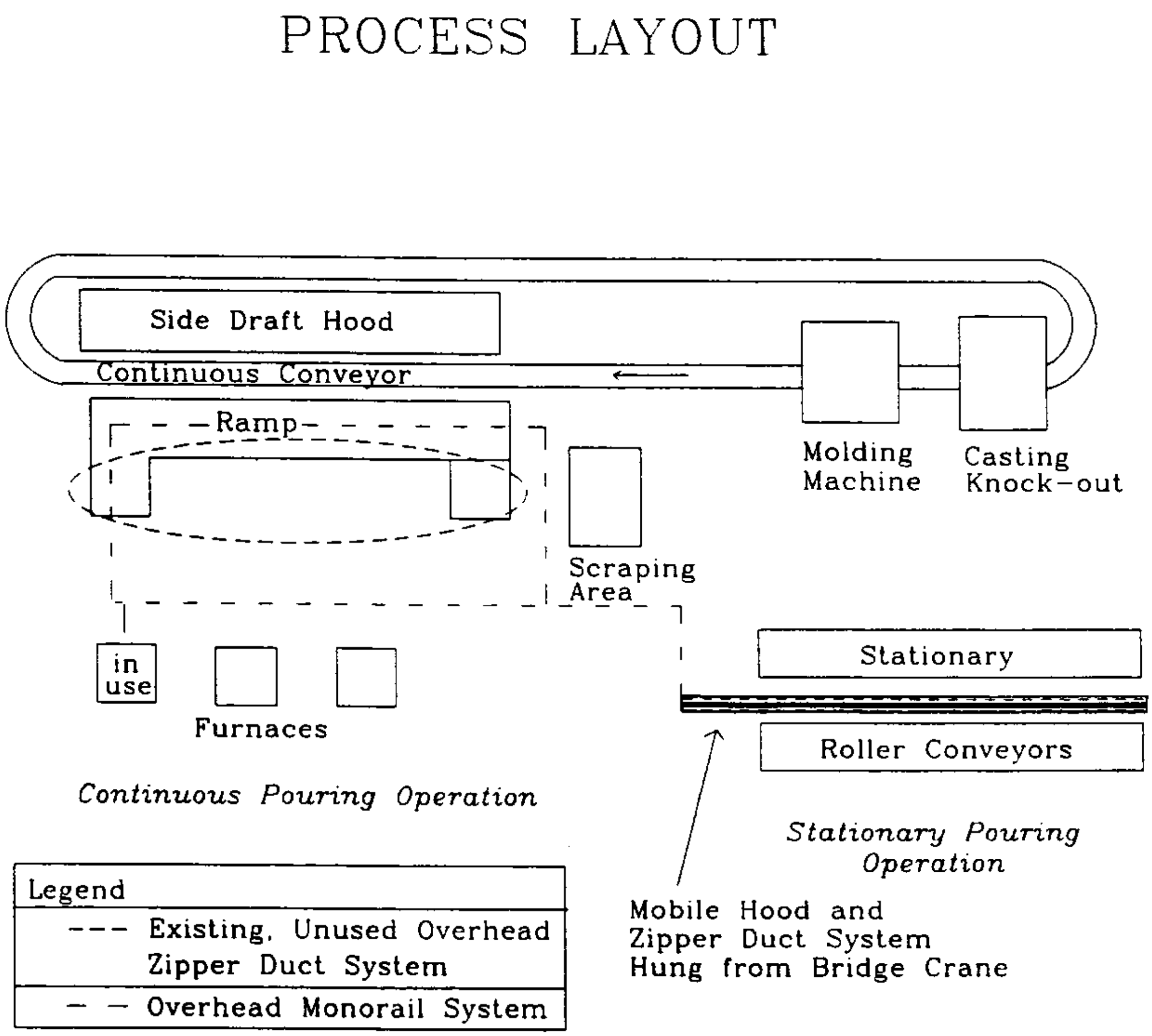


Figure 2

Velocity readings along the side draft hood of the continuous pouring operation.

William Powell Company
Cincinnati, Ohio
HETA 91-092

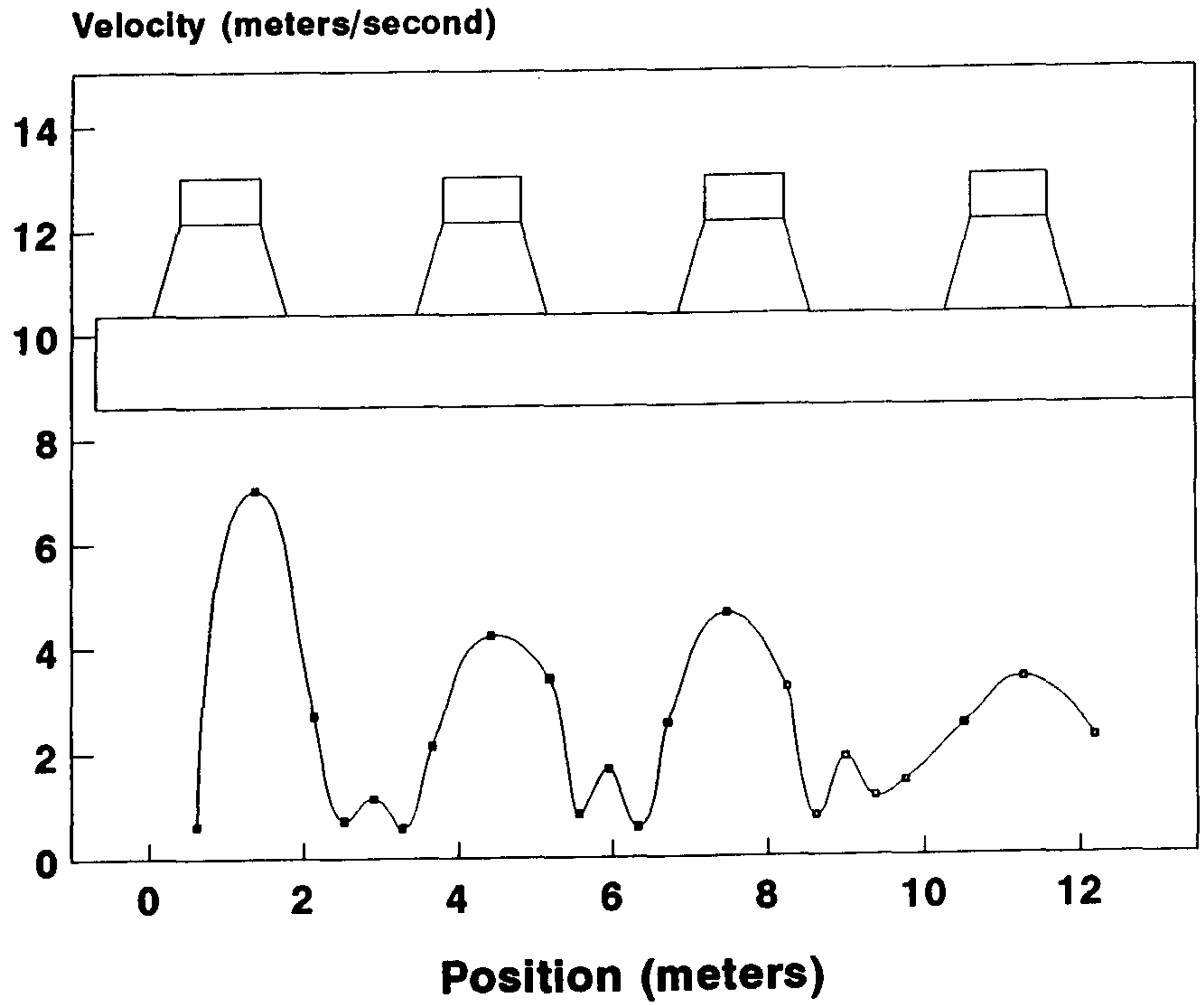
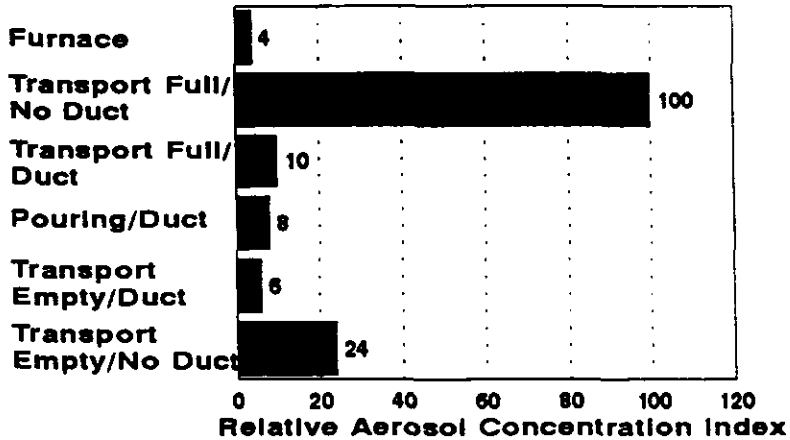


Figure 3

Contribution of the individual tasks of the stationary pouring operation to the (A) total aerosol concentration, (B) activity time, and (C) cumulative exposure.

William Powell Company
Cincinnati, Ohio
HETA 91-092

A.



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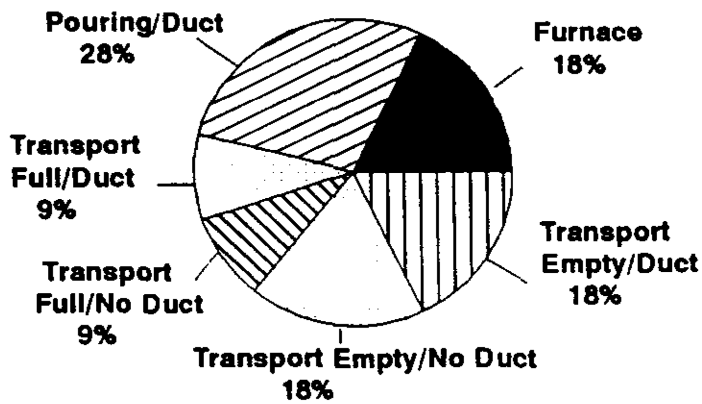

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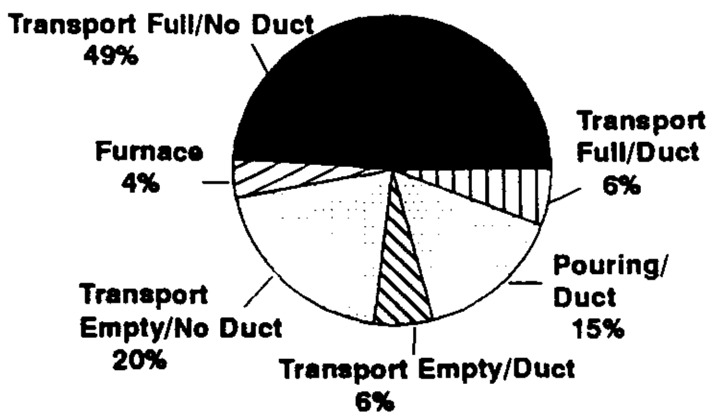


Figure 4

Contribution of the individual tasks of the continuous pouring operation to the (A) total aerosol concentration, (B) activity time, and (C) cumulative exposure.

William Powell Company
Cincinnati, Ohio
HETA 91-092

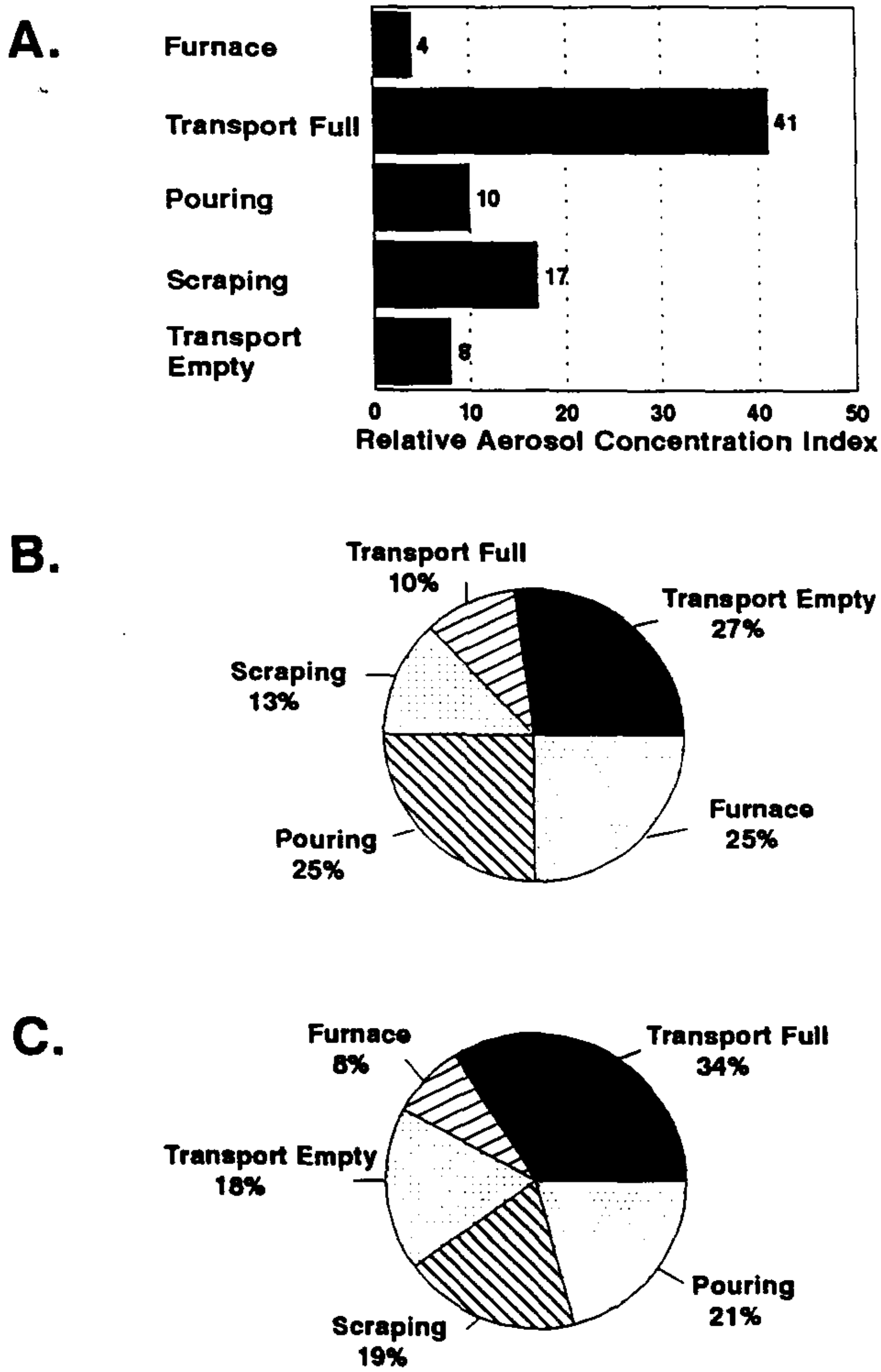


Figure 5

Theoretical exposure reductions for the individual tasks of the continuous pouring operation with the implementation of engineering controls.
William Powell Company
Cincinnati, Ohio
HETA 91-092

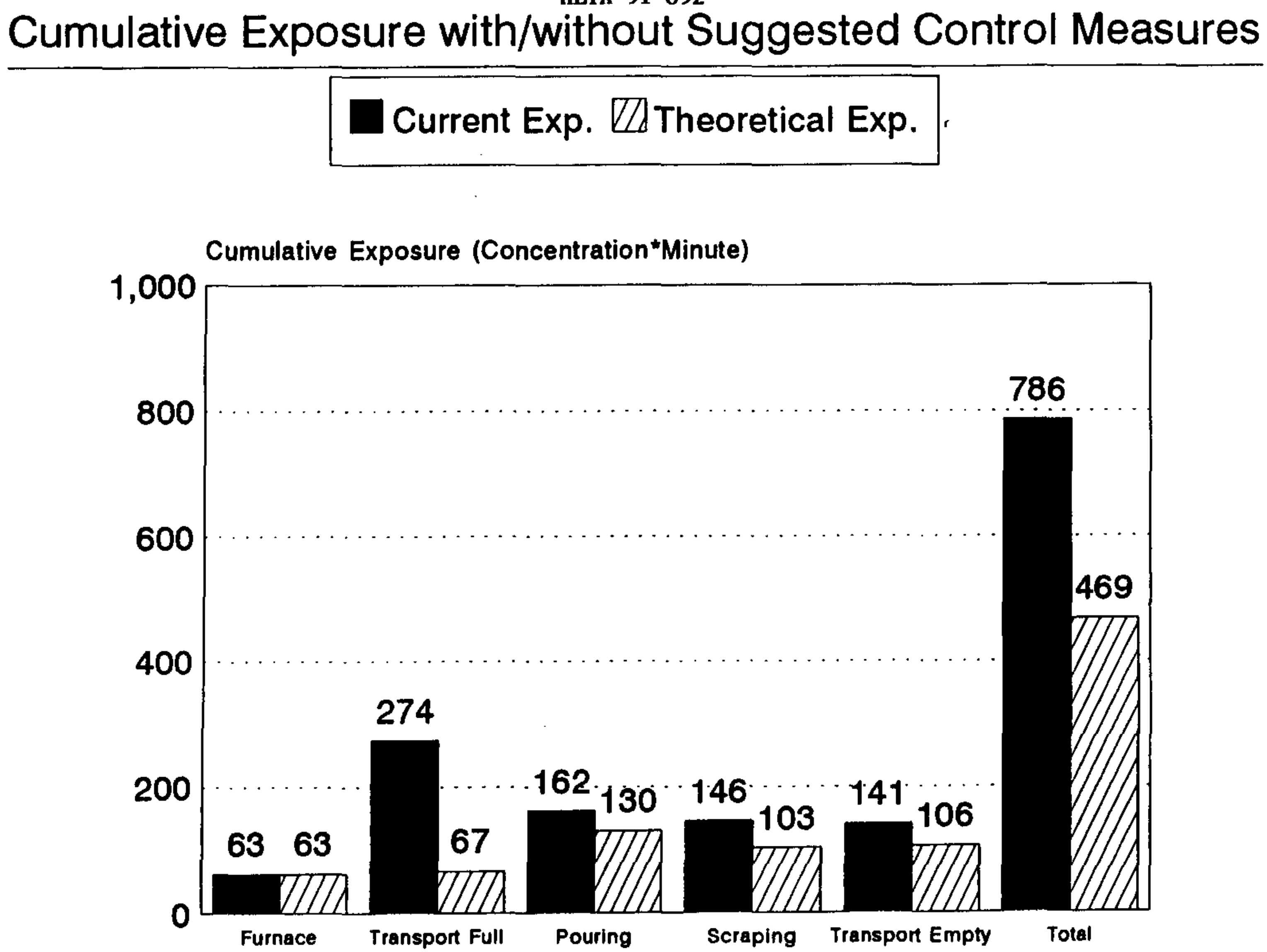
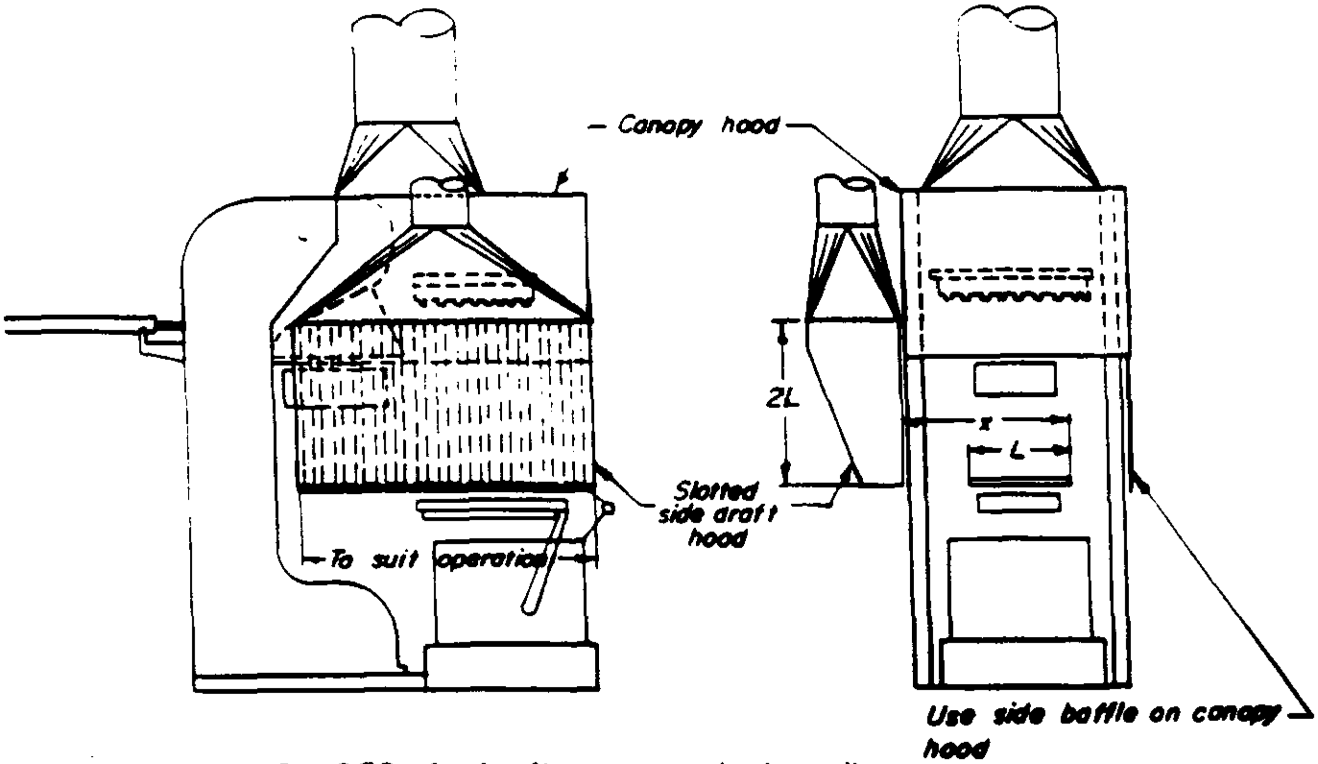


Figure 6

William Powell Company
Cincinnati, Ohio
HETA 91-092



Q = 250 cfm/sq ft canopy - single unit
150 cfm/sq ft canopy - double unit
Entry loss = 0.25 VP for tapered take-off

Slotted side draft hoods required to remove smoke as hot cores emerge from machine.
Capture velocity = 75 fpm minimum
$Q = 75(10x^2 + \text{hood area})$
Entry loss = 1.78 slot VP + 0.25 duct VP

Conveyor or cooling area require ventilation for large cores. Scrap conveyor or tote boxes may require ventilation also.

AMERICAN CONFERENCE OF GOVERNMENTAL INDUSTRIAL HYGIENISTS	
SHELL CORE MOLDING	
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