U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
CENTER FOR DISEASE CONTROL
NATIONAL INSTITUTE FOR OCCUPATIONAL SAFETY AND HEALTH
CINCINNATI, OHIO 45226

HEALTH HAZARD EVALUATION DETERMINATION
REPORT NO.76-43 A-F-429

HERSEY PRODUCTS COMPANY, INC.
GILBERTVILLE, MASSACHUSETTS

SEPTEMBER 1977

I. TOXICITY DETERMINATION

A combined environmnetal-medical evaluation of particulate, vaporous, and gaseous contaminant exposures by workers involved in founding of ferrous and non-ferrous castings has been completed at the Hersey Products Company, Gilbertville, Massachusetts. The following determinations with regard to employee health are based on environmental and medical data collected, occupational health criteria, and available literature on the toxicity of the substances evaluated.

A. Ferrous Foundry

1. The shell and no-bake core makers, sand molders, metal pourers, fettlers, sand muellers, cupola tenders, and shakeout personnel were exposed to toxic concentrations of respirable crystalline silica.

2. The large metal pourers were exposed to potentially toxic concentrations of carbon monoxide. The no-bake core makers, cupola tenders, small pourers, and shakeout personnel were not exposed to toxic concentrations of carbon monoxide.

3. The shell core machine operator was exposed to toxic concentrations of airborne formaldehyde. This operator was not exposed to toxic concentrations of ammonia, phenol, or hydrogen cyanide.

4. The no-bake core maker was not exposed to toxic concentrations of phosphoric acid or furfural. The no-bake core painter was not exposed to toxic concentrations of furfural or isopropanol.

5. The metal pourers were not exposed to toxic concentrations of particulate polycyclic organic matter, benzo(a)pyrene, benzo(e)pyrene, iron oxide fumes, ammonia, phenol, hydrogen cyanide, or formaldehyde.

6. The snagger-grinder operators were exposed to toxic concentrations of iron oxide dust and total particulate. The pedestal-grinder operators were not exposed to toxic concentrations of these contaminants.

7. The tar coaters were not exposed to toxic concentrations of xylene, toluene, or petroleum distillates.

B. Non-Ferrous Foundry

1. The workers involved in sand molding, metal pouring, and shakeout were exposed to toxic concentrations of respirable crystalline silica.

2. The shell core machine operator was not exposed to toxic concentrations of ammonia, phenol, hydrogen cyanide or formaldehyde.

3. The fettler was exposed to toxic concentrations of inorganic lead.

4. The five non-ferrous foundry workers complained of a metallic taste and occasional to recurrent chills suggestive of a self-limiting illness known as "brass chills". The airborne concentrations of copper and zinc, metals that at sufficient levels may cause this illness, were below the prescribed health limits at the time of the NIOSH survey.

5. The furnace tender was not exposed to toxic concentrations of gaseous or particulate inorganic fluorides.

II. DISTRIBUTION AND AVAILABILITY OF DETERMINATION REPORT

Copies of this Determination Report are currently available upon request from NIOSH, Division of Technical Service, Information and Dissemination Section, 4676 Columbia Parkway, Cincinnati, Ohio 45226. After 90 days the report will be available through the National Technical Information Service (NTIS), Springfield, Virginia 22150. Information regarding its availability through NTIS can be obtained from NIOSH, Publications Office at the Cincinnati address. Copies have been sent to:

a. Hersey Products Company, Inc., Gilbertville, Massachusetts 01301
b. Authorized Representative of the International Molders and Allied Workers Union - Local Number 5
c. International Molders and Allied Workers of America, 1225 E. McMillan Street, Cincinnati, Ohio 45206
d. U.S. Department of Labor - OSHA - Region I
e. NIOSH - Region I

For the purpose of informing the approximately sixty "affected employees", this Determination Report shall be "posted" for a period of at least thirty calendar days in a prominent place(s) readily available to the workers.

III. INTRODUCTION

Section 20(a)(6) of the Occupational Safety and Health Act of 1970, 29 U.S.C. 669 (a)(6), authorizes the Secretary of Health, Education, and Welfare, following a written request by an employer or authorized representative of employees, to determine whether a substance normally found in the place of employment has potentially toxic effects in such concentrations as used or found.

The National Institute for Occupational Safety and Health (NIOSH) received six such requests from an authorized representative of the Hersey Products Company, Inc. Of these six requests, five (HHE 76-43 A,B,C,E and F) were concerned with worker exposure to foundry sand and its additives, vapors, gases, and metallic oxides and particulate generated during the founding of ferrous (grey iron) and non-ferrous (bronze and aluminum) castings. The sixth request (HHE 76-43 D) was concerned with employee exposure to organic vapors at a casting coating operation. Signs or symptoms of worker exposure were not listed on the respective request forms.

IV. HEALTH HAZARD EVALUATION

A. Process Description and Associated Potential Health Hazards

The Hersey Products Company is engaged in the founding of ferrous (grey iron) and non-ferrous (bronze and aluminum) castings. The ferrous foundry manufactures water meters and pressure fittings, and general castings such as machine tools. The non-ferrous foundry casts water meter components and general industrial type castings such as valve bodies. The employee distribution consists of 60 workers in the ferrous and 4 in the non-ferrous foundries. The former figure also includes 2 persons working in a casting coating building. In addition, there are 20 administrative and clerical employees giving a total employment of 82. The processes used are similar to most foundry operations, i.e. (1) core making, (2) sand molding, (3) melting and pouring (4) shakeout and sand reclamation, and (5) fettling. A brief description of the process stages relative to each foundry and the associated potential health hazards are described below.

a. Ferrous Foundry

1. Core Making: The sand cores are produced by the shell, no-bake, and oven-bake processes. The shell cores are prepared from a urea-phenol-formaldehyde-sand mixture. The cores are produced by blowing the resin-sand mixture into a metal mold pre-heated to 400 to 450°F, holding for approximately 30 seconds to allow the binder to cure, then removing the finished core or core segment from the mold. Formaldehyde, phenol, hydrogen cyanide, carbon monoxide, and ammonia are reported to be evolved from thermal degradation of the binder system during curing.[1,2] The latter substance results from the decomposition of hexamethylene tetramine (HMTA) which acts as a catalyst for the resin. The HMTA concentrations were not evaluated because a satisfactory sampling and analytical method was not available. The process involves one person, 8-hours per day, 40-hours per

week. The employee's principal exposure occurs while removing the finished core from the mold and when carrying it to a storage table or rack beside the machine.

A urea-furan binder system is used in the no-bake cores. The binder system is based on a urea-formaldehyde resin reacted with furfural alcohol, in which the setting reaction is catalyzed by addition of phosphoric acid at the time of mixing in a screw type mixer positioned above the pattern box. The resin was generally present at about 2 percent of the sand and the catalyst at up to 30 percent of the resin. After mixing, the sand mixture drops by gravity onto the pattern where it is compacted, thus forming a core. The cured core is transported to the "paint area" where an employee paints the cores with finely powered graphite suspended in a solution of isopropyl alcohol. The alcohol paint is coated on the core by spraying and then it is ignited. The heat from the burning alcohol serves to dry out the paint leaving a veneer which prevents the molten metal during pouring from entering the core. No-bake cores are made one shift per day involving two persons, the core maker and core washer, for eight hours. The potential airborne exposures of the core maker would include furfural alcohol and phosphoric acid. Those of the core painter would include isopropyl alcohol and furfural alcohol, and possibly carbon monoxide.

The oven-bake cores employ an oleoresinous binder system which is a combination of oil, kerosene, cereal-binder (mostly starch and dextrin), phenolic coated sand, and water. For example, a 300 pound batch of core sand would consist of 4 pounds of cereal-binder, 1 quart of kerosene, 2 quarts of oil, and water as needed. Turn-over draw machines are used to make the cores. The operator shovels the sand mixture onto the pattern and the jarring and jolting action of the machine compacts the sand mixture forming a "green core". Depending on size, the core is taken to one of three gas-fired baking ovens set at about 400°F for curing. Cores less than 10 pounds are baked in a reach-in oven and cores greater than 10 pounds are cured in walk-in ovens. The cores are placed in and removed from the ovens by a core finisher who also pastes the core halves together after they've cooled. The oven-bake cores are made one shift per day requiring 2 core makers and 3 core finishers for 8 hours. Other than casting sand dust, the core makers are not believed to be exposed to any other airborne contaminants that could present a health problem under conditions of use. The core finishers are potentially exposed to thermal degradation products of the core oils and resin such as ammonia, acrolein, and carbon monoxide.[3] However, based on failure of the exposed finishers to elicit any symptoms of upper respiratory tract irritation, it is doubtful that a toxic exposure to the latter two lachcrimators exists. Based on the extent of exposure, it is also doubtful that a toxic exposure to carbon monoxide exists; this was confirmed by detector tube sampling.

In addition to the foregoing air contaminants, the core making personnel also are exposed to crystalline silica particulate inherent to general workroom activities. The siliceous sand used in core preparation was determined to have a crystalline silica content of around 95 percent. Samples of dust that had settled on rafters located at the shell core and no-bake core operations showed a crystalline silica content of 34 and 65 percent, respectively.

2. Sand Molding: The ferrous castings are produced in green sand molds. The term "green sand" implies that the bonding agent in the sand is some form of clay such as bentonite used at this foundry. The clay is plasticized with about 3 to 5 percent water. The green sand molds also contain organic additives such as dextrine, wood flour and pulverized coal dust (sea coal) which are present in amounts of up to about 5 percent of the weight of the sand. Sea coal is added to provide a reducing atmosphere at the mold-metal interface and cushion the shock of thermal expansion of the sand when the metal is poured into the mold cavity.[4]

The sand molds are constructed using standard sifting, pneumatic compacting and manual finishing techniques. The process consists of compacting prepared sand around a pattern so as to leave an opening in the sand which reproduces the outside contours of the pattern; the cores are set in position within the opening left by the patterns; then the two mold sections are joined together. The sand molds are made using 5 of 14 available squeezer, 3 pin lift, and 2 roll-over machines. The machines operate 1 shift per day for 8-hours employing 5, 3, and 2 persons, respectively. The molders were exposed to crystalline silica particulate.

3. Melting and Pouring: The grey iron alloy is prepared in a standard coke fired cupola furnace. Each melt or heat starts by placing the coke, pig iron, scrap (pure metal and alloys), and limestone into the furnace. Once the molten alloy has been heated to the required temperature (about 2500°F) the furnace is tapped and the molten metal flows into preheated ladles. The ladles are of varying sizes; some requiring two men to handle. From the ladles the molten metal is poured into sand molds. The cupola is prepared for a melt by the tender and charged by two melters. The pouring personnel include 5 pourers and 2 tenders. Of these, 3 pour small molds (1 man per ladle) and 2 pour large molds (2 men per ladle). The tenders bring the ladle to the large mold pourers and return the empty ladle to the cupola for refilling. Once pouring begins it continues until all molds have been cast; the pouring period usually runs from 1100 to 1430 hours.

The cupola personnel may be exposed to carbon monoxide generated from the reduction of the primary ore. This exposure may be highly acute on the charging platform, surrounding catwalks, and around the base of the furnace.

The five pourers are exposed to a variety of air contaminants resulting from the thermal decomposition of the organic binders and carbonaceous materials contained in the sand cores and molding sand. The principal gases evolved during pouring of castings include carbon monoxide and low molecular weight hydrocarbons with smaller amounts of ammonia, formaldehyde, and hydrogen cyanide.[5] Recent research provides evidence that the thermal decomposition of green sand molds produces many organic pyrolysis products which include benzo(a)pyrene and benzo(e)pyrene.[6] The pourers are also exposed to iron oxide fume (ferric oxide). They are also exposed to airborne silica dust generated from adjacent operations such as shakeout.

4. Shakeout and Sand Reclamation: After a cooling interval, the poured castings encased in their molds are moved to 1 of 2 shakeout grates or stations. The small molds are individually dumped on a mechanically vibrating conveyor grate by 3 utility men. The molding sand falls through the grating to a conveyor belt which transports the sand to the reclaim system or sand mueller; the castings proceed along the vibrating grate to a wheelabrator for abrasive cleaning. The large molds are either mechanically or manually shaken out. Some of the large molds are placed on a stationary vibrating shakeout grate where the sand falls to the floor and is pushed into piles and returned to the sand mueller by a pay loader. The castings are transported to a wheelabrator. Others are cleaned by striking them with a mallet and probing them with rods while the molds hang from a hoist. A pay loader returns the sand to the reclaim system and the castings are taken to the wheelabrator. (Generally, small mold shakeout occurs between 1100 to 1439 hours and large mold shakeout between 1430 to 2400 hours.) No mechanical ventilation is provided at either of the shakeout operations.

Reclamation and reconditioning of the used sand is accomplished by manual and automatic muellers. The reconditioning materials including water, bentonite, sea coal, wood flour and sand are added by a "sand preparer" at the manual mueller; this is done automatically as needed at the automatic mueller. The former mueller requires one person, "sand preparer", for 5 continuous hours beginning at 0600 hours each day. The latter mueller requires a sand preparer for 3 non-consecutive hours stretched over the 8 hour work period.

Crystalline silica dust is the principal exposure of the shakeout and sand reconditioning personnel; although the employees on shakeout may also be exposed to some of the organic binder pyrolysis products such as the low molecular weight hydrocarbons previously listed.

5. Chipping, Grinding, and Finishing Operations: After the castings have been tumbled in a wheelabrator (a power-rotating metal drum in which castings are cleaned by tumbling them with an abrading material to free them of scale and adhering sand) any remaining undesirable projections are removed by chipping and grinding in the finishing department. The

department includes 6 snagger-grinder stations and 3 double headed pedestal grinders involving 5 and 4 workers for 8-hours per day, respectively. The snagger-grinders remove the superfluous projections on the castings with power-operated chisels and any remaining rough spots and/or chisel marks are eliminated by hand held and/or pedestal grinders. The airborne exposures of the cleaning room personnel include crystalline silica and iron oxide dust.

After cleaning, the water meter castings are transported to the coal tar building for coating. The process consists of manually dipping a casting into a tank containing a coating solution made up of mineral spirits and coal tar which exists in a one to four ratio, respectively. The coating solution is maintained at ambient temperatures. Two employees are exposed intermittently over a one to three hour period each day. The tar coaters are potentially exposed to petroleum distillates (naphtha) and low molecular aromatic hydrocarbons such as toluene and xylene.

b. Non-Ferrous Foundry

The non-ferrous foundry produces both bronze and aluminum alloy castings; the latter making up about 75 percent of the production. Concurrent founding of the respective alloys generally does not occur during the same day. Due to the limited number of personnel (4) assigned to the non-ferrous operation, multiple job responsibilities are expected of each worker. Thus, a worker is potentially exposed to multiple chemical agents over the workday. The foundry personnel consists of (a) one melter who operates the furnaces and assists in pouring; (b) two inspectors responsible for core making and/or sand molding and/or shakeout; and (c) one fettler responsible for chipping, grinding, and finishing of the castings. The majority of the equipment and operating techniques are similar to those described for the ferrous works. Thus, only a brief description follows.

1. Core Making: The cores are produced by the shell and oven-bake methods. The phenolic and oleoresinous binder systems, equipment, operating techniques, and exposure substances are basically identical to those described for the ferrous works. The cores are usually made by one person during 0600 and 0800 hours each day.

2. Sand Molding: The molds are made using the standard sifting, pneumatic compacting, and manual finishing techniques as described for the ferrous works, except that squeeze machines are only used. The molds are usually made by one person during 0600 to 1000 hours each day.

The molder is principally exposed to crystalline silica particulate; however, because the molding station is in close proximity to the pouring (casting) floor, exposure to the metal alloying elements is also likely.

3. Melting and Pouring: Melting is carried out on a batch basis from cold charges using different furnaces to melt the respective alloys. The bronze base alloy is melted in one 1000 pound electric-fired arc furnace and two 220 pound crucibles. The aluminum base alloy is heated in two 750 pound fuel-fired crucibles.

Approximately 2 to 3 pounds of powdered flux is added to the molten aluminum alloy per heat. The flux contains around 2-3 percent sodium nitrate as its oxidizing agent and around 20 percent sodium fluorosilicate (sodium silicofluoride - Na_2SiF_6) as its catalytic accelerator or controlling agent; less than 2 percent clay; and 75 percent sodium and potassium chlorides. The decomposition products of sodium fluorosilicate are expected to be sodium fluoride (NaF), either aluminum fluoride anhydrous (AlF_3) or hydrate ($AlF_3 \cdot 3\frac{1}{2}H_2O$), and possibly hydrofluorides such as hydrogen fluoride. The resulting dry powdered dross is reportedly low in metal,[3] insoluble (0.0 percent) and soluble (0.004 percent) fluorides, and free silica (1.0 percent) content.[5] The dross is basically aluminum oxide and potassium chloride.[5] In addition to this fluxing procedure, the molten alloy is degassed by flushing the metal with nitrogen. Nitrogen gives rise to no problems of fume and other problems are not anticipated. During melting, the furnace operator is exposed to inorganic fluorides existing as gases, fumes, and particulates, crystalline silica dust, carbon monoxide, and oxides of the alloying elements including copper, zinc and aluminum. Exposure to crystalline silica dust, carbon monoxide, and oxides of the alloying elements are also likely during metal casting.

During melting and pouring of the bronze base alloy the workers are exposed to the alloying elements (copper, lead, zinc and nickel) existing as metal oxide fume, carbon monoxide, and free silica dust.

4. Shakeout and Sand Reclamation: The shakeout process is very similar to that used for the small molds in the ferrous foundry. The molds are manually dumped on a mechanically vibrating conveyor grate, the sand falls through the grating to a conveyor belt which transfers it to an automatic sand mueller for reprocessing. The reconditioning materials are similar to those used in the ferrous works, excluding the addition of "sea coal". The shakeout personnel are exposed to free silica.

5. Chipping, Grinding, and Finishing Operations: The fettling equipment and operating techniques are similar to those described in the ferrous foundry; however, no castings are coated. The inhalation health hazards associated with the above operations include exposure via inhalation and ingestion to metal dusts (lead, copper, zinc, tin, nickel, and aluminum).

B. Evaluation Design

A preliminary survey was conducted at the Hersey Products Company, Inc., on April 22, 1976. Background information about processes, materials, work schedules, and employee profiles basic to establishing a follow-up study protocol were obtained. Additionally, limited air monitoring was conducted at the shell core, metal casting, and casting coating operations. Informal interviews were completed on randomly selected workers from each of the respective operations. Based upon the air monitoring data, employee interviews, and the toxicological activity of the substances likely to exist at the previously discussed operations, a follow-up environmental-medical survey was conducted to adequately characterize and assess worker exposure to these contaminants.

The follow-up survey was conducted June 29-30, and July 1, 1976. With the exception of pattern making, air sampling was conducted at all of the operations in the ferrous and non-ferrous foundries. Included were core making, sand molding, melting, metal casting, shakeout, and fettling. Air samples were also collected at the casting coating operation. The medical evaluation consisted of a health questionnaire survey of essentially every exposed worker. Also, five employees of the non-ferrous foundry and five controls from the ferrous foundry received blood lead and erythrocyte protoporphyrin determinations.

C. Evaluation Methodology

Exposures to airborne crystalline silica, metal fumes and particulate, carbon monoxide, aliphatic and aromatic hydrocarbons were measured using personal and/or work area sampling techniques. The workers' wore a personal sampling apparatus consisting of a battery-powered vacuum pump and some type of device placed at the breathing zone, such as a filter, solid sorbent or glass impinger containing a reagent, appropriate for the particular air contaminant being measured. General workroom air contaminant levels were measured by placing a stationary sampler at a fixed site in the immediate work vicinity.

a. Environmental Methodology

1. Crystalline Silica: Personal and stationary workroom respirable dust samples were collected using two-stage aerodynamic size-selective samplers. The personal samples were collected at the workers' breathing zone on a tared FWS-B filter contained in a 2-piece cassette mounted in a 10 mm cyclonic separator; air was pulled through the sampler at a rate of 1.7 liters per minute (lpm). The core making, molding, shakeout, and fettling areas were established as stationary sampling stations. The dust specimens were collected on a tared FWS-B filter contained in a 3-piece cassette mounted in a one-half inch steel cyclone; the flowrate was regulated at 9 lpm by a critical flow orifice. The total respirable

mass concentration of the dust was determined by weighing the filter before and after sampling using a semimicro balance with a sensitivity of 0.01 milligrams (mg). The total crystalline silica content (mg) of the respirable fraction of dust was determined by x-ray diffraction.[6] Total milligrams of crystalline silica is defined to include all crystalline forms of silica such as quartz, cristobalite, and tridymite.

2. Inorganic Metals (Lead, Copper, Zinc, Nickel, Aluminum, and Iron and Total Particulate: Metal fumes are formed by the evaporation, condensation, oxidation of metals in air. Such occurs in foundries during melting and pouring of metal alloys. Therefore, the samples collected at these operations were presumed to contain metallic oxide fume, in contrast to those collected at the fettling operations which were presumed to contain metallic oxide dust. The metals were collected on a tared polyvinyl chloride filter mounted in a 3-piece closed face cassette using a vacuum pump operating at 1.5 lpm. The metal concentrations were determined by wet ashing the filters in nitric acid and analyzing by atomic absorption spectrophotometry.[7] The lower limit of analytical detection using this technique for lead, copper, zinc, nickel, aluminum, and iron was reported as 7, 5, 1, 5, 15, and 5 ug, respectively.

3. Carbon Monoxide: Worker exposure to carbon monoxide was measured using direct reading gas detector tube units certified (Certification No. TC-84-012) under Title 42 of the Code of Federal Regulations, Part 84). Basically, a certified tube must have ±35 percent accuracy at one-half the exposure limit and ±25 percent at 1 to 5 times the limit.[8] The samples were taken as close to the worker's breathing zone as permissible by the operation, i.e. the threat of sand mold explosion prevented true breathing zone measurements. The breathing zone may be defined as the area within 230 mm (9 inches) of the worker's nose and mouth. An attempt was made to conduct personnel monitoring using a sampling train consisting of a length of tubing in series with a vacuum pump modified to accomodate a mylar bag. Air collected in the bag was used for subsequent analysis by a direct reading instrument - an Ecolyzer Model 2400. Though this procedure would have provided a better index of the worker's breathing zone exposure to carbon monoxide, it was abandoned due to the threat of the mylar bag catching fire or being punctured by hot sparks during metal casting.

Worker exposure to carbon monoxide (CO) was also measured by an expired air analysis method using a breath-hold technique.[9] The concentration of CO in the expired air is an indicator of the percent of hemoglobin (Hb) bound as carboxyhemoglobin (COHb). In this procedure, the subject exhales completely, fills his lungs rapidly and holds for 20 seconds while being timed; then exhales a small portion (several hundred milliliters) to the ambient air, and the remainder is admitted to an evacuated bag. The former maneuver is necessary, since the expired air represents unequilibrated gas from the pulmonary dead space. The CO level in the exhaled air was measured, in parts of gas per million parts of contaminated air by volume, with an Ecolyzer Model 2400. The COHb level in percent saturation was calculated using Ringold's equation:[9]

$$\text{COHb\%} = 0.5 + \frac{\text{CO in ppm}}{5.}$$

Pre and post shift breath analysis samples were collected from the core room personnel (finishers and painters) and a cupola tender. Pre and post exposure samples were collected from a small mold shakeout employee, and metal casting personnel, i.e. immediately before shakeout or metal casting and immediately after completion of the respective activities. The employees' smoking habits were recorded. We did not ask the employees to refrain from smoking during the workday because we wanted the sample also to be representative of their normal smoking routine.

4. Particulate Polycyclic Organic Matter (PPOM): Total particulate samples were obtained using a 0.8 micrometer (um) pore size silver membrane filter preceeded by a glass fiber filter and back-up pad mounted in a 3-piece open face cassette; flow rate of 2 lpm. The cyclohexane-soluble PPOM was determined by using ultrasonic extraction and gravimetric techniques. Benzo(a)pyrene (BaP) and Benzo(e)pyrene (BeP) were then quantitatively determined utilizing gas chromatography and flame ionization detection. Results for BaP and BeP are reported as total BaP/BeP as the analytical method does not distinguish between these compounds. The detection limit was 0.5 ug for BaP/BeP per filter.

Cyclohexane was utilized as the extraction solvent due to the toxicity of benzene. If benzene had been used to extract these samples, the volatile concentrations could have been slightly higher.[10] However, for most practical purposes the analytical results using benzene or cyclohexane are the same. The use of cyclohexane for analysis of PPOM is preferred by several authorities.[11-14]

5. Total Inorganic Fluorides: Gaseous fluorides were collected in 15 ml of a sodium acetate solution contained in a midget impinger and particulate fluorides on a 0.8 um filter mounted in a 3-piece closed face cassette which preceeded the impinger. The impinger and cassette were coupled by a length of tygon tubing no greater than one inch in length. The system operated at a flow rate of 1 lpm to obtain a sample of not more than 200 liters. The two mediums were analyzed separately by an ion specific electrode method and the concentration of total inorganic fluorides was reported for each.[15] The lower limit of detection was reported as 3 ug per sample.

6. Formaldehyde: Airborne formaldehyde was collected in 15 ml of a 1 percent sodium bisulfite solution contained in a midget impinger; flow rate of 1 lpm. In order to address the NIOSH recommended ceiling concentration of 1 ppm, determined over a 30 minute period, 30 minute samples were obtained. The concentration of formaldehyde was determined colorimetrically.[16] The lower limit of detection was reported as .2 ug per ml.

7. Ammonia: Ammonia was collected in 15 ml of a .01N sulfuric acid solution contained in a midget impinger; flow rate of 1 lpm. The peak concentrations of ammonia produced with each core removal cycle were measured by obtaining 5 minute air samples over this period. The concentration of ammonia was determined colorimetrically. The lower limit of detection was reported as 5 ug per ml.

8. Phenol: Phenol was collected in 15 ml of a .1N sodium hydroxide solution contained in a midget impinger; flow rate of 1 lpm. The concentration of phenol was determined by gas liquid chromatography.[17] The lower limit of detection was reported as 2 ug per ml.

9. Hydrogen Cyanide: Hydrogen cyanide was collected in 15 ml of a .1N sodium hydroxide solution contained in a midget impinger; flow rate of 1 lpm. The samples were analyzed by an ion specific electrode method for the cyanide ion.[18] The lower limit of detection was reported as 2 ug per ml.

10. Phosphoric Acid: Phosphoric acid was collected on a 0.8 um pore size filter mounted in a 3-piece closed face cassette; flow rate of 1.5 lpm. The samples were analyzed by a titration method measuring total phosphate ion. The lower limit of detection was reported as .9 ug per filter.

11. Furfural and Isopropanol: These substances were collected concurrently by drawing air at 200 cc/min through a glass tube containing 100 mg of activated charcoal to trap the contaminant vapors. The vapors were desorbed from the charcoal with carbon disulfide and analyzed by a gas chromatographic method. The lower limit of detection reported for these substances was .01 mg.

12. Organic Solvents: Vapors of toluene, xylene, and petroleum distillates were collected concurrently on 100 mg of activated charcoal contained in a glass tube. Due to the intermittent nature of the coal tar coating operation, low (200 cc/min) and high (1 lpm) flow rate samples were collected. The respective maximum sampling periods were 2 hours (120 minutes) and .17 hours (10 minutes), respectively. The vapors were desorbed with carbon disulfide and analyzed by gas chromatography.[19]

b. Medical Methodology

A total of 40 employees at the foundry were studied. All were men. Thirty-five employees of the ferrous foundry representing all job categories received medical evaluations along with the 5 employees in the non-ferrous foundry. All employees were interviewed concerning past occupational history and present or recent medical symptoms using a questionnaire constructed to cover possible medical symptoms associated with the toxic substances present. In addition to the interview, the 5 employees of the non-ferrous foundry and 5 controls from the ferrous foundry received blood lead and erythrocyte protoporphyrin determinations. Specifics of numbers of workers, average age, length of service, past history of work with lead, and job categories are included in Tables 1 and 2.

D. Evaluation Study Criteria

a. Criteria for Assessing Workroom Concentrations of Air Contaminants

Three primary sources of criteria are used to assess workroom concentrations of the air contaminants evaluated: (1) NIOSH Criteria Documents on Recommended Occupational Health Standards (use based on availability). (2) Recommended and Proposed Threshold Limit Values (TLV's) and their supporting documentation as set forth by the American Conference of Governmental Industrial Hygienists (ACGIH), 1976. (3) Occupational Health Standards promulgated by the U.S. Department of Labor - OSHA (Federal Register, July 1, 1975, Volume 39, Title 29, Part 1910, Subpart Z, Section .1000).

These criteria are based on the current state of knowledge concerning the toxicity of these substances and designed to protect individuals occupationally exposed to these substances for an 8-hour or up to a 10-hour workday, 40-hour workweek over a normal lifetime. Because of wide variation in individual susceptibility, however, a small percentage may be affected more seriously by aggravation of a pre-existing condition or by development of an occupational illness.

The criteria represent 8-hour or 10-hour time-weighted averages, i.e. airborne concentrations averaged with regard to their duration, occurring over an 8-hour or 10-hour period. Certain agents are associated with a ceiling designation defined for a short interval (30 minutes or less). Such designations stem from the fact that such agents may provide irritation, sensitization or acute poisioning immediately, or after a short latent period, upon even short exposures.

In the following tabulation of environmental criteria, the most appropriate value (in the opinion of the authors) is presented with its reference and other information (such as OSHA standards) footnoted. The OSHA health standards applicable to the substances measured for this determination are presented only to provide the employer with a perspective on the existing state of compliance or non-compliance with Federal Regulation. Consequently, no discussion of their relationship to the contaminant levels measured will be presented. However, due to the nature of the OSHA standard for silica, the standard and corresponding exposure concentration for each sample have been calculated and are presented in Tables 3-9. The calculated OSHA standard should be compared to the total dust concentration listed.

Workroom Environmental Criteria

Substance	Time-Weighted Average (TWA) 8-Hour	Time-Weighted Average (TWA) 10-Hour	Ceiling Value
[1]Crystalline Silica (Respirable Fraction)	----------------	50 ug/M^{3}[a]	
[2]Lead and Its Inorganic Compounds	----------------	100 ug/M^{3}	
[3]Carbon Monoxide	35 ppm[b]	----------------	200 ppm
[4]Zinc Oxide Fume or Dust	5 mg/M^{3}[c]	----------------	15 mg/M^{3}
[5]Ammonia	----------------	----------------	50 ppm
[6]Phenol	20 mg/M^{3}	----------------	60 mg/M^{3}
[7]Hydrogen Cyanide	----------------	----------------	4.7 ppm
[8]Toluene	100 ppm	----------------	200 ppm
[9]Xylene	----------------	100 ppm	200 ppm
[10]Inorganic Fluorides	----------------	2.5 mg/M^{3}	
[11]Isopropyl Alcohol	----------------	400 ppm	800 ppm
[12]Formaldehyde	----------------	----------------	1 ppm
[13]Copper Fume	----------------	200 ug/M^{3}	
[14]Copper, Dusts and Mists	1 mg/M^{3}		
[15]Tin Oxide	2 mg/M^{3}		
[16]Iron Oxide Fume	5 mg/M^{3}		
[17]Nickel, Soluble Compounds (as Ni)	----------------	15 ug/M^{3}	
[18]Furfural - Skin	5 ppm		
[19]Phosphoric Acid	1 mg/M^{3}		
[20]Particulate Polycyclic Organic Hydrocarbons as Benzene Solubles	200 ug/M^{3}		
[21]Nuisance Particulates			
Respirable Fraction	5 mg/M^{3}		
Total	10 mg/M^{3}		
[22]Petroleum Distillates	2000 mg/M^{3}		

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a. Denotes micrograms of contaminant per cubic meter of contaminated air.
b. Denotes parts of contaminant per million parts of contaminated air.
c. Denotes milligrams of contaminant per cubic meter of contaminated air.

[1] Reference: NIOSH Criteria Document (1974). Federal Occupational Health Standard (1975) for the respirable fraction is calculated by dividing 10 mg/M^3 by the percent Quartz + 2, 8-hour TWA.

[2] Reference: NIOSH, E.J.Baier: Testimony given before U.S. Department of Labor - OSHA - Public Hearing on Occupational Lead Standard, March, 1977. Proposed Federal Occupational Health Standard (1975) is 100 ug/M^3, 8-hour TWA.

[3] Reference: NIOSH Criteria Document (1972). Federal Occupational Health Standard (1975) is 50 ppm, 8-hour TWA.

[4] Reference: NIOSH Criteria Document (1975). Federal Occupational Health Standard (1975) is 5 mg/M^3, 8-hour TWA.

[5] Reference: NIOSH Criteria Document (1974). Federal Occupational Health Standard (1975) is 50 ppm, 8-hour TWA.

[6] Reference: NIOSH Criteria Document (1976). Federal Occupational Health Standard (1975) is 19 mg/M^3, 8-hour TWA.

[7] Reference: NIOSH Criteria Document (1976). Federal Occupational Health Standard (1975) is 10 ppm, 8-hour TWA.

[8] Reference: NIOSH Criteria Document (1973). Federal Occupational Health Standard (1975) is 200 ppm, 8-hour TWA and 300 ppm ceiling value.

[9] Reference: NIOSH Criteria Document (1975). Federal Occupational Health Standard (1975) is 100 ppm, 8-hour TWA.

[10] Reference: NIOSH Criteria Document (1975). Federal Occupational Health Standard (1975) is 2.5 mg/M^3, 8-hour TWA.

[11] Reference: NIOSH Criteria Document (1976). Federal Occupational Health Standard (1975) is 400 ppm, 8-hour TWA.

[12] Reference: NIOSH Criteria Document (1976). Federal Occupational Health Standard (1975) is 3 ppm, 8-hour TWA, 5 ppm for a period of up to 30 minutes, and 10 ppm maximum peak above acceptable ceiling value of 5 ppm.

[13] Reference: ACGIH TLV (1976). Federal Occupational Health Standard is 0.1 mg/M^3, i-hour TWA.

[14] Reference: ACGIH TLV (1976). Federal Occupational Health Standard is 1 mg/M^3, 8-hour TWA.

[15] Reference: ACGIH TLV (1976). Federal Occupational Health Standard is 10 mg/M^3, 8-hour TWA.

[16] Reference: ACGIH TLV (1976). Federal Occupational Health Standard is 10 mg/M^3, 8-hour TWA.

[17] Reference: NIOSH Criteria Document (1977). Federal Occupational Health Standard is 1 mg/M^3, 8-hour TWA.

[18] Reference: ACGIH TLV (1976). Federal Occupational Health Standard is 5 mg/M^3, 8-hour TWA.

[19] Reference: ACGIH TLV (1976). Federal Occupational Health Standard is 1 mg/M^3, 8-hour TWA.

[20] Reference: ACGIH TLV (1976).

[21] Reference: ACGIH TLV (1975).

[22] Reference: Federal Occupational Health Standard (1975).

b. Medical Criteria

The medical criteria used to determine a toxic response to the substances under investigation consists of biological test data and symptoms and signs which each agent produces when a toxic exposure occurs. A brief review of the known pathophysiological effects of the substances determined to be causing a toxic or potentially toxic exposure to the workers under conditions used or found follows:

1. Crystalline Silica: The most important health concern from excessive inhalation of crystalline silica is an increased potential for developing a form of pneumoconiosis ("dusty lung") termed silicosis.[6,20,21] Silicosis has been defined as "a disease due to breathing air containing silica (silicon dioxide), characterized anatomically by generalized fibrotic changes in both lungs, and clinically by shortness of breath, decreased chest expansion, lessened capacity for work, absence of fever, increased susceptibility to tuberculosis (some or all of which symptoms may be present), and by characteristic x-ray findings.[22] This form of pneumoconiosis usually develops after at least seven years of exposure, although a few cases have developed in as short a period of time as 1.5 years from inhalation of very high levels of silica with a high quartz content. At the other extreme, with exposure to low levels of free silica, more than twenty years may have to elapse before the disease develops to a stage when it can be diagnosed.

Early silicosis termed "simple silicosis" is usually first diagnosed by chest x-ray examination. At this stage there is little if any, functional impairment, and there are often no associated symptoms and signs. Symptoms occur when silicosis advances and becomes complicated by infection and emphysema. These changes are marked by intolerance to exertion, episodes of coughing, and production of thick sputum. When silicosis has progressed to this point, the chest x-ray is usually read as "conglomerate silicosis". Conglomerate silicosis many times progresses in spite of termination of exposure, becomes incapacitating to the affected worker, and is irreversible.

2. Iron Oxide Fume or Dust: Inhalation of iron oxide fume or dust may produce a benign lung condition termed siderosis.[23,24] Siderosis is characterized by discrete opacities observed on chest films. Little or no physical disability appears to be caused by the presence of this dust in the lungs unless, there is mixed exposure to silica dust. Workers with such an exposure may develop a disabling lung condition termed "mixed dust pneumoconiosis".

3. Formaldehyde: Irritation to the eyes, nose, mouth and throat are the most common worker health effects from inhalation of the gas.[25] Formaldehyde has a very pungent odor which is detectable at levels less than 1 ppm; discomfort noted at 2-3 ppm when a tingling sensation in the eyes, nose and throat may be felt; and a burning of eyes, nose and throat with difficult breathing at 10-20 ppm.[25] Considerable variation in individual susceptibility to formaldehyde gas is noticeable.[26] Some workers develop a physical tolerance to the irritant effects and work in concentrations intolerable to others. Others may become sensitized to it, and may become more susceptible on repeated exposure. Dermatitis may result from contact with either liquid solutions or solid materials or resins containing free formaldehyde.

4. Inorganic Lead: Inhaled or ingested, inorganic lead can be stored in the bones, kidneys, central nervous system and other body tissues. The lead stored in the bones can affect the bone marrow, causing an interference in the production of hemoglogin which can lead to anemia.[36] Continued chronic exposures to high levels of lead, even intermittent, can cause permanent damage to the nervous system and serious damage to the kidneys. Signs and symptoms of excessive lead exposure include fatigue, irritability, loss of appetite and weight, vague abdominal discomfort, and a yellow discoloration of the skin.[27] Characteristic signs of severe lead poisioning are "wrist-drop" (inability to raise the hand when the forearm is held horizontally) and abdominal colic. Sometimes a blue line of the gums is observed.

NIOSH (1977) recommends a blood lead maximum of 60 ug/100 ml of whole blood.

5. Carbon Monoxide: Inhalation of CO causes asphyxiation by combining with Hb to form COHb which interferes with the oxygen carrying capacity of the blood.[28] The effects of CO exposure on man is increased by duration of exposure, high environmental temperatures, and work effort (oxygen demand). Symptoms such as headache, nausea, fatigue, dizziness appear in healthy workers engaged in light labor near sea level when about 10 percent of the Hb is combined with CO. Such a degree of saturation could be achieved by continually breathing air containing 50 ppm of CO for about 6 to 8 hours. Disturbance of coordination, judgment, phycomotor tasks and visual acuity appear at about 2 percent COHb but do not become importantly significant until about 5 percent COHb saturation is reached.

The medical criteria used to evaluate the breath analysis data was 5 percent COHb as recommended by NIOSH.[28] The 5 percent COHb criteria only applies to industrial exposure and does not take into account smoking. The blood of cigarette smokers may contain between 3 and 10 percent COHb depending on the number of cigarettes smoked and the manner of smoking, inhaling or not inhaling.[37] The COHb of non-smokers is approximately 0.5-0.8 percent.

E. Evaluation Results and Discussion

a. Environmental Evaluation - Ferrous Foundry

1. Respirable Crystalline Silica: Respirable crystalline silica mass samples were collected during June 27 through July 1, 1976. Quartz was the only polymorph (form) of crystalline silica detected and results are therefore reported as milligrams of quartz per cubic meter of air (mg/M^3) sampled. The minimum detectable amount of quartz per filter was 0.02 mg with some samples reported as less than (<) values for milligrams quartz and airborne concentration of quartz. Since no interpretation can be placed on values reported as less than as to whether or not they are above or below the NIOSH recommended health criteria of 0.05 mg/M^3 or the action level of 0.025 mg/M^3, these results were not considered in determining whether the respective workers are exposed to concentrations of quartz that may be potentially toxic.

The results obtained from dust measurements at two types of core making processes are presented in Table 3. Six personal samples were obtained; 4 at a no-bake core and 2 at a shell core operation. The respirable quartz concentrations ranged from 0.12 to 0.33 mg/M^3 and <0.04 to 0.06 mg/M^3, respectively. All (4/4) of the samples collected at the no-bake operation exceeded the NIOSH recommended criteria of 0.05 mg/M^3. This criteria was also exceeded by 1 of 2 samples collected at the shell core operation. The higher concentrations of respirable quartz measured at the no-bake core process is attributed to the fact that it is immediately adjacent to sand molding and metal pouring stations; whereas, the shell core process occurs in a separate room and is removed from dust generating processes such as sand molding and metal casting.

Thirteen (13) personal samples were collected to evaluate the sand molders exposures to respirable quartz (Table 4). The measured airborne concentrations ranged from 0.05 to 0.97 mg/M^3. All of the samples showed concentrations equal to or greater than the 0.05 mg/M^3 NIOSH criteria.

Four (4) personal samples were collected to measure the metal casters exposure to respirable quartz (Table 5). The concentrations ranged from 0.10 to 0.26 mg/M^3. All of the samples showed concentrations in excess of the 0.05 mg/M^3 NIOSH criteria. The average concentration of 0.18 mg/M^3 was 3.6 times the NIOSH criteria.

Nine (9) personal samples were collected to measure the shakeout workers exposures to respirable quartz (Table 6). The concentrations ranged from 0.07 to 0.91 mg/M^3, which are all in excess of the 0.05 mg/M^3 NIOSH criteria. The average concentration of 0.26 mg/M^3, is 5.2 times the NIOSH criteria.

Eight (8) personal samples were collected to measure the fettlers exposure to respirable quartz (Table 7). The concentrations ranged from 0.09 to 0.31 mg/M^3, which are all in excess of the 0.05 mg/M^3 NIOSH criteria. The average concentration of 0.24 mg/M^3 is 4.8 times the NIOSH criteria.

Exposure to respirable quartz by a sand mueller and cupola tender were measured (Table 8). The concentrations of respirable quartz shown for the sand mueller are those obtained while the employee was working at the manual mueller. Consecutive day personal samples were obtained with measured concentrations of 0.37 and 0.48 mg/M^3, which are in excess of the 0.05 mg/M^3 NIOSH criteria. This average concentration of 0.43 mg/M^3 is 8.5 times the NIOSH criteria. Consecutive day personal samples were also obtained for a cupola tender. The concentrations were 1.83 and 0.13 mg/M^3 respirable quartz, which exceeds the 0.05 mg/M^3 NIOSH criteria. The average concentration of 0.98 mg/M^3 is 19.6 times the NIOSH criteria. The first sample was collected while the employee was chipping the cupola in preparation for re-lining, which occurs each morning. The second sample was also collected during cupola chipping, but was not removed after chipping as was the first sample. Thus, the data shows that the cupola tenders exposure to respirable quartz primarily occurs during cupola repair.

Table 9 shows the concentrations of respirable quartz measured by stationary samplers positioned at 3 of the 7 operations evaluated by personal monitoring. The samplers were positioned in the shell core room, sand molding area, and fettling room. The average concentrations of respirable quartz measured were 0.02, 0.32, and 0.09 mg/M^3, respectively. Comparative studies[29] of data obtained from personal breathing zone and fixed-site samples have shown that there is a limited correlation, thus no such comparison of the data collected will be made. Fixed-site samples provide useful data regarding general workroom dust levels, but do not assess worker exposure as adequately as personal samples obtained from the workers breathing zone.

2. Carbon Monoxide: Carbon monoxide (CO) exposures were estimated using detector tubes and a breath analysis technique. Detector tube measurements were made near the breathing zone of the metal pourers on June 30 and July 1, 1976. Fifteen (15) measurements were made over the pouring period (3-4 hours per day) on each of the days. Of which, 5 samples were taken each day to obtain background CO, i.e. when the employee was transporting a ladle of molten alloy to be poured or periods between pours. The CO levels measured near the breathing zone of a small pourer, while pouring, ranged from 10 to 50 ppm, with an average concentration of approximately 35 ppm. The levels during non-pouring periods ranged from 10 to 20 ppm, with an average concentration of approximately 15 ppm. The concentrations of CO measured near the breathing zone of a large pourer, while pouring, ranged from 25 to 100 ppm, with an average concentration of approximately 45 ppm. The concentrations during non-pouring periods ranged from 10-25 ppm, with an average concentration of approximately 15 ppm.

Six (6) measurements were taken at the breathing zone of a core finisher and a core painter on July 1, 1976. All samples showed a maximum level of <10 ppm.

During small mold shakeout on July 1, 1976, 7 samples were taken to evaluate a shakeout employees exposure to CO. The measured levels ranged from 5 to 40 ppm, with an average concentration of approximately 20 ppm.

The cupola tenders exposure to CO was evaluated on June 30, 1976. Two (2) samples were collected from each of 3 areas of the cupola. Included were the charging platform, catwalks, and base of the cupola. The concentrations ranged from none detected on the catwalks to 25 ppm at the base of the cupola.

It is evident from the aforementioned data that the workers are exposed to varying concentrations of CO. Exposures of the core painters and finishers appear to be low, while that of the pourers and shakeout personnel, and possibly the cupola tender are significantly higher. Based on the type of aerometric instrumentation that was available and conditions of exposure, it was difficult to obtain sufficient data to define the workers exposure in terms of a personal breathing zone TWA. However, the levels are sufficiently high to suggest that the workers, especially the large pourers, could be exposed to toxic concentrations. The biological monitoring data presented below tends to support this hypothesis.

Expired-air CO and percent carboxyhemoglobin (COHb) concentrations for pre and post exposure breath analysis samples are presented in Table 10. A total of 9 employees were tested. Three sets of data (1 set per day) were collected from 8 of the 9 persons; 1 set was obtained from the 9th worker. Because the contributions of CO from the work environment and smoking habits cannot be readily discerned, the data on the non-smokers was only used to evaluate the workers exposure to CO. The post exposure COHb determinations of the core making personnel did not exceed the 5 percent criterion which was exceeded by a large metal pourer and shakeout employee. The COHb determinations of the latter 2 persons were 1.8 and 2.2 times the 5 percent criterion, respectively. Though the data is limited, it is consistent with the aerometric data which showed that the core making personnel are exposed to low levels of CO and the pourers and shakeout employees are exposed to higher levels.

Although the data on the smokers was not directly used to show an increase COHb from occupational exposure to CO, it shows that the smokers had alveolar air concentrations of CO above their fellow non-smokers and above the 5 percent COHb level. The paramount fact is that the increased levels of COHb may affect the worker's ability to work safely.[35]

3. Ammonia, Phenol, Hydrogen Cyanide and Formaldehyde: The levels of ammonia, phenol and hydrogen cyanide measured at the breathing zone of a shell core operator were less than the limit of detection of the analytical method used. The respective detection limits reported were <0.005, <0.02, and <0.02 mg per ml. Fourteen (14) systematic measurements were made to evaluate the shell core machine operators exposure to formaldehyde. The measurements were 30 minute personal samples collected over an 8-hour work shift. The aerometric results are presented in Table 11. The airborne concentrations ranged from <0.02 to 18.3 ppm. Three (3/14) of the samples showed concentrations (4.4, 10.6 and 18.3 ppm) which exceeds the NIOSH recommended criteria of 1 ppm for any 30 minute period. The latter two concentrations also exceed the maximum exposure concentration of 10 ppm as promulgated by OSHA.

The data demonstrate that the operator is exposed to varying concentrations of formaldehyde vapor with an occasional excrescence above the ceiling limits of NIOSH and OSHA. The intra day fluctuations may be attributed to one or a combination of things. Included are employee work procedures and core type and size. The former would involve the workers breathing zone being downstream of the chemical plume emitted from the cores in transport from the core machine to the storage rack or table. However, the increased exposure concentration most likely is due to core type and size, which changed from "small to large cores" several times during the day. For example, 9 large cores were formed among the small cores within the 30 minute sampling period for sample FF-14. The resultant concentration was 10.6 ppm. Unfortunately, no other such production data was gathered. A study conducted by Kay[34] of fumes evolved from synthetic resin based sand binders, reported that formaldehyde vapor concentrations varied with core type and size. The highest levels of formaldehyde were measured where hollow, cylindrical cores were produced in the absence of mechanical ventilation. The shell core machine operator commented that the highest degree of eye and nose irritation is associated with production of the larger cores.

4. Phosphoric Acid, Furfural and Isopropanol: Personal concentrations of phosphoric acid and furfural were measured during the no-bake core making process and those of furfural and isopropanol were measured during the no-bake core painting process. The phosphoric acid results are presented in Table 12. The levels ranged from <0.9 to 21.8 ug/M^3, which are lower than the respective TLV of 1 mg/M^3. The levels of furfural were less than the limit of detection (<0.01 mg/sample) of the analytical method used.

The concentrations of isopropanol and furfural measured at the core painting operation are shown in Table 13. The levels of isopropanol ranged from 1.2 to 19.1 ppm, which are less than the criteria of 400 ppm. The levels of furfural were less than the limit of detection (<0.01 mg/sample) of the analytical method used.

5. Particulate Polycyclic Organic Matter (PPOM), Benzo(a)Pyrene (BaP), Benzo(e)Pyrene (BeP), and other Thermal Decomposition Products: Due to the toxicity of PPOM, and BaP/BeP, the thrust of our energy was directed at evaluating the pourers exposure to these contaminants. Table 14 presents the PPOM and BaP/BeP results for 8 personal samples obtained on 4 workers on June 29 and 30, 1976. The concentration of PPOM detected in the 8 samples varied from 0.69 to 5.35 ug/M^3 of air, which did not exceed the respective criteria of 200 ug/M^3. The concentrations of BaP/BeP were all less than the limit of detection (<0.5 ug/sample) of the analytical method used.

Exposure to phenol, hydrogen cyanide, formaldehyde, ammonia and carbon monoxide also were measured. The respective air contaminant concentrations (excluding carbon monoxide - see Section 2) were all <1 ppm.

6. Iron Oxide Fume and Total Particulate: Iron oxide and total particulate concentrations measured at the breathing zone of the metal pourers are presented in Table 15. The concentrations ranged from 0.11 to 0.35 mg/M^3 and from 2.08 to 6.73 mg/M^3, respectively. The levels are below the respective evaluation criteria of 5 mg/M^3 and 10 mg/M^3.

7. Metal Dust and Total Particulate: Personal exposures to iron oxide dust and total particulate by a pedestal-grinder and 2 snagger-grinder operators were evaluated (Table 16). The personal exposures of the pedestal-grinder ranged from 0.85 to 1.26 mg/M^3 and 1.78 to 2.26 mg/M^3, respectively, which does not exceed the 10 mg/M^3 evaluation criteria. The personal exposures of the snagger-grinder ranged from 5.0 to 23.5 mg/M^3 and 6.5 to 37.1 mg/M^3, respectively. It is apparent that the existing ventilation is not adequate to control the iron oxide dust and total particulates below the environmental criteria of 10 mg/M^3.

8. Toluene, Xylene and Petroleum Distillates: Due to the sparsity of castings to be tar coated, personal breathing samples with a maximum volume of 10 liters were collected. Toluene was not detected in any sample. The levels of xylene and petroleum distillates were <0.69 ppm and 0.03 mg/M^3, respectively. Both are below the respective environmental criteria.

b. Environmental Evaluation - Non-Ferrous Foundry

1. Respirable Crystalline Silica: A total of 5 personal breathing zone respirable samples and 1 source-area respirable silica sample were collected during June 29-30, 1976. The data are presented in Tables 17 and 18, respectively. The concentrations of personal respirable quartz ranged from 0.02 to 0.19 mg/M^3. Three (3/5) of the samples reported exposure concentrations equal to or greater than the NIOSH criteria of 0.050 mg/M^3 and 1 (1/5) reported a level greater than the 0.025 mg/M^3 NIOSH criteria document "action level". Workroom concentrations were determined by a high volume sampler positioned in the molding-shakeout area on June 30, 1976. The respirable quartz level measured was 0.06 mg/M^3.

2. Ammonia, Phenol, Hydrogen Cyanide and Formaldehyde: The levels of ammonia, phenol and hydrogen cyanide measured at the breathing zone of the shell core machine operator were less than the limit of detection (0.005, 0.02 and 0.02 mg/ml, respectively) of the analytical method used. The concentrations of formaldehyde measured over 30 minute periods are summarized in Table 19. The maximum concentration measured was 0.29 ppm, which is less than the 1 ppm ceiling value recommended by NIOSH.

3. Metals and Total Particulate: Concurrent exposures to inorganic lead, copper, zinc and aluminum and total particulate by aluminum and bronze foundry personnel were assessed on June 29 and 30, 1976, respectively. The aerometric results are presented in Tables 20 and 21, respectively. Worker exposure to these metals was below the respective evaluation criteria, except for a fettler exposed to excessive airborne lead on June 30 (Table 21). The worker was exposed to 0.24 mg/M^3, 8-hour TWA, which is 2.4 times the NIOSH recommended criteria of 0.10 mg/M^3. The same worker was also exposed to 0.62 mg/M^3 of copper, which is 62 percent of the 1 mg/M^3 threshold limit value recommended by the ACGIH.

4. Gaseous and Particulate Inorganic Fluorides: Exposure by a furnace tender to inorganic fluorides was assessed. The aerometric results reported as total gaseous and particulate inorganic fluorides are contained in Table 22. The workers resultant 8-hour TWA exposure (0.4 mg/M^3) did not exceed the criteria (2.5 mg/M^3) recommended by NIOSH.

b. Medical Evaluation - Ferrous and Non-Ferrous Foundries

Current and past complaints are presented in Tables 23 and 24. Of particular note are the complaints of a metallic taste and occasional to recurrent chills ("brass chills") in the non-ferrous foundry both among current workers and also among ferrous workers during past experience in the non-ferrous foundry.

This complaint coupled with the aerometric data obtained on a bronze fettler suggests that the existing ventilation is not adequate.

In the ferrous foundry the most prevalent job-related complaints were those of nose and throat dryness or irritation often related to dust; cough; and tiredness or weakness, particularly related to work in a hot environment. Eye irritation reported by a core maker was related to shell core emissions. The two job categories reporting the highest proportion of symptoms were melters and pourers. Two-thirds of the melters reported nose and throat irritation or dryness, coughing, shortness of breath and tiring easily. Tightness in the chest and pain in the chest were reported by all pourers sampled.

Table 25 presents the results of laboratory work along with normal values. Except for the non-ferrous worker with 11 years of work with possible lead exposure, the current non-ferrous workers had laboratory values comparable to those of ferrous workers with past occupational lead exposure. Blood lead levels and Erythrocyte Protoporphyrin (EP) levels among lead exposed workers were a little higher than among unexposed workers. With the exception of one low hematocrit, all others were normal. There is an unreconcilable discrepancy between the blood lead and EP values. Considering the 9 workers with both values, 7 out of 9 workers had EP values within the normal range, one was elevated but in the safe range, and one was elevated enough to suggest further study. On the other hand, looking at blood leads only one out of nine was within the normal range (by work history one would have expected at least 3 in this category); 5 out of 9 were in the elevated but safe range; 2 were in the questionable range; and one was high enough to require further medical follow-up.

Based on interviews and average blood lead values, it would appear that in the non-ferrous foundry there is sufficient exposure to lead to cause health problems or potentially cause health problems. The extent of the problem cannot be adequately determined as the reported blood levels appear to be a little high. A full assessment of the problem can be obtained by instituting a medical surveillance program for lead.

V. RECOMMENDATIONS

A. Environmental

1. Examination and testing were not conducted of the ventilation system to assess its existing efficacy. A thorough inspection and evaluation of the entire extraction system should be conducted to insure that conditions such as obstructions, leaking duct connections, torn flexible ducts, fan belt slippages, etc., are not preventing the attainment of maximum efficiency. Air flow (volume and velocity) and pressure measurements should be conducted to determine if the system is operating at the designed conditions. Adjustments or installation of a new system then should be made accordingly.

2. Every effort should be made to control production of air contaminants through engineering control. The metal casting and sand mold shakeout operations should be locally exhausted. A travelling local exhaust hood may be effective in controlling the gaseous and metal fume emmissions during metal casting.

3. Periodic cleaning of floors, equipment and overhead structures will prevent settled dust from being an ever present source of exposure. Air currents will cause settled dust to become airborne and cause an unnecessary increase in exposures. Dry sweeping and compressed air blowoff should be prohibited. Cleaning should be done using wet or vacuum methods.

4. Several methods of ventilation can be used to control the contaminants from the shell core process. These include a high standard of general dilution ventilation and local exhaust ventilation. The local exhaust system is needed to remove the contaminants during core cooling and finishing operations. A standard open face spray booth type hood may be most effective at controlling the organic chemical emissions.

The shell core makers exposure to fumes occurring while removing and transporting the cores to the finishing and storage table may be minimized by a combined blowing/extraction system. The worker could momentarily be exposed to a fume concentration with resultant lachrimation as the hot cores are removed from the molds, but this would quickly be expelled by the ventilation system.

5. Air contaminant control measures for foundries that have been standardized by the American Foundrymen's Society should be consulted.[30] Also, specific design considerations can be obtained from the Industrial Ventilation Manual published by the American Conference of Governmental Industrial Hygienists.[31]

B. Respiratory Protection

1. Engineering controls shall be used to maintain crystalline silica, inorganic lead and formaldehyde exposures below the prescribed limits. When the limits of exposure cannot be immediately met by limiting the concentrations of silica, inorganic lead or formaldehyde in the work environment by engineering and administrative controls, the Hersey Products Company should utilize a program of respiratory protection to protect every person exposed.

2. Respirator Selection and Usage

i. The Hersey Products Company should select and provide an appropriate respirator from Table 26. Based on the air concentrations of silica, inorganic lead and formaldehyde measured, appropriate respirator selection guidelines are presented. The guidelines were taken from the respective NIOSH Criteria Documents.[6,27,33]

ii. Respiratory protective devices described in Table 26, must be those approved under provisions of 30 CFR 11, i.e. only those respirators should be used which have a "Tested and Certified" number issued by NIOSH to the manufacturer of the device.

iii. A respiratory protective program meeting the requirements of 29 CFR 1910.134 should be established and enforced by management with union support. A NIOSH document titled, "A Guide to Industrial Respiratory Protection", will serve as a reference source with information for establishing and maintaining a respiratory protection program which meets the requirements of 29 CFR 1910.134.[32]

iv. When employees are exposed to multiple toxic substances, such should be considered when selecting the proper respiratory protection device. For example (1) the shell core makers are concurrently exposed to toxic concentrations of silica and formaldehyde; (2) the ferrous foundry snagger-grinders are concurrently exposed to toxic concentrations of silica, iron oxide dust and total particulate; and (3) the non-ferrous foundry shakeout/fettler is concurrently exposed to toxic concentrations of inorganic lead and silica particulate.

v. There should be an established in-plant procedure and means and facilities provided to issue respiratory protective equipment to decontaminate and disinfect the equipment, and to repair or exchange damaged equipment. Records of these activities should be maintained.

vi. Employees should be given instructions on the use of respirators assigned to them, on cleaning respirators, testing for leakage and proper use.

vii. Respirators should be issued with caution. There might be individuals in the group for whom wearing a respirator carries certain specific dangers, i.e. highly increased resistance to airflow in a person with compromised pulmonary function may be associated with acute respiratory insufficiency. Employees experiencing frequent and continuous breathing difficulty while using respirators should be evaluated by a physician to determine the ability of the worker to wear a respirator.

viii. Though no personal breathing zone exposure data was obtained on other workers such as maintenance and foreman personnel, based on the general work-room aerometric data (Table 9) it is also recommended that these persons wear respiratory protection while in the established exposure areas.

C. Environmental and Medical Surveillance

Part I, Sections 1, 2 and 8 of the NIOSH Criteria Document for Crystalline Silica, Inorganic Lead, Carbon Monoxide and Formaldehyde should be used as a guide for establishing environmental and medical surveillance programs.

The following minimal medical surveillance for inorganic lead in the non-ferrous foundry should be immediately instituted.

Blood lead analysis, on a routine basis, should be done on each worker with occupational exposure to lead to identify any worker with blood lead levels of 40 ug/100 ml or higher. Workers with blood lead levels of 60 ug/100 ml or higher should have the blood lead repeated promptly, and if still above 60 ug/100 ml should be examined by a physician to determine whether the employee has symptoms of lead intoxication and should be removed from further exposure to lead until the blood lead is below 60 ug/100 ml. If the blood lead is 80 ug/100 ml or greater, the worker should be removed from further lead exposure immediately, even before the second blood's value is known.

D. General

1. On several occasions, NIOSH representatives observed men working beneath a suspended and unsupported sand mold. It is strongly recommended that such unsafe procedure be prohibited.

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Table 1

Characterization of Workers Studied, All Male

Hersey Products Company, Inc.
Gilbertville, Massachusetts

June, 1976

	FERROUS FOUNDRY			NON-FERROUS FOUNDRY
	History of Occupational Lead Exposure			
	NO	YES	TOTAL	
Number	30	5	35	5
Average Age	39.7	31.2	38.5	29.6
Age Range	19-64	21-41	19-64	20-37
Length of any foundry work				
Average	12.2y	3.5y	11.0y	6.6y
Range	1w - 29y	22m - 8 1/4y	1w--29y	1/2y - 16 1/2y
Length of non-ferrous foundry work or other occupational lead exposure				
Average	0	1.7y	--	4.4y
Range	0	5m - 2 1/2y	--	1/2y - 11y

Table 2

Job Categories and Number of Workers Studied

Hersey Products Company, Inc.
Gilbertville, Massachusetts

June,1976

JOB TITLE	FERROUS FOUNDRY	NON-FERROUS FOUNDRY
Sand Mixers	2	0
Core Makers	8	0
Molders	8	1
Melters & Cupola Operator	3	1
Pourers	2	0
Utility Men	5	1
Shakeout	3	0
Grinding & Finishing	4	1
Shipping Inspector	0	1
TOTAL	35	5

Table 3

Summary of Personal Sampling Concentration Data

for

Total Respirable Free Silica and Total Respirable Particulate - Ferrous Foundry

Hersey Products Company, Inc.
Gilbertville, Massachusetts

June 30 and July 1, 1976

Sample Date	Sample Number	Job Description and/or Classification	Sampling Period	Sample Volume liters	Total Free Silica		Airborne Concentration Data-mg/m^3(a)		OSHA Silica Standard mg/m^3
					mg	%	Total Free Silica	Total Respirable Dust	
6/30	FB-78	Shell Core Maker	0600-1200 1245-1425	782	0.05	21	0.06	0.24	0.43
7/1	PV-399	Shell Core Maker	0612-1155	573	<0.02	<25	<0.04	0.33	<0.40
8/30	PV-196	No-Bake Core Maker	0612-1157 1240-1415	748	0.25	61	0.33	0.55	0.16
7/1	PV-59	No-Bake Core Maker	0607-1155 1238-1410	748	0.17	81	0.23	0.28	0.12
6/30	PV-136	No-Bake Core Maker	0612-1157 1240-1415	748	0.09	39	0.12	0.31	0.24
7/1	PV-161	No-Bake Core Maker	0612-1155 1240-1410	737	0.15	83	0.20	0.24	0.12
Environmental Criteria							0.05 mg/M^3	5 mg/M^3	

a. Denotes milligrams of contaminant per cibic meter of contaminated air.

Summary of Personal Sampling Concentration Data
for
Total Respirable Free Silica and Total Respirable Particulate - Ferrous Foundry

Hersey Products Company, Inc.
Gilbertville, Massachusetts

June 29-30, and July 1, 1976

Sample Date	Sample Number	Job Description and/or Classification	Sampling Period	Sample Volume liters	Total Free Silica		Airborne Concentration Data-mg/m^3(a)		OSHA Silica Standard mg/m^3
					mg	%	Total Free Silica	Total Respirable Dust	
6/29	PV-79	Pin-Lift Molder (New Foundry)	0615-1200 1231-1400	738	0.72	84	0.97	1.16	0.12
6/30	PV-201	Pin-Lift Molder (New Foundry)	0605-1150 1234-1508	848	0.08	35	0.10	0.27	0.27
6/30	PV-147	Pin-Lift Molder (New Foundry)	0614-1152 1249-1410	712	0.39	87	0.55	0.63	0.11
6/29	PV-171	Pin-Lift Molder (Old Foundry)	0825-1155 1236-1455	593	0.18	64	0.31	0.47	0.15
6/30	PV-121	Pin-Lift Molder (Old Foundry)	0600-1150 1236-1440	806	0.22	19	0.27	1.46	0.48
6/29	PV-117	Squeezer Molder (New Foundry)	0628-1155 1247-1423	719	0.07	32	0.09	0.31	0.29
6/30	PV-113	Squeezer Molder (New Foundry)	0616-1155 1238-1425	758	0.05	18	0.07	0.37	0.50
6/29	PV-90	Roll-Over Molder (Old Foundry)	0801-1205 1240-1422	588	0.13	57	0.22	0.39	0.17
6/30	PV-141	Roll-Over Molder (New Foundry)	0734-1150 1235-1540	750	0.12	28	0.16	0.57	0.33
7/1	PV-397	Roll-Over Molder (New Foundry)	0617-1159 1238-1430	767	0.13	38	0.17	0.44	0.25
7/1	FB-418	Roll-Over Molder (New Foundry)	0617-1154 1240-1440	781	0.04	14	0.05	0.37	0.63
6/30	PV-173	Intermediate Molder (New Foundry)	0608-1153 1240-1505	833	0.38	56	0.46	0.82	0.17
6/30	PV-212	Intermediate Molder (New Foundry)	0610-1150 1239-1504	825	0.29	54	0.35	0.65	0.18
Environmental Criteria							0.05 mg/M^3	5.0 mg/M^3	

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a. Milligrams of contaminant per cubic meter of contaminated air.

Table 5

Summary of Personal Air Sampling Concentration Data
for
Total Respirable Free Silica and Total Respirable Particulate - Ferrous Foundry

Hersey Products Company, Inc.
Gilbertville, Massachusetts

July 1, 1976

Sample Number	Job Description and/or Classification	Sampling Period	Sample Volume liters	Total Free Silica		Airborne Concentration Data-mg/m^{3}(a)		OSHA Silica Standard mg/m^3
				mg	%	Total Free Silica	Total Respirable Dust	
FB-421	Large Mold Pourer	1130-1540	425	0.06	11	0.14	1.23	0.77
PV-97	Large Mold Pourer	1339-1545	418	0.09	35	0.21	0.62	0.27
PV-406	Small Mold Pourer	1133-1542	423	0.04	15	0.10	0.64	0.59
PV-415	Small Mold Pourer	1135-1539	415	0.11	28	0.26	0.95	0.33
Environmental Criteria						0.05 mg/M^3	5.0 mg/M^3	

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a. Milligrams of contaminant per cubic meter of contaminated air.

Table 6

Summary of Personal Air Sampling Concentration Data for Total Respirable Free Silica and Total Respirable Particulate - Ferrous Foundry

Hersey Products Company, Inc.
Gilbertville, Massachusetts

June 29-30, and July 1, 1976

Sampling Date	Sample Number	Job Description and/or Classification	Sampling Period	Sample Volume liters	Total Free Silica		Airborne Concentration Data-mg/m^3(a)		OSHA Silica Standard mg/m^3
					mg	%	Total Free Silica	Total Respirable Dust	
6/29	PV-162	Small Shake-Out (New Foundry)	1208-1526	337	0.04	31	0.12	0.38	0.30
6/29	PV-87	Small Shake-Out (New Foundry)	1156-1510	329	0.30	14	0.91	1.03	0.63
6/30	PV-71	Small Shake-Out (New Foundry)	1158-1605	420	0.05	22	0.12	0.55	0.43
6/30	PV-74(b)	Small Shake-Out (New Foundry)	0646-1530	891	0.05	8	0.06	0.70	1.0
7/1	PV-102	Small Shake-Out (New Foundry)	1139-1555	435	0.03	17	0.07	0.41	0.53
7/1	PV-99	Small Shake-Out (New Foundry)	1240-1541	308	0.08	24	0.26	1.06	0.38
6/30	PV-101	Large Shake-Out (Old Foundry)	1615-1825 1905-2312	641	0.06	27	0.09	0.34	0.34
6/30	PV-126	Large Shake-Out (Old Foundry)	1617-1825 1905-2250	600	0.04	27	0.07	0.25	0.34
7/1	PB-411	Wheelabrator Oper.	0945-1200 1245-1600	459	0.30	17	0.65	3.90	0.53
Environmental Criteria							0.05 mg/M^3	5.0 mg/M^3	

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a. Milligrams of contaminant per cubic meter of contaminated air.
b. Worked at the wheelabrator from 0600 to 1200 and on shake-out from 1230-1530 hrs.

Table 7

Summary of Personal Sampling Concentration Data for Total Respirable Free Silica and Total Respirable Particulate - Ferrous Foundry

Hersey Products Company, Inc.
Gilbertville, Massachusetts

Sampling Date	Sample Number	Job Description and/or Classification	Sampling Period	Sample Volume liters	Total Free Silica		Airborne Concentration Data-mg$^{3(a)}$		OSHA Silica Standard mg/m^3
					mg	%	Total Free Silica	Total Respirable Dust	
6/29	PV-129	Snagger-Grinder	0734-1201 1235-1523	740	0.22	8	0.30	3.73	1.0
6/29	PV-109	Snagger-Grinder	0738-1200 1246-1521	709	0.18	9	0.25	2.89	0.91
6/30	PV-130	Snagger-Grinder	0711-1125 1240-1531	723	0.18	12	0.25	2.07	0.71
6/30	PV-75	Snagger-Grinder	0710-1153 1240-1500	719	0.14	12	0.19	1.65	0.71
7/1	PV-67	Snagger-Grinder	0710-1100 1235-1525	680	0.21	10	0.31	3.24	0.83
7/1	PV-358	Pedestal-Grinder	0719-1200 1235-1556	819	0.18	18	0.22	0.12	0.50
6/29	PV-121	Pedestal-Grinder	0736-1201 1243-1515	709	0.22	19	0.31	1.66	0.48
6/30	PV-154	Pedestal-Grinder	0714-1151 1245-1525	743	0.07	18	0.09	0.54	0.50
Environmental Criteria							0.05 mg/M^3	5.0 mg/M^3	

a. Milligrams of substance per cubic meter of contaminated air.

Table 8

Summary of Personal Sampling Concentration Data
for
Total Respirable Free Silica and Total Respirable Particulate - Ferrous Foundry

Hersey Products Company, Inc.
Gilbertville, Massachusetts

June 20 and 30, 1976

Sampling Date	Sample Number	Job Description and/or Classification	Sampling Period	Sample Volume liters	Total Free Silica		Airborne Concentration Data-mg³(a)		OSHA Silica Standard mg/m³
					mg	%	Total Free Silica	Total Respirable Dust	
6/29	PV-112	Sand Mullor	0520-1125	621	0.23	9	0.37	4.06	0.91
6/30	PV-87	Sand Mullor	0518-1120	615	0.30	14	0.48	3.40	0.63
6/29	PV-83	Cupola Tender (Chipping)	0525-0600	60	0.11	8	1.83	22.8	1.0
6/30	PV-321	Cupola Tender(b)	0515-0608 1000-1205	303	0.04	14	0.13	0.93	0.63
Environmental Criteria							0.05 mg/M³	5.0 mg/M³	

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a. Milligrams of contaminant per cubic meter of contaminated air.
b. Chipping of the cupola walls during 0515-0608; lining and charging during 1000-1205.

Table 9

Summary of Work-Area Sampling Concentration Data for Total Respirable Free Silica and Respirable Particulate - Ferrous Foundry

Hersey Products Company, Inc.
Gilbertville, Massachusetts

June 29-30, and July 1, 1976

Sampling Date	Sample Number	Sampling Station	Sampling Period	Sample Volume liters	Total Free Silica mg	Total Free Silica %	Airborne Concentration Data-mg$^{3(a)}$ Total Free Silica	Airborne Concentration Data-mg$^{3(a)}$ Total Respirable Dust	OSHA Silica Standard mg/m^3
6/29	PV-108	Pin-Lift Machine (Old Foundry)	0740-1128 1138-1601	4419	0.44	13	0.10	0.76	0.67
6/29	PV-163	" "	0740-1128	2052	0.34	20	0.16	0.81	0.45
6/29	PV-267	" "	1138-1601	2367	0.44	25	0.18	0.72	0.37
6/29	PV-89	Shell Core Machine	0742-1410	3492	0.03	8	0.01	0.11	1.0
6/29	PV-153	Shell Core Machine	0742-1410	3492	0.08	73	0.02	0.39	0.13
6/29	PV-95	Pin-Lift Machine (New Foundry)	0745-1140 1145-1615	4545	1.7	88	0.38	0.43	0.11
6/29	PV-86	" "	0745-1140	2115	2.2	78	1.05	1.28	0.13
6/29	PV-91	" "	1145-1615	2430	1.5	70	0.63	0.89	0.14
6/30	PV-198	Pin-Lift Machine (Old Foundry)	0625-1305	3600	1.0	30	0.28	0.92	0.31
6/30	PV-107	" "	1320-1540	1260	0.23	20	0.18	0.90	0.45
6/30	PV-350	" "	0625-1305	3600	0.60	20	0.17	0.85	0.45
6/30	PV-379	" "	1320-1540	1260	0.21	16	0.16	1.02	0.56
6/30	PV-68	Pin-Lift Machine	0627-1544	5013	1.7	38	0.34	0.90	0.25
	PV-422	(New Foundry)	0627-1544	5013	1.3	53	0.26	0.49	0.18
7/1	FB-424	Finishing Room	0701-1135 1145-1445	4086	0.27	9	0.07	0.73	0.91
7/1	FB-434	" "	0701-1135	2466	0.23	7	0.10	1.33	1.1
7/1	PV-170	" "	1145-1445	1620	0.17	10	0.11	1.04	1.0
6/30	PV-167	Large Shake-Out (Old Foundry)	1640-2318	3582	0.11	20	0.03	0.16	0.45
6/30	PV-443	" "	1640-2318	3582	0.05	8	0.01	0.18	1.0
Environmental Criteria							0.05 mg/M^3	5.0 mg/M^3	

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a. Milligrams of contaminant per cubic meter of contaminated air.

Table 10

Expired Air Carbon Monoxide (CO) and Carboxyhemoglobin (COHb) Concentrations

Hersey Products Company, Inc.
Gilbertville, Massachusetts

June 29-30, 1976 and July 1, 1976

Date	No of Subject	Job Classification	S[1]	NS[2]	Pre-Exposure Appx. Time	Pre-Exposure Air Level-ppm	Pre-Exposure % COHb	Post-Exposure Appx. Time	Post-Exposure Air Level-ppm	Post-Exposure % COHb	Cigarette Smoking Habits Pre-Exposure[3]	Cigarette Smoking Habits Post-Exposure[4]
6/29	1	Core Painter		x	0600	9	2.3	1430	15	3.5		
6/30	1	Core Painter		x	0600	10	2.5	1430	15	3.5		
7/1	1	Core Painter		x	0600	20	4.5	1430	16	3.7		
				AVERAGE		13	3.1		15.3	3.6		
6/29	3	Core Finisher		x	0600	6	1.7	1430	6	1.7		
6/30	3	Core Finisher		x	0600	6	1.7	1430	7	1.8		
7/1	3	Core Finisher		x	0600	13	3.5	1430	15	4.1		
				AVERAGE		8.3	2.4		9.3	2.5		
6/29	4	Core Finisher	x		0600	20	4.5	1430	28	6.1	5	12
6/30	4	Core Finisher	x		0600	25	5.5	1405	26	5.7	2	4
7/1	4	Core Finisher	x		0600	27	5.9	1500	27	5.9	1	1
				AVERAGE		24	5.3		27	5.9		
6/29	5	Large Pourer		x	1110	13	3.1	1500	28	6.1		
6/30	5	Large Pourer		x	1200	11	2.9	1545	31	6.7		
7/1	5	Large Pourer		x	1130	19	4.3	1500	23	5.1		
				AVERAGE		14	3.4		27	6.0		
6/29	6	Large Pourer	x		1100	39	8.3	1515	52	10.9	10	8
6/30	6	Large Pourer	x		1100	52	10.9	1545	56	11.7	12	1
7/1	6	Large Pourer	x		1100	54	11.3	1545	56	11.7	12	1
				AVERAGE		48	10.2		54.7	11.4		
6/29	7	Small Pourer	x		1100	24	5.3	1510	51	10.7	9	5
6/30	7	Small Pourer	x		1200	32	6.9	1545	42	8.9	3	5
7/1	7	Small Pourer	x		1100	40	8.5	1545	33	7.0	4	6
				AVERAGE		32	6.9		42	8.9		
6/29	8	Small Pourer	x		1100	30	6.5	1505	40	8.5	6	15
6/30	8	Small Pourer	x		1100	28	6.1	1545	36	7.7	4	6
7/1	8	Small Pourer	x		1030	27	5.9	1545	37	8.0	5	4
				AVERAGE		28	6.2		38	8.1		
6/29	9	Cupola Tender	x		0600	25	5.5	1510	42	8.9	2	20
6/30	9	Cupola Tender	x		0600	24	5.3	1500	49	10.3	5	25
7/1	9	Cupola Tender	x		0600	41	8.7	1500	41	8.7	2	20
				AVERAGE		30	6.5		44	9.3		
7/1	10	Small Shake-out		x	1100	13	3.1	1500	32	6.9		
Environmental Criteria							5% COHb			5% COHb		

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1. Denotes that the employee is a smoker.
2. Denotes that the employee is not a smoker.
3. Denotes the number of cigarettes smoked before the pre-exposure sample was taken
4. Denotes the number of cigarettes smoked after the pre-exposure sample was taken but before the post-exposure sample was taken.

Table 11

Formaldehyde Concentrations Measured at the Breathing Zone of the Shell Core Machine Operator - Ferrous Foundry

Hersey Products Company, Inc.
Gilbertville, Massachusetts

June 29, 1976

Sample Number	Sampling Period	Sample Volume-liters	Airborne Concentration-ppm[a]
FF-1	0614-0644	30	0.41
FF-2	0645-0715	30	<.02
FF-3	0716-0746	30	0.08
FF-4	0747-0817	30	<.02
FF-5	0818-0848	30	4.49
FF-6	0849-0919	30	18.3
FF-7	0920-0950	30	0.45
FF-8	0950-1020	30	0.57
FF-9	1021-1051	30	0.49
FF-10	1052-1122	30	0.41
FF-11	1130-1200	30	0.24
FF-12	1230-1300	30	<.02
FF-13	1305-1335	30	0.37
[illegible]-14	1336-1406	30	10.6
Environmental Criteria			1 ppm

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a. Parts of airborne formaldehyde per million parts of contaminated air by volume.

Table 12

Concentrations of Phosphoric Acid Measured at the Breathing Zone of the No-Bake Core Maker - Ferrous Foundry

Hersey Products Company, Inc.
Gilbertville, Massachusetts

June 29-30 and July 1, 1976

Sampling Date	Sample Number	Sampling Period	Sample Volume liters	Airborne Concentration $\mu g/m^3$ (a)
6/29	FAA-100	0625-0955	320	9.1
6/29	FAA-101	0957-1200 1238-1415	330	18.2
6/30	FAA-102	0612-1115	455	2.0
6/30	FAA-103	1240-1415	143	<0.9
7/1	FAA-104	0607-1019	378	3.4
7/1	FAA-105	1019-1155 1238-1410	282	21.8
Environmental Criteria				1000 ug/M^3

a. Micrograms of phosphoric acid per cubic meter of contaminated air by weight.

Table

Concentrations of Furfural and Isopropanol Measured at the Breathing Zone of the No-Bake Core Painter - Ferrous Foundry

Hersey Products Company, Inc.
Gilbertville, Massachusetts

June 29-30, and July 1, 1976

Sampling Date	Sample Number	Sampling Period	Sample Volume-liters	Airborne Concentrations-ppm[a] Furfural	Isopropanol
6/29	CT-150	0630-0800	19.7	<L.D.[b]	19.1
6/29	CT-154	0800-0930	18.9	<L.D.	4.7
6/29	CT-1293	0935-1113	21.9	<L.D.	1.2
6/29	CT-1292	1115-1200	27.9	<L.D.	11.5
6/30	CT-1334	0612-0800	22.1	<L.D.	43.1
6/30	CT-1290	0800-0955	26.6	<L.D.	13.8
6/30	CT-1288	1000-1157	23.4	<L.D.	10.7
6/30	CT-151	1240-1415	19.0	<L.D.	15.2
7/1	CT-367	0612-0755	20.6	<L.D.	17.0
7/1	CT-1001	0800-0958	24.8	<L.D.	9.6
7/1	CT-1002	1000-1155	24.5	<L.D.	8.6
7/1	CT-1003	1240-1410	20.7	<L.D.	10.5
Environmental Criteria					400 ppm

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a. Parts of Isopropanol per million parts of contaminated air by volume.
b. Less than the lower limit of detection (0.01 mg per sample).

Table 14

Summary of Personal Air Sampling Concentration Data for Particulate Polycyclic Organic Matter (PPOM) as Cyclohexane Solubles and Benzo{a} Pyrene(BaP)/Benzo{e} pyrene(BeP) - Ferrous Foundry

Hersey Products Company, Inc.
Gilbertville, Massachusetts

June 29 and 30, 1976

Sampling Date	Sample Number	Job Description and/or Classification	Sampling Period	Sample Volume liters	Airborne Concentration Data-ug/m$^{3(a)}$ PPOM	Airborne Concentration Data-ug/m$^{3(a)}$ BaP/BeP
6/29	SMF-17	Small Mold Pourer	1155-1504	378	1.4	<0.5
6/29	SMF-1	Small Mold Pourer	1205-1504	358	0.69	<0.5
6/30	SMF-21	Small Mold Pourer	1200-1544	449	2.89	<0.5
6/30	SMF-27	Small Mold Pourer	1211-1542	422	1.85	<0.5
6/29	SMF-15	Large Mold Pourer	1158-1501	366	3.00	<0.5
6/29	SMF-11	Large Mold Pourer	1206-1510	368	1.32	<0.5
6/30	SMF-26	Large Mold Pourer	1208-1542	428	5.35	<0.5
6/30	SMF-22	Large Mold Pourer	1213-1537	408	0.87	<0.5
Environmental Criteria					200 ug/M^3	

a. Denotes micrograms of contaminant per cubic meter of contaminated air.

Table 15

Summary of Personal Air Sampling Concentration Data
for
Iron Oxide Fume and Total Particulate Measured During Metal Casting - Ferrous Foundry

Hersey Products Company, Inc.
Gilbertville, Massachusetts

Sampling Date	Sample Number	Job Description and/or Classification	Sampling Period	Sampling Volume Liters	Airborne Concentration Data - mg/M^3 (a) Iron Oxide Fume (Fe_2O_3)	Total Dust
6/30	PV-191	Small Mold Pourer	1200-1544	336	0.21	2.76
6/30	PV-435	Small Mold Pourer	1211-1542	317	0.34	5.91
7/1	PV-82	Small Mold Pourer	1133-1542	374	0.14	2.08
7/1	PV-442	Small Mold Pourer	1135-1539	366	0.35	6.73
6/30	PV-134	Large Mold Pourer	1208-1542	321	0.22	4.91
6/30	PV-106	Large Mold Pourer	1213-1537	306	0.23	2.97
7/1	PV-133	Large Mold Pourer	1130-1540	375	0.18	3.39
7/2	PV-158	Large Mold Pourer	1139-1545	369	0.11	2.76
Environmental Criteria					5 mg/M^3	10 mg/M^3

a. Denotes milligrams of contaminant per cubic meter of contaminated air.

Table 16

Summary of Personal Air Sampling Concentration Data for Iron Oxide Dust and Total Dust Measured During Casting Finishing - Ferrous Foundry

Hersey Products Company, Inc.
Gilbertville, Massachusetts

Sampling Date	Sample Number	Job Description and/or Classification	Sampling Period	Sampling Volume Liters	Airborne Concentration Data - mg/M^3 (a) Iron Oxide Dust (Fe_2O_3)	Total Dust
6/29	PV-276	Snagger-Grinder	0734-1201	401	8.25	12.2
6/29	PV-53	Snagger-Grinder	1235-1523	170	15.2	24.8
6/30	PV-73	Snagger-Grinder	0711-1125 1240-1531	638	9.69	14.1
6/30	PV-159	Snagger-Grinder	0710-1153 1240-1500	634	5.08	6.58
6/29	PV-283	Pedestal-Grinder	0736-1201 1243-1515	626	0.85	1.78
6/30	PV-88	Pedestal-Grinder	0714-1151 1245-1525	656	1.26	2.26
Environmental Criteria					5 mg/M^3	10 mg/M^3

a. Denotes milligrams of contaminant per cubic meter of contaminated air.

Table 17

Summary of Personal Sampling Concentration Data for Total Respirable Free Silica and Total Respirable Particulate - Non-Ferrous Foundry

Hersey Products Company, Inc.
Gilbertville, Massachusetts

June 29-30, 1976

Sampling Date	Sample Number	Job Description(a)	Sampling Period	Sample Volume Liters	Total Free Silica		Airborne Concentration Data - mg/M^3(b)		OSHA Silica Standard mg/M^3
					mg	%	Total Free Silica	Total Respirable Dust	
6/29	RPV-85	Molding/Pouring/Shakeout	0520-1155 1233-1523	961	0.05	19	0.05	0.27	0.48
6/29	RPV-116	Shakeout/Fettling	0530-1155 1233-1523	982	0.04	31	0.04	0.13	0.30
6/29	RPV-169	Fettling	0534-1155 1233-1621	1035	0.02	40	0.02	0.04	0.24
6/30	RPV-205	Molding/Pouring/Shakeout	0520-1200 1235-1430	876	0.04	15	0.05	0.30	0.59
6/30	RPV-197	Shakeout/Fettling	0525-1200	672	0.13	62	0.19	0.31	0.16
Environmental Criteria							0.05 mg/M^3	5 mg/M^3	

a. Denotes job descirption(s) of the employee during the sampling interim.
b. Denotes milligrams of contaminant per cubic meter of contaminated air.

Table 18

Summary of Work-Area Sampling Concentration Data for Total Respirable Free Silica and Total Respirable Particulate - Non-Ferrous Foundry

Hersey Products Company, Inc.
Gilbertville, Massachusetts

Sample Number	Sampling Station	Sampling Period	Sample Volume Liters	Total Free Silica mg	Total Free Silica %	Airborne Concentration Data - mg/M^3 (a) Total Free Silica	Airborne Concentration Data - mg/M^3 (a) Total Respirable Dust	OSHA Silica Standard mg/M^3
ARPV-55	Molding/Shakeout Floor	0535-1430	4815	0.28	29	0.06	0.20	32
Environmental Criteria						0.05 mg/M^3	5 mg/M^3	

a. Milligrams of contaminant per cubic meter of contaminated air.

Table 19

Formaldehyde Concentrations Measured at the Breathing Zone
of the
Shell Core Machine Operator - Non-Ferrous Foundry

Hersey Products Company, Inc.
Gilbertville, Massachusetts

June 29, 1976

Sample Number	Sampling Period	Sample Volume Liters	Airborne Concentration ppm[(a)]
FH - 1	1417-1447	30	0.03
FH - 2	1453-1523	30	0.24
FH - 3	1530-1600	30	0.24
FH - 4	1605-1623	30	0.29
Environmental Criteria			1 ppm

a. Parts of formaldehyde per million parts of contaminated air by volume.

Table 20

Personal Exposures to Metallic Aerosols and Total Particulate
by
Aluminum Foundry Workers

Hersey Products Company, Inc.
Gilbertville, Massachusetts

June 29, 1976

Sample Number	Job Description[(a)]	Sampling Period	Sample Volume Liters	Airborne Concentration Data - ug/M^3 (b)					Total Particulate mg/M^3 (c)
				Lead	Copper	Zinc	Aluminum	Nickel	
APV-365	Melter	0520-0745	218	<7	3	131.8	77.3	<5	0.59
APV-274	Pourer/Shakeout	0757-1155 1233-1410	503	<7	18	18	42.0	<5	0.86
APV-81	Utility	0530-0755	218	<7	3	31.8	95.5	<5	2.2
APV-284	Utility/Shakeout	0755-1155 1233-1523	615	<7	3	11.3	69.4	<5	1.0
APV-369	Fettler	0534-1155	914	<7	23.1	7.8	35.6	<5	0.36
Environmental Criteria				100	1000	5000	10000	15	10

a. Denotes job description(s) of the employee during the sampling interim.
b. Denotes micrograms of contaminant per cubic meter of contaminated air.
c. Denotes milligrams of contaminant per cubic meter of contaminated air.

Table 21

Personal Breathing Zone Exposures to Metallic Aerosols and Total Particulates
by the
Bronze Foundry Workers

Hersey Products Company, Inc.
Gilbertville, Massachusetts

June 30, 1976

				Airborne Concentration Data					
Sample Number	Job Description[a]	Sampling Period	Sample Volume Liters	Lead ug/M^3[b]	Copper ug/M^3	Zinc ug/M^3	Aluminum ug/M^3	Nickel ug/M^3	Total Particulate mg/M^3[c]
BPV-92	Melting/Pouring	0520-1035	473	25.5	8.5	297.8	<15	<5	0.79
ABPV-349	Pouring/Shakeout	1035-1200 1235-1330	210	<7	19.1	<1	<15	<5	0.27
ABPV-114	Molding/Pouring	0530-1200 1235-1354	704	12.9	10.0	52.9	61.4	<5	1.61
ABPV-410	Utility-man	0525-1200	593	22.0	11.9	111.9	91.5	<5	1.64
ABPV-407	Fettling	0600-1200 1235-1410	683	242.7	618.6	102.9	63.2	<5	1.69
Environmental Criteria				100	1000	5000	10000	15	10

a. Denotes job description(s) of the employee during the sample interim.
b. Denotes micrograms of contaminant per cubic meter of contaminated air.
c. Denotes milligrams of contaminant per cubic meter of contaminated air.

Table 22

Gaseous and Particulate Inorganic Fluoride Concentrations Measured at the Breathing Zone of an Aluminum Furnace Tender

Hersey Products Company, Inc.
Gilbertville, Massachusetts

Sample Number	Sampling Period	Sample Volume Liters	Airborne Concentrations -mg/M^3[a] Gaseous	Particulate	Total
FLI-1	0747-1030	163	0.06		1.25[b]
FLA-1	0747-1030	163		1.19	
FLI-2	1030-1155/1233-1400	172	<L.D.[c]		<L.D.
FLA-2	1030-1155/1233-1400	172		<L.D.	
Environmental Criteria					2.5

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a. Milligrams of contaminant per cubic meter of air.
b. Sum of the gaseous and particulate inorganic fluorides.
c. Less than the limit of detection (3 ug per sample).

Table 23

Worker Complaints as Obtained by Questionnaire, Current and Past

Hersey Products Company, Inc.
Gilbertville, Massachusetts

June 1976

	FERROUS FOUNDRY				NON-FERROUS FOUNDRY	
	No history of occupational lead exposure		History of occupational lead exposure			
SYMPTOM	Probably job related	Probably not job related	Probably job related	Probably not job related	Probably job related	Probably not job related
"Brass Chills"	0	-	2	-	3	-
Metalic Taste	0	0	1	0	2	0
Eye Irritation	1	2	1	0	0	1
Nose &/or Throat Irritation &/or Dryness	6	3	1	1	1	0
gh	4	7	1	0	0	0
Chest Tightness or Pain	1	1	0	1	0	0
Shortness of Breath	2	5	0	2	0	1
Other Respiratory Problems	1	2	0	0	0	0
Poor Appetite, Nausea, Vomitting or Stomach Problems	2	2	1	1	0	0
Constipation and/or Abdominal Cramping	0	0	1	0	0	1
Nervousness and/or Irritability	3	6	0	1	0	0
Tiredness or Weakness	4	4	2	0	0	0
Muscle or Joint Pain	2	7	1	0	0	0
Skin/Rashes	3	1	0	0	1	0
Sleep Problems	0	4	0	1	0	0
her Problems	0	7	0	1	0	0
Total Number Of Workers	30		5		5	

Table 24

Worker Complaints as Obtained by Questionnaire, Current and Past

Hersey Products Company, Inc.
Gilbertville, Massachusetts

June 1976

	FERROUS FOUNDRY		NON-FERROUS FOUNDRY
	No history of occupational lead exposure	History of occupational lead exposure	
Total Number of Workers	30	5	5
Total workers with complaints probably job related	17	4	5
Total workers without complaints probably job related	13	1	0
Total workers with complaints probably not job related	24	3	3
Total workers without complaints probably not job related	6	2	2
Total workers with some complaint	27	5	5
Total workers with no complaints	3	0	0

Table 25

Laboratory Results of Blood Tests

Hersey Products Company, Inc.
Gilbertville, Massachusetts

June 1976

	FERROUS FOUNDRY			NON-FERROUS FOUNDRY	
	History of Occupational Lead Exposure				
	No	Yes	Total		NORMALS(Male)
Number of Workers Tested	3	2	5	4	
Blood Lead (ug/100 ml whole blood)					
Average Value	49.3	59.5	53.4	59.0(n=5)	less than 40*
Range	41-57	59-60	41-60	38-82	
Erythrocyte Protoporphyrin (ug/100 ml whole blood)					
Average Value	23.0	33.0	27.0	96.0	less than 60@
Range	20-24	32-34	20-34	20-275	
Hematocrit (%)					
Average Value	42.5	43.8	43.0	39.2	40-54
Range	40.5-44.0	43.5-44.0	40.5-44.0	32.5-42.5	
Years of Occupational Exposure to Lead					
Average	0	3.3	0.9	4.4	--
Range	--	2-2½	0-2½	½-11	

*Blood leads on adults with no occupational exposure to lead are usually below 40 ug/100 ml whole blood. Levels between 40 and 60 ug/100 ml indicate increased exposure to lead, but generally are considered safe. The status of blood levels between 60 and 80 ug/100 ml are in doubt, but the likelihood of toxic symptoms are known to increase as the blood lead levels increase above 80 ug/100 ml.

@Erythrocyte Protoporphyrin (EP) levels have been studied in children, but not as well in adults. A level of 60 roughly corresponds to a blood lead of 40 ug/100 ml whole blood. In adults an EP level of 200 roughly corresponds to a blood lead of 60 ug/100 ml.

Table 26:

Recommendations for Respirator Usage at Airborne Crystalline Silica, Inorganic Lead Particulate and Formaldehyde Above the Exposure Limit.

Hersey Products Company, Inc.
Gilbertville, Massachusetts

Substance	Concentration of Contaminant in Multiples of Limit	Recommended Respirator Type
Silica	Less than or equal to 5x	Single use (valueless type) dust respirator.
Silica	Less than or equal to 10x	Quarter or half mask respirator with replaceable dust filter or single use (with valve) dust respirator.
Lead Dust	Less than or equal to 7x	Air purifying respirator (except single use types), with fume or high efficiency particulate filter (99.97% efficient against 0.3 micron size particles).
Formaldehyde	Less than or equal to 2x,	Chemical cartridge respirator and organic vapor cartridge and full facepiece.
	Greater than 2x, up to 10x	Chemical cartridge respirator and organic vapor cartridge and full facepiece.
	Greater than 10x, up to 100x	Full-face mask, chest-or back-mounted type, with industrial size organic vapor canister.