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THE MUELLER COMPANY
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I. SUMMARY

On April 20, 1988, the National Institute for Occupational Safety and Health (**NIOSH**) received a confidential request for a Health Hazard Evaluation from an authorized employee representative at the Mueller Company, a grey iron and brass casting foundry located in Decatur, Illinois. The request concerned employee exposures to formaldehyde in the core-making room and pour deck areas.

On July 26-27, 1988, an initial site visit was conducted to evaluate employee exposure to formaldehyde and review medical records. Preliminary recommendations were provided in a letter to the Mueller Company dated August 11, 1988. Results of formaldehyde sampling were reported to the company in a letter dated September 22, 1988. In an effort to assess the effects of seasonally reduced dilution ventilation upon formaldehyde levels in the core-making room, NIOSH returned to Mueller on December 2, 1988, to perform formaldehyde monitoring in the winter months; medical interviews of employees and, air monitoring for silica and metals were also conducted.

Results of the formaldehyde exposure monitoring from the initial survey ranged from 0.32 ppm to 0.65 ppm. The formaldehyde exposures during the follow-up survey ranged from 0.27 ppm to 1.21 ppm. These personal formaldehyde exposure levels exceeded the NIOSH recommendation to maintain formaldehyde exposures at the lowest feasible level. Three of seven exposure results exceeded the OSHA permissible exposure limit of 1 ppm; all but two exposures were in excess of the OSHA action level of 0.5 ppm. Results for respirable dust sampling measured 4.34 mg/m^3 in the breathing-zone of the muller operator and 1.46 mg/m^3 at a location 10 feet from the front of the muller at breathing zone height. The silica content of these respirable dust samples were 60.2% and 50.0%; yielding respirable silica concentrations of 2.43 mg/m^3 and 1.38 mg/m^3, respectively. The respirable silica exposure exceeded 0.05 mg/m^3, the NIOSH REL published before NIOSH considered silica a potential occupational carcinogen, the OSHA PEL of 0.1 mg/m^3, and the ACGIH TLV of 0.1 mg/m^3. Cristobolite was not detected in these samples. Exposure monitoring for metals on the pour deck area measured detectable concentrations of aluminum, calcium, cadmium, copper, iron, magnesium, manganese, lead, and zinc. Exposure to cadmium, lead, and zinc exceeded one or more of the OSHA, NIOSH, or ACGIH exposure criteria for these metals as fume.

Medical interviews of workers from the core room identified symptoms of headache, sinus pain, nausea, and eye irritation. One worker was verified as having been diagnosed with silicosis; another worker had been removed from the core-making area for having formaldehyde-related dermatitis.

Based on the environmental air monitoring results, worker exposures to formaldehyde and silica exceeded the NIOSH Recommended Exposure Limits and the OSHA Permissible Exposure Limits. Exposures to metal fumes of cadmium, lead, and zinc on the pour deck exceed the NIOSH recommended Exposure Levels, the OSHA Permissible Exposure Limits, and/or the ACGIH Threshold Limit Values. However, the workers on the pour deck wore appropriate respiratory protection. Medical complaints included headaches, sinus pain, nausea, eye irritation, dermatitis, and a diagnosed case of silicosis. Recommendations to reduce the exposure potential to formaldehyde, silica, and metal fumes within this foundry are provided in Section VIII.

KEYWORDS: SIC 3362 (Brass, Bronze Casting Foundries), formaldehyde, silica, cadmium, lead, zinc, foundry.

II. INTRODUCTION

On April 20, 1988, the National Institute for Occupational Safety and Health (**NIOSH**) received a confidential request for a Health Hazard Evaluation from an authorized employee representative at the Mueller Company, a grey iron and brass casting foundry located in Decatur, Illinois. The request concerned employee exposures to formaldehyde in the core-making room and pour deck.

On July 26-27, 1988, an initial site visit was conducted to evaluate employee exposure to formaldehyde and review medical records. Preliminary recommendations regarding material substitution, local exhaust ventilation, biological monitoring, medical surveillance, preventive maintenance, machine guarding, work practices, personal hygiene, hazard communication, and the establishment of a safety committee were made in a letter to the Mueller Company dated August 11, 1988. Results of formaldehyde sampling were reported to the company in a letter dated September 22, 1988. NIOSH returned to Mueller to perform formaldehyde monitoring in the winter months (December 2, 1988) to assess the effects of reduced dilution ventilation upon formaldehyde levels and to conduct sampling for silica, lead, solvent, and metal fume exposures in the core room and pour deck. A medical evaluation, consisting of employee interviews, was also performed at that time. A letter dated December 20, 1988, provided the Mueller Company with summary results of the medical interviews and additional recommendations for improving the work environment of the plant.

III. BACKGROUND

Mueller Company is a grey iron and brass foundry that produces valves for water and gas distribution service. At the time of these surveys, the Mueller Company operated a mulling operation, core room, and pouring deck operation within the brass foundry. The company prepared cores by a traditional foundry casting process using a formaldehyde-based resin system. The required ingredients (sand, clay, and binders) were mulled and transferred to the appropriate packing location. The sand core was then made by placing the mulled mixture into a core box (bench molding) or core molding machine. The sand core then passed through a curing oven. After curing, the cores were cleaned, inspected, and transferred to the pour deck of the foundry.

The raw metal charge consisted of ingots, which were composed of approximately 76% copper, 12-13% zinc, and 6-7% lead. The ingots were charged into electric induction furnaces and melted. At the correct temperature, the melted charge was tapped and transferred to pouring stations. On the pouring lines, the molten metal was poured into molds and cores under local exhaust ventilation. After pouring, the molds were allowed to cool for a pre-determined amount of time. The molds were transferred to the shake-out area where the castings were separated from the mold and sand. After shake-out, cast parts were transferred to the rough grind area, where casting surfaces were ground to remove gross imperfections. As necessary, parts received final finishing, were assembled, and packed for shipment.

IV. METHODS

A. Environmental Evaluation

On July 27, 1988, personal breathing zone (**PBZ**), full-shift, samples for formaldehyde in air were collected for various jobs in the core making process of the foundry. These samples were collected on solid sorbent media (Orbo-22 tubes from Supelco, Inc.) using battery-powered sampling pumps calibrated at a flow rate of 80 milliliters per minute (**mL/min**).

On December 2, 1988, a follow-up survey was conducted to characterize personal exposures to formaldehyde, respirable silica, and metal fumes. This formaldehyde exposure monitoring was performed to evaluate exposures when dilution ventilation was at a minimum (i.e. closed windows and doors) compared to the initial survey conducted on July 26-27, 1988. Full-shift PBZ and general area (**GA**) air samples were collected to represent employee exposures to formaldehyde during various jobs in the core making process. Samples were collected as above, using solid sorbent media (Orbo-22 tubes, Supelco, Inc.) and battery-powered personal sampling pumps calibrated at 50 mL/min. The sampling media from both surveys was analyzed for formaldehyde by gas chromatography in accordance with NIOSH Method 2502.[1]

Two full-shift air samples, one PBZ and one GA, were collected to represent employee exposure to respirable dust and respirable silica while mixing sand in the muller. Samples were collected using 10 millimeter (**mm**) nylon cyclones (Mine Safety Appliance Co.) and FWSB filters in two-piece cassettes with battery-powered personal sampling pumps calibrated to 1.7 liters per minute (**L/min**). Gravimetric analysis for respirable dust was done in accordance with NIOSH Method 0600.[1] The method was modified as follows: 1) The filters were stored in an environmentally controlled room (21$\pm$3 C and 40$\pm$3% RH) and were subjected to the room conditions for a long duration to effect stabilization. Therefore, the method's 8-16 hour time for stabilization between tare weighings has been reduced to 5-10 minutes. 2) The filters and back-up pads were not vacuum desiccated. A modified version of NIOSH method 7500 was used to analyze the samples for silica (quartz and cristobalite) by X-ray diffraction.[1] The modifications included dissolving the filters in tetrahydrofuran rather than ashing them in a furnace; and running standards and samples concurrently with preparing an external calibration curve from the integrated intensities rather than using the suggested normalization procedure.

Five PBZ full-shift samples were collected for metals in the pour deck area. Sampling was performed using 0.8 micron (**µM**) pore-size 37 mm mixed cellulose ester (**MCE**) filters in three-piece cassettes with battery powered sampling pumps calibrated to 1.7 L/min. Samples were analyzed using inductively coupled plasma emission spectroscopy (**ICP**) in accordance with NIOSH method 7300.[1]

A Draeger colorimetric detector tube was used to collect and analyze an air sample in the core making area for phenol.

Smoke tubes were used to test the efficacy of ventilation hoods by tracing the direction of airflow at the entrance and exit ends of the curing ovens.

B. Medical Evaluation

The medical records of workers in the core-making and pour deck areas were reviewed during the initial survey. Individual workers from the core-making area were interviewed and physically examined by a NIOSH physician during the follow-up survey. Based on the record review, it was determined there was no need to interview workers from the pour deck area.

V. EVALUATION CRITERIA

A. Environmental Evaluation

As a guide to the evaluation of the hazards posed by work place exposures, NIOSH field staff employ environmental evaluation criteria for the assessment of a number of chemical and physical agents. These criteria are intended to suggest levels of exposure to which most workers may be exposed up to 10 hours per day, 40 hours per week for a working lifetime without experiencing adverse health effects. It is, however, important to note that not all workers will be protected from adverse health effects if their exposures are maintained below these levels. A small percentage may experience adverse health effects because of individual susceptibility, a pre-existing medical condition, and/or a hypersensitivity (allergy). In addition, some hazardous substances may act in combination with other work place exposures, the general environment, or with medications or personal habits of the worker to produce health effects even if the occupational exposures are controlled to the level set by the evaluation criterion. These combined effects are not often considered by the evaluation criteria. Also, some substances are absorbed by direct contact with the skin and mucous membranes, and thus potentially increase the overall exposure. Finally, evaluation criteria may change over the years as new information on the toxic effects of an agent become available.

The primary sources of environmental evaluation criteria for the work place are: 1) NIOSH Criteria Documents and Recommended Exposure Limits (**RELs**)[2], 2) the American Conference of Governmental Industrial Hygienists' (**ACGIH**) Threshold Limit Values (**TLVs**)[3], and 3) the U.S. Department of Labor, Occupational Safety and Health Administration (**OSHA**) Permissible Exposure Limits (**PELs**)[4]. The OSHA PELs may also be required to take into account the feasibility of controlling exposures in various industries where the agents are used; the NIOSH-recommended exposure limits, by contrast, are based primarily on concerns relating to the prevention of occupational disease. In evaluating the exposure levels and the recommendations for reducing these levels found in this report, it should be noted that industry is legally required to meet those levels specified by an OSHA PEL.

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

B. Formaldehyde

Formaldehyde is a colorless gas with a strong, pungent odor detectable at low concentrations. It is commonly utilized as formalin, an aqueous solution containing 37-50% formaldehyde by weight.[5] It is widely used in the production of resins, in the manufacture of many other compounds, as a preservative, as a sterilizing agent, and as an embalming fluid.[6]

Exposure to formaldehyde can occur through inhalation or skin absorption.[7] The primary non-carcinogenic effects associated with formaldehyde exposure are irritation of the mucous membranes of the eyes and respiratory tract, and allergic sensitization of the skin. The first signs or symptoms noticed on exposure to formaldehyde, at concentrations ranging from 0.1 to 5 ppm, are burning of the eyes, tearing, and general irritation of the upper respiratory passages. However, there appears to be a great deal of variation among individuals, both in terms of their susceptibility and tolerance.

Dermatitis due to skin contact with formaldehyde solutions and formaldehyde-containing resins is a well-recognized problem. Both primary skin irritation and allergic dermatitis have been reported.[5] Dermatitis may appear a few days following the commencement of work or may not appear for a number of years following exposure.[7]

In two separate studies, formaldehyde has induced a rare form of nasal cancer in rodents following repeated inhalation exposure.[8,9] Concern over the possible human carcinogenicity of formaldehyde has prompted several epidemiological studies of workers exposed to formaldehyde. An association between formaldehyde exposure and cancer of the upper respiratory passages in humans has been reported.[10] In this proportionate mortality study of workers exposed to formaldehyde in the garment industry, statistically significant excesses in mortality from cancers of the buccal cavity and connective tissue were found. No cases of nasal cancer were observed, however. In a reanalysis of a National Cancer Institute study, "a statistically nonsignificant but suggestive increase for age-adjusted relative risk for buccal and pharyngeal cancer among employees with greater than 0.5 ppm average exposure in plants manufacturing formaldehyde resins" was found.[11]

In 1984, Ulsamer et al. reviewed 4 animal inhalation studies. No teratogenic effects were reported in these studies.[12] No birth defects were reported in a study which involved the application of formalin to the backs of pregnant hamsters.[13] No data were found linking formaldehyde with teratogenic effects in humans. There is one report in which an increased incidence of menstrual disorders, and of complications of pregnancy and delivery, were reported among women workers exposed to formaldehyde at a textile factory in the USSR.[14] The relevance of these findings has been criticized, however, due to a lack of information regarding the suitability of the control group and potential confounding factors.[15]

In April 1981, NIOSH issued Current Intelligence Bulletin 34, "Formaldehyde: - Evidence of Carcinogenicity", DHHS (NIOSH) Publication No. 81-111.[16] In this bulletin, NIOSH recommends that formaldehyde be handled as a potential occupational carcinogen and that appropriate controls be used to reduce worker exposure to the lowest feasible level. This recommendation was based primarily on a study in which nasal cancers developed in rats and mice following repeated inhalation exposures of approximately 15 ppm formaldehyde. In December, 1987, OSHA published an amended formaldehyde standard, 29 CFR 1910.1048.[17] This standard reduced the

PEL from 3 ppm to 1 ppm, as an eight-hour TWA. In addition, a 15-minute short term exposure limit was (**STEL**) was set at 2 ppm. ACGIH has given formaldehyde an A2 designation, indicating that ACGIH considers formaldehyde a suspected human carcinogen. The ACGIH TLV for formaldehyde is 1 ppm as an eight-hour TWA and 2 ppm as a fifteen- minute STEL. ACGIH has recently proposed a ceiling limit of 0.3 ppm formaldehyde in their notice of intended changes for 1990-1991.[3] This value will be reconsidered for the adopted TLV list after two years.

C. Respirable Particulates

Respirable dust generated during foundry work consists of solid particles of metals, silica, and other materials which may be suspended in air and inhaled into the deep portions of the lung (the air sacs, or alveoli). The current OSHA PEL for respirable "nuisance" dust (particulates not otherwise regulated) is 5 milligrams per cubic meter (**mg/M^3**) of air.[4] The 1989-1990 ACGIH TLV for total nuisance dust, Particulates Not Otherwise Classified (**PNOC**), is 10 mg/M^3.[3] These evaluation criteria were established to minimize mechanical irritation of the eyes, nose, throat and lungs. Because the particulates in a foundry may consist mainly of silica and metals, the nuisance dust criteria may not apply.

D. Silica

Crystalline silica, usually referred to as free silica, is defined as silicon dioxide (**SiO_2**) molecules arranged in a fixed pattern, as opposed to a nonperiodic, random molecular arrangement referred to as amorphous silica. The three most common forms of free silica encountered in industry are quartz, tridymite, and cristobalite, with quartz being by far the most common form. The principle adverse health effect of crystalline silica is the dust-related respiratory disease, silicosis. Silicosis is a form of diffuse interstitial pulmonary fibrosis resulting from the deposition of respirable crystalline silica in the lung. Conditions of exposure may affect both the occurrence and severity of the disease. Although silicosis usually occurs after fifteen or more years of exposure, latent periods of only a few years are well recognized and are associated with intense exposures to respirable dust high in free silica. In its early stages, simple silicosis usually produces no symptoms. However, both acute silicosis (a different disease process associated with repeated high exposures) and complicated silicosis (progressive massive fibrosis, PMF) are associated with shortness of breath, intolerance for exercise, and a marked reduction in measured pulmonary function. Diagnosis is most often based on a history of occupational exposure to free silica and the characteristic appearance of the disease on chest X-rays. Respiratory failure and premature death may occur in advanced forms of the disease. Individuals with silicosis are also at increased risk of developing tuberculosis. No specific treatment is available for silicosis, and the disease may progress even after the worker's exposure to silica has ceased.[18]

Several epidemiological studies have shown an association between silicosis and lung cancer.[19,20,21] In its 1987 Monograph on silica, the International Agency for Research on Cancer (**IARC**) reviewed the data regarding crystalline silica and determined that there is sufficient evidence for the carcinogenicity in laboratory animals and limited evidence for human carcinogenicity.[22] The data meet OSHA's definition of a potential occupational carcinogen as defined in 29 CFR 1990. Based on this recent evidence, NIOSH has revised its policy on crystalline silica exposure criteria and has recommended that OSHA consider crystalline silica as a potential occupational carcinogen.[23]

The current OSHA PEL for crystalline silica (cristobalite and tridymite) as quartz (respirable dust) is 0.05 mg/M^3 as an eight- hour TWA.[4] The OSHA PEL for crystalline silica (crystalline quartz) as quartz (respirable dust) is 0.1 mg/M^3 as an eight-hour TWA.[4] The 1989-1990 ACGIH TLVs are identical to the OSHA PELs for these compounds.[3] Because of the ubiquitous nature of exposure to crystalline silica and often concomitant occupational exposure (or through tobacco smoking) to one or more carcinogenic chemicals, the greatest degree of protection could be gained by the adherence to the NIOSH REL of 50 micrograms per cubic meter (**µg/M^3**) (for all forms of crystalline silica) which approaches the lowest quantifiable limit of detection. This rationale would apply to protection against silicosis as well as the reported potential carcinogenicity from exposure to certain crystalline silicas.

E. Lead

Inhalation and ingestion of lead dust and fume are the major routes of lead exposure in industry. Lead exposure by ingestion occurs from lead dust deposited on hands, food, cigarettes, or other objects. Once absorbed, lead is excreted from the body very slowly. Absorbed lead can damage the kidneys, peripheral and central nervous systems, and the blood forming organs (bone marrow). These effects may be felt as weakness, tiredness, irritability, digestive disturbances, high blood pressure, kidney damage, mental deficiency, or slowed reaction time. Chronic lead exposure is associated with infertility and with fetal damage in pregnant women.

Blood lead levels below 40 micrograms per decaliter (**µg/dL**) of whole blood are considered to be normal levels which may result from daily environmental exposure.[24] However, fetal damage in pregnant women may occur at blood levels as low as 30 µg/dL. Lead levels between 40 and 60 µg/dL in lead-exposed workers indicate excessive absorption of lead and may result in some adverse health effects. Levels of 60-100 µg/dL represent unacceptable elevations which may cause serious adverse health effects. Levels over 100 µg/dL are considered dangerous and often require hospitalization and medical treatment.

The OSHA standard for lead in air, 29 CFR 1910.1025, mandates a PEL of 50 µg/M^3 as an eight-hour TWA.[24] The standard also dictates that workers with blood lead levels greater than 50 µg/dL must be immediately removed from further lead exposure and, in some circumstances workers with blood lead levels of less than 50 µg/dL must also be removed. Removed workers have protection for wages,benefits, and seniority for up to 18 months until their blood levels decline to below 50 µg/dL an they can return to lead work areas. The 1990-1991 ACGIH TLV for lead is 0.15 mg/M^3, as an eight-hour TWA.[3] NIOSH is currently reviewing the data on health effects of lead to determine what new recommendations are warranted to protect worker health.

F. Cadmium

Cadmium is a toxic heavy metal which may enter the body either by inhalation or ingestion of the cadmium metal or oxide fume. Once absorbed into the body, cadmium accumulates in organs throughout the body, but major depositions occur in the liver and kidneys. Acute inhalation exposure to high levels of cadmium can cause pneumonia or pulmonary edema, as well as liver or kidney damage.[25] Chronic exposure may lead to emphysema of the lungs and kidney disease, or cancer of the prostate.[26] There is also limited evidence that occupational cadmium exposure may be associated with lung cancer.

NIOSH recommends that worker exposure to cadmium be reduced to the lowest feasible level.[2] The 1990-1991 ACGIH for Cadmium oxide fume is 0.05 mg/M^3, expressed as a ceiling, indicating that this is a level that may not be exceeded at any time during the work day. Furthermore, there is a notice of intended changes to the TLVs to reduce the TLV for cadmium compounds to 0.01 mg/M^3, eight- hour TWA and to designate cadmium compounds as suspected human carcinogens.[3] The current OSHA PEL for cadmium oxide fume is 0.1 mg/M^3 with a ceiling level of 0.3 mg/M^3 and OSHA is in the rulemaking process for promulgating an expanded health standard for occupational exposure to cadmium.[4]

G. Copper

Inhalation of copper fume produces irritation of the upper respiratory tract and metal fume fever. In workers exposed to copper fume, typical metal fume fever has been described as lasting twenty-four to forty-eight hours.[6]

The OSHA PEL for copper fume is 0.1 mg/M^3 as an eight-hour TWA.[4] The 1990-1991 ACGIH TLV for copper fume 0.2 mg/M^3 as an eight-hour TWA.[3] The NIOSH REL for copper fume is 0.1 mg/M^3 as an eight-hour TWA.[2]

H. Iron

Inhalation of iron oxide fume causes siderosis, an asymptomatic condition often referred to as a "benign pneumoconiosis" because of its appearance on a chest x-ray. Exposures of six to ten years are usually required before changes recognizable by x-ray occur; the retained iron material produces x-ray shadows that may be indistinguishable from a true pneumoconiosis.[6] One study of 25 welders exposed to iron oxide for an average of 18.7 years had shadows on chest x-ray consistent with siderosis, but there was no change in pulmonary function.[27]

The OSHA PEL for iron oxide fume is 10 mg/M^3 as an eight-hour TWA.[4] The 1990-1991 ACGIH TLV for iron oxide fume is 5 mg/M^3 as an eight-hour TWA.[3] There is no NIOSH REL for iron oxide fume.

I. Magnesium

Inhalation of magnesium oxide fume results in mild irritation of the eyes and nose. Experimental exposures have resulted in the development of metal fume fever, however, there are no reports of metal fume fever resulting from industrial exposure to magnesium oxide.[6]

The OSHA PEL for magnesium oxide is 5 mg/M^3 for respirable fume, as an eight-hour TWA.[4] The 1990-1991 ACGIH TLV for magnesium oxide fume is 10 mg/M^3 as an eight-hour TWA.[3] NIOSH has not recommended an exposure limit for magnesium oxide fume.

J. Manganese

Foundry use of manganese is mainly in iron and steel alloys and as an agent to reduce oxygen and sulfur content of molten steel. Manganese fumes may be a minor irritant to the eyes and respiratory tract. Chronic exposure to manganese can lead to an extremely disabling disease resembling Parkinsonism.[6]

The OSHA PEL for manganese fume is 1 mg/M^3 as an eight-hour TWA, with a STEL of 3 mg/M^3.[4] The 1990-1991 ACGIH TLV is identical to the OSHA values.[3] NIOSH has not recommended an exposure limit for manganese.

K. Zinc

Zinc metal is used in galvanizing, electroplating, in dry cells, in alloys, and as zinc oxide in pigments. Inhalation of zinc oxide fume causes an influenza-like illness termed metal fume fever.[6] An attack usually subsides after six to twelve hours, but may last up to 24 hours; usually with complete recovery. Most workers develop a resistance to these attacks, but it is quickly lost; attacks tend to be more severe on the first day of the workweek.

The OSHA PEL for zinc oxide fume is 5 mg/M^3 as an eight-hour TWA, with a STEL of 10 mg/M^3.[4] The 1990-1991 ACGIH TLV for zinc oxide fume is identical to the OSHA values.[3] The NIOSH REL for zinc oxide fume is 5 mg/M^3 as a ten-hour TWA, with a 15 mg/M^3 ceiling value.[2]

L. Phenol

Phenol enters the body through skin absorption, inhalation, and ingestion. Phenol is an irritant to the eyes, skin, and mucous membranes. Systemic effects of absorption include convulsions, as well as kidney and liver damage. Signs and symptoms can develop rapidly and lead to serious consequences, including shock, collapse, coma, convulsions, cyanosis, and death.

The OSHA PEL for phenol is 5 ppm as an eight-hour TWA.[4] The 1990-1991 ACGIH TLV for phenol is identical to the OSHA value.[3] The NIOSH REL for phenol is 5.2 ppm as a ten-hour TWA, with a 15.6 ppm ceiling limit.[2]

VI. RESULTS AND DISCUSSION

A. Environmental

Results of the formaldehyde exposure monitoring from the initial survey (July 27,1991) ranged from 0.32 ppm to 0.65 ppm as shown in Table 1. The results indicate that formaldehyde exposure levels for the various jobs in the core making process exceeded the NIOSH recommendation to maintain exposures to the lowest feasible level. Eight-hour time-weighted average (**TWA**) personal breathing zone (**PBZ**) exposures for the "4-D" operator (0.60 ppm) and one core cleaner (0.65ppm) exceeded the OSHA action level of 0.5 ppm.

Results for formaldehyde monitoring conducted during the follow-up survey (December 2, 1988) are shown in Table 2. These 8-hour TWA PBZ exposures ranged from 0.27 ppm for an employee in core storage to 1.21 ppm for the "4-D" Operator. Two general area (**GA**) air samples collected at the exit end of the curing oven on the CB5 machine and at the north wall from this machine found 1.32 and 1.39 ppm respectively. These results show that reduced natural dilution ventilation (windows closed) of the work space did affect employee exposures, and that employee exposures to formaldehyde exceeded the NIOSH recommendations to maintain exposures below the lowest feasible level. The results in Table 2 show that several employees were potentially exposed to levels of formaldehyde in excess of the OSHA permissible exposure limit of 1 ppm, and that all but two exposures were in excess of the OSHA action level of 0.5 ppm.

Smoke tube measurements conducted on both visits indicated that the local exhaust ventilation (**LEV**) system performance had improved from the initial site visit. Smoke tube evaluation of the LEV hoods on the curing ovens showed improved capture and removal of gases generated by the process during the second visit. This may have been the result of no cross drafts from the windows being closed and/or the discontinued use of pedestal comfort fans. However, the increase in formaldehyde concentrations within the core-making room area in the winter indicates that the LEV systems on the ovens were not effective in reducing formaldehyde exposure.

Phenol was not detected by the colorimetric tube method in any of the areas sampled in the core-making room.

Respirable dust and respirable silica samples (one PBZ and one GA) were collected in the muller operation during the December 2, 1991, survey. The muller operator was not required to, nor did he, wear respiratory protection. Results for respirable dust sampling measured 4.34 mg/M^3 in the PBZ sample on the muller operator and 1.46 mg/M^3 at a location 10 feet from the front of the muller at breathing zone height. The silica content of these respirable dust samples were 60.2% and 50.0%; yielding respirable silica concentrations of 2.43 mg/M^3 and 1.38 mg/M^3, respectively. The PBZ respirable silica exposure exceeded the NIOSH REL of 0.05 mg/M^3, the OSHA PEL of 0.1 mg/M^3, and the ACGIH TLV of 0.1 mg/M^3 for respirable silica. The samples were also analyzed for cristobolite; the result for all samples was non-detectable.

PBZ samples for metals were collected during the December 2, 1991, survey on the pour-deck of the foundry area. Five samples were collected; 1 on a furnace operator, 3 on "ladlemen", and 1 sample on a utilityman. All workers, except one ladleman, were wearing powered-air-purifying respirators. Results for metals are summarized in Table 3. The samples were analyzed for the following minerals and metals: Aluminum (**Al**), Arsenic (**As**), Barium (**Ba**), Beryllium (**Be**), Cadmium (**Cd**), Calcium (**Ca**), Cobalt (**Co**), Chromium (**Cr**), Copper (**Cu**), Iron (**Fe**), Lithium (**Li**), Magnesium (**Mg**), Manganese (**Mn**), Molybdenum (**Mo**), Nickel (**Ni**), Lead (**Pb**), Phosphorus (**P**), Platinum (**Pt**), Selenium (**Se**), Silver (**Ag**), Sodium (**Na**), Tin (**Sn**), Tellurium (**Te**), Thallium (**Tl**), Titanium (**Ti**), Tungsten (**W**), Vanadium (**V**), Yttrium (**Y**), Zinc (**Zn**), and Zirconium (**Zr**). Only results for those minerals and metals detected (Al, Ca, Cd, Cu, Fe, Mg, Mn, Pb, and Zn) on the samples are reported in Table 3. Eight-hour TWA's for Al fume ranged from 0.02 to 0.03 mg/M^3 and were considerably less than the exposure criteria of 5.0 mg/M^3. Ca was found on all 3 samples with eight-hour TWA concentrations ranging from 0.04 to 0.06 mg/M^3; the results were considerably less than the OSHA, NIOSH, or ACGIH exposure criteria. Eight-hour TWA's for Cd fume ranged from less than the limit of detection [1 microgram per filter (**ug/filter**)] to 0.03 mg/M^3, with 3 of the 5 samples having detectable levels. All 3 samples exceeded the NIOSH REL of lowest feasible level (**LFL**) and the ACGIH TLV of 0.01 ug/M^3 for Cd. The results for Cu fume indicated exposure potential ranged from eight-hour TWAs of 0.02 mg/M^3 to 0.06 mg/M^3; which is below the exposure criteria of OSHA,

NIOSH, and ACGIH. Eight-hour TWA concentrations for Fe fume ranged from 0.05 to 0.59 mg/M^3. These Fe results are considerably below the OSHA, NIOSH, and ACGIH exposure criteria. The results for Mg fume on all five samples was 0.01 mg/M^3 as eight-hour TWA's, and is considerably less than the exposure criteria of 10.0 mg/M^3. Mn was found on 2 of the 5 samples with eight hour TWA concentrations of 0.02 and 0.12 mg/M^3; these concentrations are less than the exposure criteria of 1.0 mg/M^3. Employee exposure potential to Pb fume ranged from 0.04 mg/M^3 to 1.0 mg/M^3 (eight-hour TWA's). It should be noted that the Ladle Operator on the iron pour deck was not wearing a respirator resulting in actual exposure at the OSHA PEL of 0.05 mg/M^3. The OSHA PEL of 0.05 mg/M^3 was exceeded in 3 out of 5 samples and approached the PEL in the other 2. Eight-hour TWA's for Zn fume ranged from 0.30 mg/M^3 to 11.5 mg/M^3 exceeding the OSHA PEL, NIOSH REL, and ACGIH TLV in 3 of 5 samples.

B. Medical

During the initial survey on July 27, 1988, the NIOSH physician reviewed medical records of approximately 20 workers from the core room area. These records were maintained by the occupational medical consultant to the company. The records indicated complaints of dermatitis, upper and lower respiratory tract irritation, and symptoms of mucous membrane irritation. Results of urine formic acid, a metabolite of formaldehyde, were recorded for several individuals. Although the monitoring for urine formic acid in formaldehyde exposed workers was adjusted for creatinine, appropriate controls (non-exposed workers) were not chosen or monitored, pre- and post-exposure urine specimens were not collected, and adjustments for smoking and eating habits were not made. Therefore, it was felt the information from this medical monitoring was of little utility in evaluating worker's formaldehyde exposure.

During the December 2, 1988, survey approximately 12 workers were interviewed to assess the types of symptoms experienced in the core room area. Complaints included headaches, sinus pain, nausea, and eye irritation. One worker was identified as having been diagnosed as having silicosis. Another worker reported having been removed from the core-making area for formaldehyde-related dermatitis. Also from the medical interviews, it was determined that immunological testing had been performed using an enzyme linked immunosorbent assay (**ELISA**) to detect antibodies to formaldehyde. The medical records of these individuals were examined and verified these reported conditions.

VII. CONCLUSIONS

Based on the results of the personal exposure monitoring, worker exposures to formaldehyde and silica exceeded (for certain jobs in the core-making area) the OSHA PELs, NIOSH RELs, and the ACGIH TLVs for these agents. Formaldehyde exposure was shown to increase within the core-making area during the winter months when the windows were shut and natural dilution ventilation was minimal. From the metal fume monitoring conducted on workers on the pour deck area, it was determined that exposure potential existed for the metals Ca, Cd, Cu, Fe, Mg, Mn, Pb, and Zn. Exposure potential for the metals Cd, Pb, and Zn were found to exceed (for certain jobs) the respective OSHA, NIOSH, or ACGIH exposure criteria; however workers in these jobs did wear the appropriate respiratory protection therefore actual exposure to metal fumes were lower. Health symptoms and complaints of workers in the core-making area were found to be compatible with formaldehyde and silica exposure. At least one worker probably had silicosis and one worker was identified with dermatitis that was believed to be related to formaldehyde exposure.

VIII. RECOMMENDATIONS

The following recommendations were offered at the conclusion of the initial site visit and remained relevant after the follow-up survey.

1. The possibility of substituting a "low free-formaldehyde" resin binder for the resin binder currently used should be thoroughly explored by the Mueller Company. The resin binder is undoubtedly the source of the formaldehyde found in the core room environment. Success in reducing the amount of formaldehyde from this source will certainly reduce the formaldehyde exposure potential.

2. Formaldehyde exposure potential can also be reduced by the implementation of appropriate engineering controls. The local exhaust ventilation system (**LEV**) installed on the ovens should be evaluated for design efficiency. These LEVs were shown, with smoke tubes, to be improperly installed (the LEV hoods at the end of the ovens) and inefficient in removing oven gases (both the intra-oven exhausts and end of oven exhaust hoods). A copy of the NIOSH Recommendations for Control of Occupational Safety and Health Hazards - Foundries, which contains ventilation diagrams and recommendations appropriate for foundry operations at the Mueller Company was provided to the plant Safety Director following the initial survey.

3. Until further studies demonstrate its utility, the routine use of urine formic acid as an indicator of formaldehyde exposure is **not** recommended. The information which could possibly be derived from this technique is substantially confounded if the samples are not adjusted for creatinine, proper controls are not selected, pre- and post-exposure samples are not collected, and information on smoking and eating habits are not evaluated. Formaldehyde exposures should be evaluated by industrial hygiene monitoring until adequate control measures are implemented. Also, continued medical surveillance is recommended. A copy of the recommended medical surveillance program for formaldehyde workers was provided to Mueller following the initial survey.

4. The hot shell core machine should be properly maintained and/or equipped with shielding or guards to minimize the dust generated by this machine. It was apparent that the operator of this machine is exposed to considerable amounts of dust (silica) and that this exposure could easily be reduced with controls. Exposure monitoring for silica should be conducted on the shell core operators, muller operator, mold box workers, and shake-out workers.

5. Safety guards should be installed on the core presses to prevent possible injury to the fingers and hands. As currently operated, these presses present pinch points to the operator.

6. Several work practices were observed which should be modified or avoided to further reduce exposure potential. The doors of the muller mixer should be kept closed during mixing and when materials are not being added to the mixer. The mixer operator should be instructed in the proper way to add material to the mixer without increasing his exposure by placing his breathing zone in the mixer opening. The hot shell core operator should be instructed in the proper way to spray on the core release agent so that this process does not result in overspray on the skin or back-spray into the operator's face. The use of man cooler fans should be evaluated for each process and the proper use of these fans reviewed with employees. During the first survey, several

fans were improperly positioned and were either contributing to the worker's exposure and/or defeating exhaust ventilation systems.

7. Eating, drinking, and smoking should not be permitted in the core room. These practices in a foundry core room can contribute to an employees potential for exposure. At the very minimum, workers should be required to wash their hands and face prior to eating or smoking.

8. A written hazard communication program needs to be developed in accordance with OSHA regulations. Since the company had the applicable regulation, the requirements of the program were discussed and several options in administering the program were suggested at the time of the initial survey.

9. A joint management/union safety committee should be established to investigate, react, and respond to health and safety issues outlined in these recommendations. One individual should be responsible and accountable for the overall health and safety program for the company.

10. Environmental sampling and blood lead monitoring should be continued in accordance with frequencies specified in the OSHA Lead Standard. The current biologic monitoring program is adequate for monitoring blood lead levels. NIOSH did not evaluate the medical surveillance program for, or worker exposure to silica and lead. However, to assist the Mueller Company and its employees, a copy of a recommended medical surveillance program for silica was provided to the Safety Director following the initial survey. The OSHA required medical program for lead exposed workers is found in 29 CFR 1910.1025.

11. The housekeeping in the muller area needs to be improved to reduce exposure potential to silica. The sand spillage and fugitive silica dust should not be allowed to buildup in the area.

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Copies of this report are being sent to:

1. Confidential Requestor.
2. Mueller Company, 500 West El Dorado, Decatur, Illinois 62525.
3. Milan Racic, Health and Safety Director, Allied Industrial Workers of America, 3520 West Oklahoma Ave., Milwaukee, Wisconsin 53215.
4. Occupational Safety and Health Administration (OSHA) Region V.
5. Illinois State Department of Health, Springfield, Illinois.

For the purposes of informing affected workers, 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
PERSONAL FORMALDEHYDE EXPOSURE LEVELS
Mueller Company Foundry
Decatur, Illinois

July 27, 1988
HETA 88-240

Job Title	Sample Time (Minutes)	Sample Volume (Liters)	Formaldehyde Exposure-ppm*
Mueller Oper.	434	34.8	0.47
"4-D" Oper.	431	33.6	0.60
Core Cleaner	435	35.1	0.65
CB5 Core Maker	437	36.4	0.49
Core Cleaner	438	33.7	0.38
Laempe Oper.	401	32.0	0.33
Bench Core Maker	433	35.3	0.32
Set-up; Auto.	432	43.7	0.40

Exposure Criteria:		
	NIOSH REL	LFL**
	ACGIH TLV	1.0
	OSHA PEL	1.0

*ppm - parts of formaldehyde per million parts of air.
**LFL - lowest feasible limit.

TABLE 2
FORMALDEHYDE EXPOSURE LEVELS
Mueller Company Foundry
Decatur, Illinois

December 2, 1988
HETA 88-240

Job Title	Sample Time (Minutes)	Sample Volume (Liters)	Formaldehyde Exposure-ppm*
Mueller Oper.	446	22.2	0.48
"4-D" Oper.	455	23.0	1.21
Core Cleaner #1	455	22.0	0.96
CB5 Core Maker	451	22.7	1.18
Core Cleaner #2	453	22.7	1.03
Laempe Oper.	(not operating during this survey)		
Bench Core Maker	454	22.7	0.53
Set-up; Auto.	458	21.0	0.94
General Area/ CB5 Core Oven	376	19.9	1.32
General Area/ North Wall	400	17.8	1.39

Exposure Criteria:	NIOSH REL	LFL**
	ACGIH TLV	1.0
	OSHA PEL	1.0

*ppm - Parts of formaldehyde per million parts of air.
**LFL - lowest feasible limit.

Table 3
Monitoring Results for Metals and Minerals
The Mueller Company Foundry, Decatur, Illinois
December 2, 1988 / HETA 88-240

Job Title	Sample Time (Minutes)	Sample Volume (Liters)	--------Air Concentration of Metals mg/m^3*------ Al	Ca	Cd	Cu	Fe	Mg	Mn	Pb	Zn
Ladle Operator** Iron Pour Deck	419	930	0.02	0.06	ND	0.06	0.59	0.01	0.12	0.05	0.22
Ladle Operator Brass Pour Deck	409	818	0.03	0.05	0.04	0.05	0.05	0.01	0.02	1.00	11.5
Ladle Operator Brass Pour Deck	408	816	0.03	0.04	0.02	0.04	0.08	0.01	ND	0.47	6.31
Furnace Operator	406	812	0.02	0.05	ND	0.02	0.12	0.01	ND	0.04	0.30
Utility Man	415	830	0.03	0.04	0.02	0.05	0.07	0.01	ND	0.55	9.89
Evaluation Criteria(mg/m^3)											
OSHA PEL			5.0	5.0	0.10	0.10	10.0	10.0	1.0	0.05	5.0
NIOSH REL			5.0	2.0	LFL	0.10	5.0	---	1.0	***	5.0
ACGIH TLV			5.0	2.0	0.05	0.20	5.0	10.0	1.0	0.15	5.0

*Symbols for Metals: Al=Aluminum, Ca=Calcium, Co=Cobalt, Cu=Copper, Fe=Iron, Mg=Magnesium, Mn=Manganese, Pb=Lead, Zn=Zinc.
mg/m^3 = milligrams of metal per cubic meter of air.
** - Did not wear powered air purifying respirator; all other individuals sampled did wear respirator.
ND = Non detected.
LFL = Lowest Feasible Limit
*** - NIOSH is currently reviewing the data on health effects.