

LEAD PROBLEMS IN GRAY IRON FOUNDRIES

by

Carmen W. Pompeii

Submitted in Partial Fulfillment of the Requirements

for the Degree of

Master of Science

in the

Chemistry

Program

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THESIS

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TITLE LEAD PROBLEMS IN GRAY IRON FOUNDRIES

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ABSTRACT

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In order to determine whether or not potentially hazardous lead concentrations are present in gray iron foundry processing and employee's breathing zone, the lead concentrations were determined at various locations within several foundries. The foundries used in this study were limited to those that use crushed engine blocks in their feedstock. In addition, the possible sources of the airborne lead were investigated. The investigation was conducted to determine the type of scrap material used in the feedstock. The composition of the feedstock does not change from foundry to foundry, the only variable would be the type of scrap material used. The feedstock consists of pig iron, steel plate, reclaimed risers and sprues, and scrap.

The engine block material was returned to the laboratory to be acid washed for determination of lead. The results of the leaching showed that scrap containing carbon residue were found to contain the highest lead values, 14.71 mg/mL.

Since the gray iron foundry industry uses electric melt and cupola melt as the primary melting sources, a determination was made to evaluate lead levels at those facilities. Personal exposure results

for cupola melt foundry show the transfer ladle operator exposure to lead to be 0.11 mg/m^3 , cupola tender 0.08 mg/m^3 , iron pourers exposure average was 0.06 mg/m^3 , and the cupola chargers' exposure averaged 0.05 mg/m^3 . Personal samples collected in the electric melt foundry showed the highest exposure to the furnace operator, as large as 1.44 mg/m^3 , furnace charger 1.14 mg/m^3 , bull ladle operator 0.22 mg/m^3 and iron pourers 0.33 mg/m^3 .

The results of the airborne lead sampling indicate that the gray iron foundry industry, which processes scrap engine material, has a potentially serious health problem. This problem is occurring during the melting and pouring of molten metal. The results of the personal exposures indicate a serious violation of the present OSHA standard for lead.

A source of lead, which may not be readily recognized in the reclaiming of old engines, is leaded gasoline. Upon remelting the scrap, the lead residue found on the engine block material, is boiled off and releases lead fumes into the breathing zone of the employees.

This work demonstrated that the procedures outlined in this thesis are reliable and reproducible for the determination of lead in feedstock material. The results of personal exposure sampling show that employees working in gray iron foundries using scrap engine block material are exposed to excessive amounts of lead. Lead has been detected in other kinds of feedstock for foundries. Studies similar to the ones done here are very much needed as potentially serious health hazards may exist at foundries that use those various feedstock.

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ABBREVIATIONS AND DEFINITIONS

mg/m ³	Milligrams per cubic meter of air
μg/mL	Micrograms per milliliter
mm	Millimeter
nm	Nanometer
°F	Degree Fahrenheit
°C	Degree Celsius
PEL	Permissible Exposure Level
TWA	Time Weighted Average (Employee's exposure averaged over any 8-hour work shift of a 40-hour work week)
PPE	Personal Protective Equipment
OSHA	Occupational Safety and Health Administration
ANSI	American National Standards Institute
NIOSH	National Institute for Occupational Safety and Health
ACGIH	American Conference of Governmental Industrial Hygienists
MSA	Mine Safety Appliance
gray iron	High carbon ferrous alloy

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CHAPTER I

RECOGNITION OF LEAD AS A HEALTH HAZARD

The history of lead has been traced as far back as 3000 B.C. The earliest known specimen was a figure found at Dardanelles on the site of the ancient city of Abydos. Egyptian hieroglyphics of about 1500 B.C. make reference to lead and lead plates and statues found in the tomb of Rameses III.^{1,2}

The first fully documented reference to lead colic was by Hippocrates in 370 B.C., however, Nicander, in second century B.C., described the symptoms of lead poisoning much more accurately and in more detail. The symptoms were well recognized when Deoscorides described lead poisoning in 2 B.C. Vitruvius, in 1 B.C., recognized the hazard associated with the use of lead piping in water systems, and it was suggested that the fall of the Roman Empire might be ascribed to the use of lead acetate to sweeten wine. Citois and De la Mach, in the seventeenth century, recognized this practice as dangerous. Sir George Barker, in 1767, traced lead colic, called "Devonshire colic", to cider which had been contaminated with lead. In 1814, Orfila published a treatise on toxicology in which he mentioned lead.²

The first noted publication on lead was by Tanquered des Planches³ in 1839, a treatise on lead disease. In 1840, the association of the "Burtonian Line," a blue line of the gum, with lead absorption was made by Burton.⁴ At the time of this discovery, the

publication of chemical methods for detection of lead in blood and/or urine was developed.

Legislation was not introduced to control this industrial hazard until the Factory Act of 1864 in Europe; other regulations were introduced in 1878 and 1883. The first study of the effects of lead absorption came in 1892 by Garrod in his study of porphyrinuria in human plumbism. It was not until 1899 that lead poisoning became a fully recognized disease.²

In 1903, the Austro-Hungarian government ordered an investigation of lead poisoning in the smelting industry. This survey showed thirty-nine cases of lead colic among workers in the Pribiam works from 1894 to 1903.

In 1905, the German government established the "German Regulations for Lead Smelting Works." The regulation called for sufficient air exchanges in the melt area, smooth walls and floors to prevent lead dust accumulation, and the cleaning of the areas to be accomplished by a wet method to allay dust at least daily. The regulation called for capturing the dusts, gases, and lead fumes as near as possible at the point of origin. Women and young persons were not permitted in smelting areas and those employed in charging blast furnaces were not permitted to work more than eight hours daily. The regulation also called for complete suits of working clothes, including caps and respirators, showering at least daily, and restricting food, cigars, and cigarettes in the regulated areas of the smelting operation. This regulation took effect on January 1, 1908.⁵

The French passed legislation in 1908 known as "French Regulations Relating to Precautions Against Industrial Lead Poisoning."

This regulation contained all the requirements of the German Regulation plus requiring a surgeon at every work to examine every man on the premises at least once a month. The regulation also required the posting of a notice pointing out the causes of plumbism, the means of preventing it, or of curing it.⁶

The first noted regulation in the United States was adopted by the State of New Jersey in 1914. The regulation covered the lead and copper industries within the state. This regulation adopted practically all the precautions abroad, but there was no regulation forbidding the workers in the more dangerous processes from working more than a limited number of hours per day.⁷

Development of a Lead Standard in the United States

At one time, an airborne exposure limit to lead of 0.50 mg/m^3 was generally accepted, although the source of this limit is not well documented. In 1933, the first written proposal for limiting lead dust and fume in industry was made by Russell, et al.,⁸ based on the recommendations of a 1928 Public Health Service survey. The proposed standard called for an airborne exposure limit of 0.15 mg/m^3 . In the 1930's and 1940's, a value of 0.15 mg/m^3 was a common, but often unachieved, goal.

In 1943, Kehoe and other members of the Committee on Lead Poisoning of the American Public Health Association recommended 0.15 mg/m^3 as a time weighted average limit.⁹ In an article published in 1947, Winn and Shroyer¹⁰ concluded that maintenance of the average concentration of lead dust and fume at or below 0.50 mg/m^3 , combined with a medical program, would assure adequate control.

The 0.15 mg/m³ limit value continued to be the most often accepted value until 1957. In that year the American Conference of Governmental Industrial Hygienist (ACGIH) increased the limit to 0.20 mg/m³ in the belief that the past standard was too stringent. The American opinion seems to have been that the 0.20 mg/m³ value was adequate to prevent episodes of lead intoxication. At a meeting in Amsterdam in November 1968, The International Subcommittee for Occupational Health of the Permanent Commission and International Association of Occupational Health recommended a limit of 0.15 mg/m³ for a 40-hour work week.¹¹

In 1967, The American National Standards Institute's Z-37 Committee established 0.20 mg/m³ as its acceptable concentration for lead. The ACGIH recommended, in 1971, lowering their exposure limit from 0.20 mg/m³ to 0.15 mg/m³. This appears to have been based on the recommendations of the International Subcommittee for Occupational Health, 1968 meeting.¹²

In 1970, with the establishment of the Occupational Safety and Health Act, The Occupational Safety and Health Administration set a workroom air standard of 0.20 mg/m³ based on an eight-hour time-weighted average for lead and its inorganic compounds. The background for this standard was based on a national consensus standard, ANSI Z-37.11-1969. ANSI provided no basis for its recommendation.¹³

In January 1973, the Director of NIOSH submitted to the Secretary of Labor a criteria document recommending lowering the existing permissible exposure limit for inorganic lead from 0.20 mg/m³ to 0.15 mg/m³. A joint effort by both OSHA and NIOSH upon analysis

and review of new scientific data not available in the original criteria document, recommended that the 0.15 mg/m^3 be reduced to a lower value.

In October 1975, OSHA proposed a new Occupational Safety and Health standard for exposure to lead. The standard included a permissible exposure limit of 0.1 mg/m^3 combined with provisions for environmental monitoring, medical surveillance, employee training, and other protective measures.

The present lead standard was published in November 1978. The new standard had a time weighted average level of 0.05 mg/m^3 , to which an employee may be exposed, and called for lower exposure levels during longer working days. The standard requires companies to provide for environmental monitoring, biological monitoring (when environmental levels exceed 0.03 mg/m^3), hygiene facilities and practices, medical removal protection, and employee information and training.¹⁴

Statement of the Problem

The ferrous foundry industry consists of gray iron, white iron, ductile iron, and alloy gray iron. The foundries of concern in this research are those producing gray iron castings. Gray iron castings consist of high-carbon ferrous alloys. The ferrous alloys are produced by combining iron, carbon, and silicon with small percentages of manganese, sulfur, and phosphorus.¹⁵

An occupational disease claim was filed with the Industrial Commission of Ohio in 1976 by a furnace operator, contending that he had contracted lead poisoning from working in a gray iron foundry.

An industrial hygiene survey was conducted at that gray iron foundry to investigate possible sources of lead. Actual field measurements were taken for the detection of airborne metal fumes and particulate to which the employees were exposed. The melting process used at this facility consisted of electric induction furnaces.

The discovery of airborne lead at that foundry and the knowledge of adverse health effects caused by inhalation and ingestion of lead, indicate the need for further research in the area.

Since the gray iron foundry industry may employ other methods to melt the scrap, it was of interest to determine the lead levels from other melt processes for comparison. The two most important melting processes used in the gray iron foundry industry are electric induction and cupola furnaces.

The feed scrap material used in the foundry melt may vary considerably. It is the intent of this thesis to limit the scope of research to those foundries using crushed or whole engine block material. The reason for the limitation was that the initial foundry, where lead had been detected, was processing clean crushed engine blocks in the melting process.

It is the purpose of this thesis to present procedures for the recognition and evaluation of lead in gray iron foundries. The procedures outlined in this paper will be easily reproduced to insure uniformity for evaluating possible sources of lead contamination. Also, it is the purpose of this thesis to bring to light the possible adverse health conditions, which may occur from exposure to lead fume and particulate, when reclaiming scrap engine block material.

CHAPTER II

MATERIAL AND APPARATUS

The necessary equipment used for the collection of environmental samples for metal fumes consists of a MSA model G personal sampling pump, manufactured by the Mine Safety Appliance Company, Pittsburgh, Pennsylvania. A three foot piece of Tygon flexible plastic tubing, R3603, one quarter inch inside diameter, 7/16 inch outside diameter, manufactured by Norton Plastics and Synthetics Division, Akron, Ohio. The tubing was used to connect the filter to the sampling pump. The filter unit was a three piece polystyrene cassette containing a mixed cellulose ester filter, 37 mm diameter 0.8 micron pore size, and a cellulose support pad. The filter and cassettes were obtained from Millipore Corporation, Bedford, Massachusetts. A Simpson Volt-Ohm-Milliammeter Model 260 manufactured by Simpson Electric Company, Chicago, Illinois, was used. The volt meter was used to determine the voltage on the battery packs for the MSA personal sampling pumps.

The Eberbach water bath shaker, used for the leaching of scrap parts, was manufactured by Eberbach Company, Ann Arbor, Michigan. This equipment was equipped with a variable speed control and a heating unit for temperature control of water. An IEC Clinical Centrifuge, manufactured by Damon Division, IEC, Needham Heights, Massachusetts was used to separate the solution and particulate matter before analysis.

The instrument used for analysis of the acid bath solutions was an Instrumentation Laboratory AA-AE, Model 157, atomic absorption spectrophotometer, manufactured by Instrumentation Laboratory, Lexington, Maine. The lead standard used to set the internal curve was purchased from Harleco, Gibbstown, New Jersey. The standard contained 1.0 mg/mL of lead.

The environmental samples were sent to certified laboratories* for analysis. The samples were analyzed using a Jarrell Ash Atom. Comp., Model 975, Plasma Emission Spectrograph, manufactured by Fisher Scientific, Pittsburgh, Pennsylvania. The acids used to prepare the filters and engine parts for analysis were: ACS reagent grade nitric acid (70.5%), containing 2.0×10^{-5} per cent lead and ACS reagent grade hydrochloric acid (37%), containing 1.0×10^{-5} per cent lead. The acids were obtained from Mallenckrodt, Inc., Paris, Kentucky. The lead concentration was determined by the manufacturer and noted on the label.

The various parts of the crushed engine block were obtained in the foundry yard and from the scrap supplier. The parts were collected for semi-quantitative analysis for lead. The parts consisted of the cylinder wall sections, piston connecting rods, piston head, and valve stems. The cylinder walls were rust coated on the external side and had a noticeable silvery flashing on the internal side of the engine. The piston connecting rods had a faint oily coating, probably because they were submerged in the crankcase oil.

*Ohio Health Department Laboratory, Columbus, Ohio,
University of Wisconsin Occupational Health Laboratory, Madison,
Wisconsin.

The valve stems were noted to have a large carbon residue accumulation and a rusty appearance. The scrap supplier usually will wash the crushed engine parts to remove the excess oil and grease. The wash material is a strong alkaline material, usually sodium hydroxide. The alkaline solution removes oils and grease, but does not have any affect on the surface metals and carbon residue.

Four foundries were sampled to determine employee exposure to lead fumes. Two foundries used electric induction melting furnaces to process their metal. Two foundries used cupola melt process to prepare their molten metal.

Electric melt foundry No. 1 consisted of three 15-ton furnaces and a preheater. A charge for the furnace consisted of steel plate, pig iron, reclaim, and crushed engine blocks. The charge was placed in the preheater for approximately fifteen minutes at a temperature of 1000°F. The charge was then taken from the preheater by charging bucket to any one of the three furnaces. The charge was melted at 2800°F in the furnace before being poured into transfer ladles, which supply the floor pouring ladles.

Electric melt foundry No. 2 was equipped with one electric furnace. The capacity of the furnace was approximately two tons. There was no preheating operation performed at this location. The operation consisted of charging engine heads, manifolds, water pumps, and other engine accessory parts. The procedure used was to pour only half the furnace capacity. See Figure 1 for a diagram of an electric melting furnace.

The cupola foundries use what is called a cupola melt furnace. A cupola furnace is a 20 to 40 foot vertical cylinder steel-plate

stack, lined with refractory material. Air enters through openings near the bottom of the stack, making coke extremely hot. The heat causes the metal to melt and trickle down through the coke and collect on the sandy bottom. See Figure 2 for a diagram of a cupola furnace.

Cupola foundry No. 1 was equipped with two 5-ton furnaces. The furnaces were not operating at the same time. The procedure for loading the furnace consisted of placing coke in the bottom of the stack, then a layer of scrap metal, pig iron and steel plate, and then a layer of limestone. The addition of these three layers would be continued during the entire day.

The second cupola foundry had a furnace with a capacity of approximately one ton. This furnace was charged at least once during each pour. The charging procedure is the same as outlined previously.

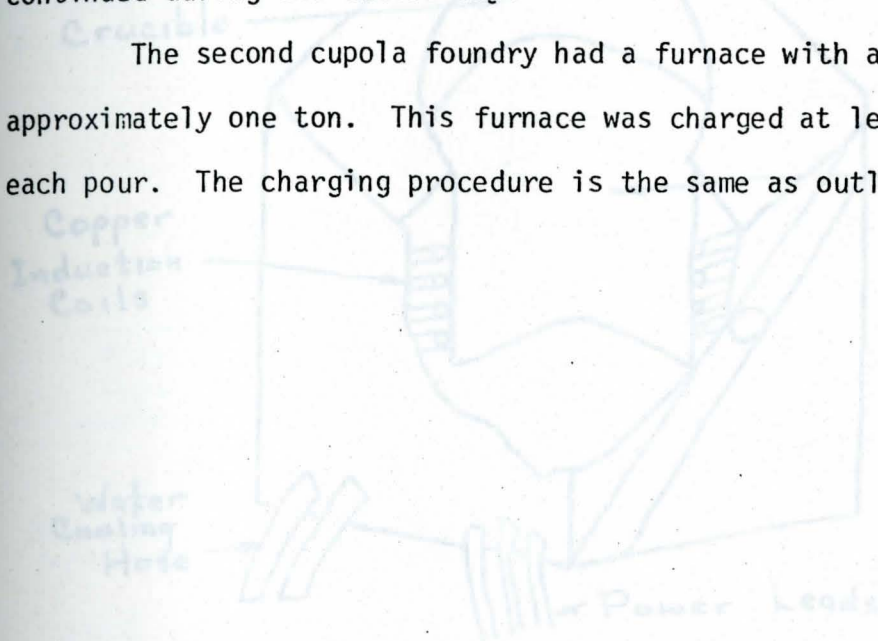


Figure 1

Diagram of Induction Melting Furnace

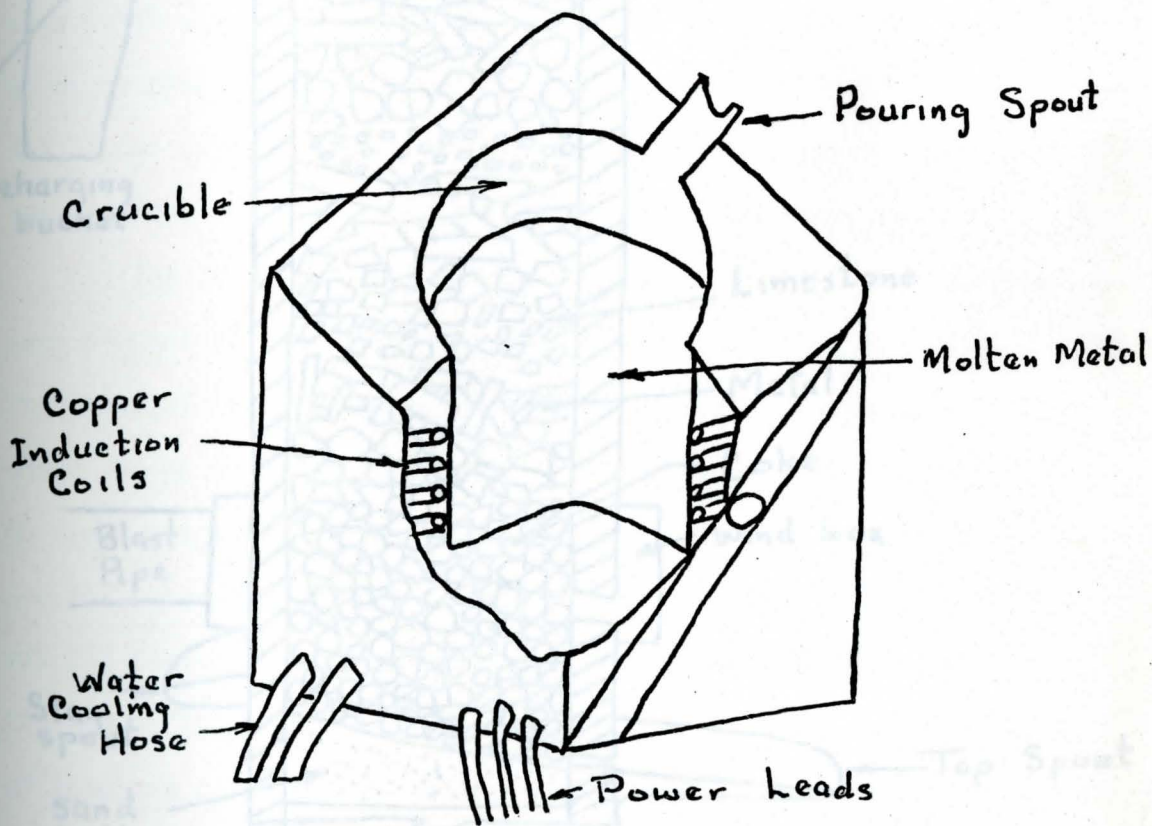


Figure 1

Diagram of Induction Melting Furnace

Figure 2

Diagram of a Typical Cupola

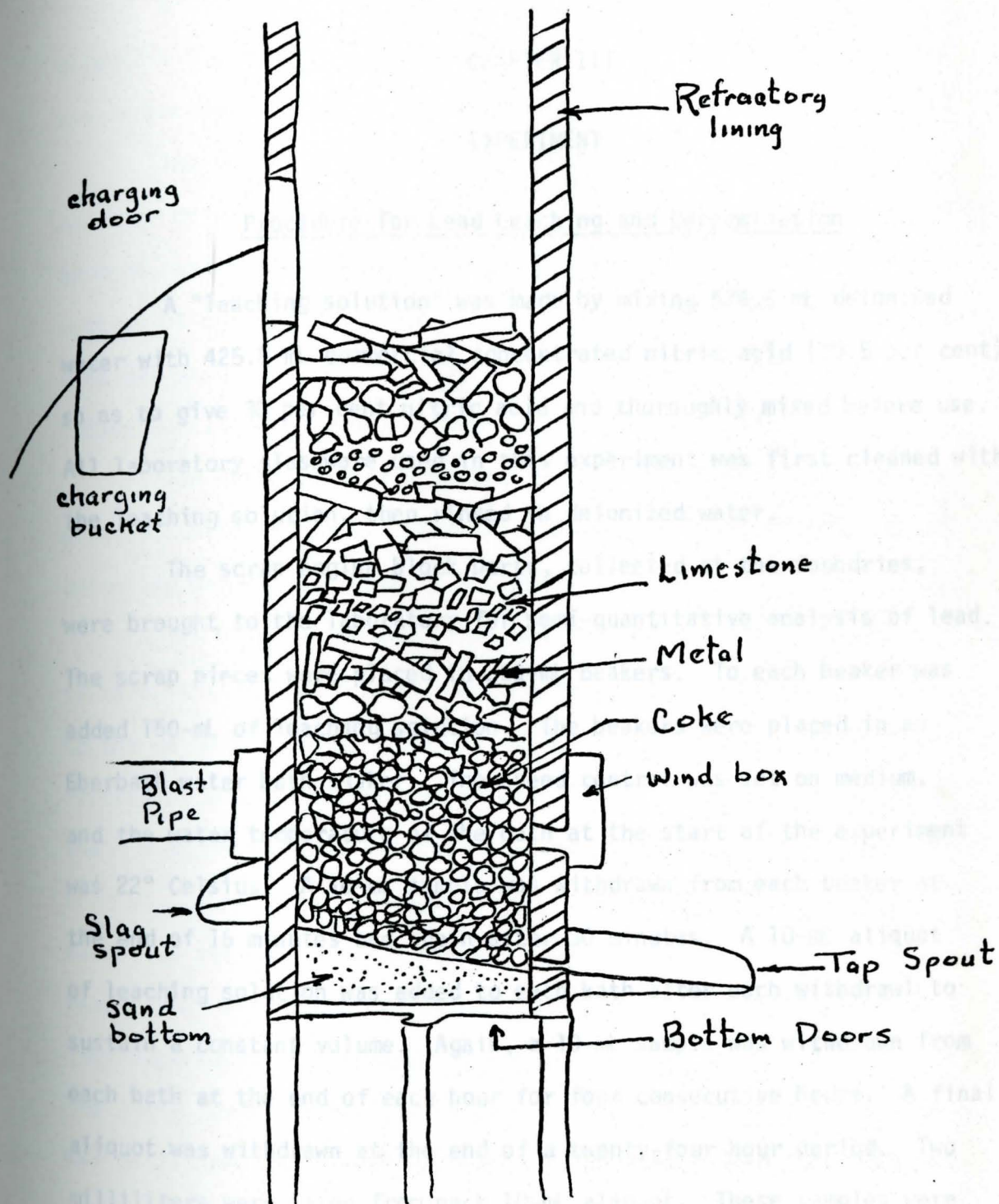


Figure 2

Diagram of a Typical
Cupola

CHAPTER III

EXPERIMENT

Procedure for Lead Leaching and Determination

A "leaching solution" was made by mixing 574.5 mL deionized water with 425.5 mL commercial concentrated nitric acid (70.5 per cent) so as to give 30 per cent nitric acid and thoroughly mixed before use. All laboratory glassware used in this experiment was first cleaned with the leaching solution, then rinsed in deionized water.

The scrap engine block parts, collected at the foundries, were brought to the laboratory for semi-quantitative analysis of lead. The scrap pieces were placed in 250-mL beakers. To each beaker was added 150-mL of leaching solution. The beakers were placed in an Eberbach water bath shaker. The speed control was set on medium, and the water temperature of the bath at the start of the experiment was 22° Celsius. A 10-mL sample was withdrawn from each beaker at the end of 15 minutes and again after 30 minutes. A 10-mL aliquot of leaching solution was added to each bath after each withdrawal to sustain a constant volume. Again, a 10-mL sample was withdrawn from each bath at the end of each hour for four consecutive hours. A final aliquot was withdrawn at the end of a twenty-four hour period. Two milliliters were taken from each 10-mL aliquot. These samples were placed in glass test tubes and the test tubes were placed in a centrifuge. The centrifuge was operated for approximately two minutes to separate any particulate matter which might adversely affect the atomic absorption instrument.

Because of the low pH of the samples, the solutions were diluted 1:4 with deionized water, in order to be drawn into the spectrophotometer without adverse effects to the unit.

The atomic absorption instrument was allowed to warm for one hour before analysis was begun. The instrument was used in the AA mode, with a wavelength setting of 217 nanometers, band slit setting of one nm, and a current of five milliamps. The fuel being used was acetylene at a setting of 15 pounds per square inch. The air intake setting was 20 pounds per square inch.

The Harleco, lead standard (1 milligram per milliliter), was diluted, using five milliliters of standard and five milliliters of deionized water, to produce a 0.5 mg/mL standard.

The blank deionized water was run through the instrument to zero it and blank out any lead content that may be present due to the deionized water. The 0.5 mg/mL standard was run through the instrument and the concentration was placed in the microprocessor. The 1.0 mg/mL standard was then entered in the instrument, and this reading placed in the microprocessor. This instrument was equipped to set up its own internal curve. This instrument can be used to read either direct concentration or absorbance of the solution. In this experiment, the instrument was set to read concentration directly. The lower limit of sensitivity of the instrument is 0.1 micrograms per milliliter and is linear from 0 to 15 mg/mL. The instrument is equipped with a deuterium lamp for automatic background correction. The acid-leached solutions were then run through the atomic absorption instrument for the quantitative detection of lead.

Procedure for Calibrating Personal Sampling Equipment

The MSA model G personal sampling pumps were calibrated following guidelines in the OSHA Industrial Hygiene Manual. The batteries were charged for 16 hours before use, and the batteries were checked with the Simpson Volt Meter to ensure proper charging. The recommended voltage for a fully charged MSA battery unit should be 6.5 volts.

The calibration train was set up, as shown in Figure 3. The 1000-mL buret was rinsed with soap solution to allow the bubbles to travel the length of the buret without disturbance. A single bubble was captured from the soap dish, and the time necessary for the bubble to indicate a flow of 1000 mL was measured. The time needed for a flow of 1000 mL should be 30 seconds, which corresponds to a flow rate of two liters per minute. The calibration procedure should be repeated to ensure proper setting. A mark on the rotometer should be properly labeled that corresponds to the center of the ball. Calibration of pumps was performed before and after each days use. Table 1 is a work sheet which is intended to assist in the documentation of calibration.¹⁶

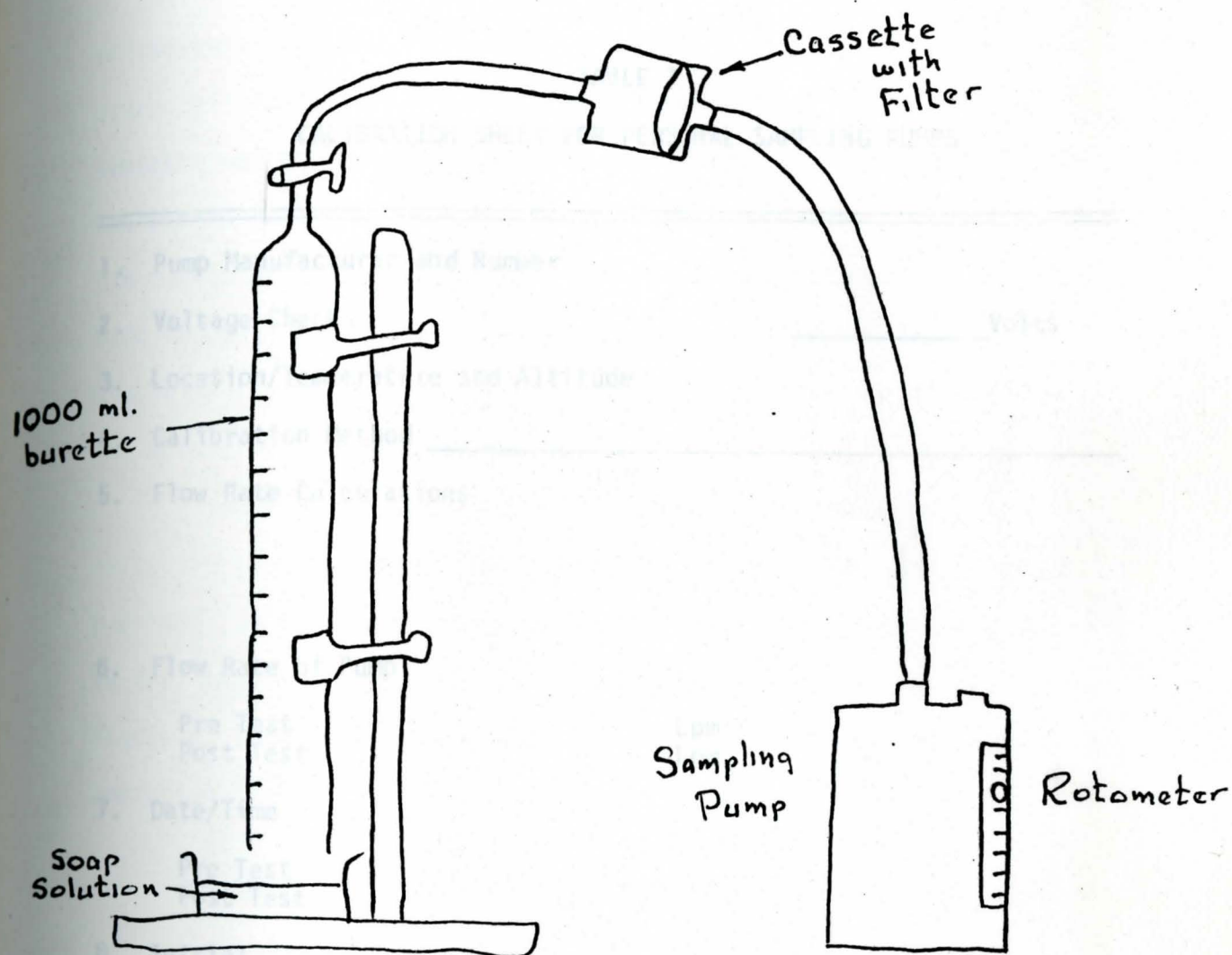


Figure 3

Calibration Setup for Metal Fume Sampling

TABLE 1
 CALIBRATION SHEET FOR PERSONAL SAMPLING PUMPS

-
-
1. Pump Manufacturer and Number
 2. Voltage Check _____ Volts
 3. Location/Temperature and Altitude
 4. Calibration Method _____
 5. Flow Rate Calculations
 6. Flow Rate of Pump

Pre Test	Lpm
Post Test	Lpm
 7. Date/Time

Pre Test	
Post Test	
 8. Initial
-
-

Procedure for Preparing Filters

The filter used in this experiment consisted of a three-piece polystyrene cassette, equipped with a cellulose back up pad and a mixed cellulose ester filter. The bottom section of the plastic cassette was equipped with an exit port. Into the bottom section was placed the 37-mm diameter cellulose back up pad. A 37-mm diameter, 0.8 micron pore size cellulose ester filter, was placed on top of the back up pad. The filter and back up pad were held in place by the middle section of the cassette. The top section was then placed on the middle section to complete the unit.

The top part was also equipped with an entrance port to allow air into the unit. The ports were plugged with plastic caps provided. A shrinkage band was placed around the cassette and allowed to dry, causing a good seal to prevent leakage through the seams. See Figure 4. The filters were then numbered numerically to prevent later confusion.^{16,17}

Procedure for the Collection and Analysis of Airborne Lead

A total of twenty-one employees were chosen to wear the equipment for the determination of lead concentration in their breathing zone. The sampling train was placed on the employees as shown in Figure 5. The pumps were checked after the first one half hour of sampling to ensure the proper flow rate was maintained. The pumps were then checked and adjusted, if necessary, to the proper flow rate at the end of each consecutive hour until the end of the sampling period. The filters were changed after four hours of sampling to ensure that they were not overloaded and to increase the confidence level of the results.

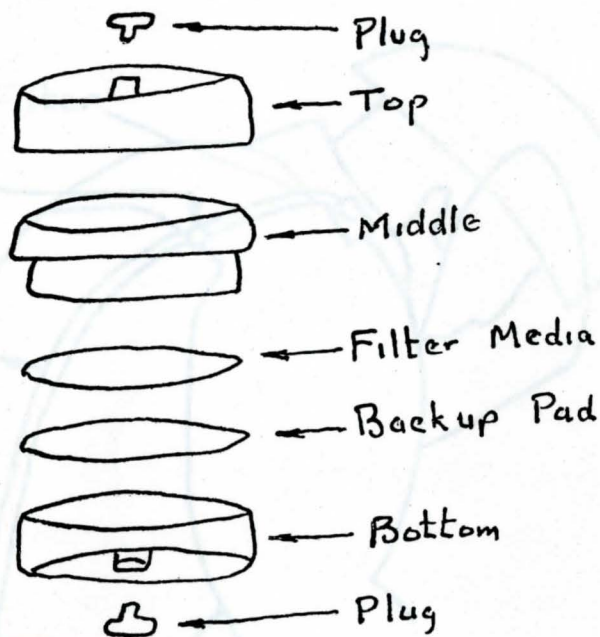


Figure 4

3 Piece Cassette Assembly

Proper Sampling Train

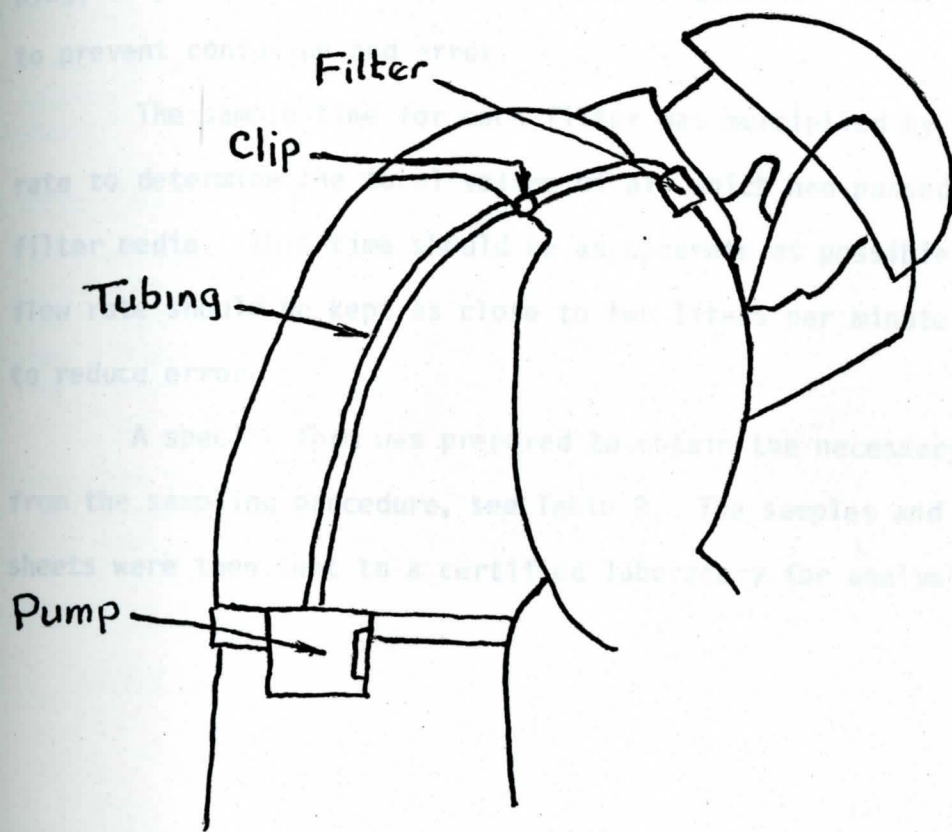


Figure 5

Proper Sampling Train

After the conclusion of sampling periods, the cassettes were removed from the sampling train. The plastic plugs were inserted in the ports, and a piece of tape placed around the cassette to hold the plugs in place. A special label was then attached to the cassettes to prevent confusion and error.

The sample time for each filter was multiplied by the flow-rate to determine the total volume of air which had passed through the filter media. This time should be as accurate as possible, and the flow rate should be kept as close to two liters per minute as possible to reduce error.

A special form was prepared to obtain the necessary information from the sampling procedure, see Table 2. The samples and sampling sheets were then sent to a certified laboratory for analysis.

Container	Results	8 Hour TSP
1.		
2.		
3.		

Miscellaneous:

Employee Job Title _____

PPE (Type and Effectiveness) _____

Job Description/Work Location _____

Exposure Control Equipment _____

Weather Conditions at Sampling Site _____

Temperature _____ Relative Humidity _____

TABLE 2
AIR SAMPLING DATA SHEET

General

Establishment (Name) _____

Address _____

State _____

Zip Code _____

Sampling Data

Employee Name and Job Title _____

Pump Number _____

Sample Media _____

Sample Number _____

Time (Minutes)

Start _____

Finish _____

Total _____

Pump Flow Rate _____

(Liters/Minutes)

Total Volume (Liters) = _____

Laboratory AnalysisContaminantResults8 Hour TWA

1. _____

2. _____

3. _____

Miscellaneous

Employee Job Title _____

PPE (Type and Effectiveness) _____

Job Description/Work Location _____

Exposure Control Equipment _____

Weather Conditions at Sampling Site: _____

Temperature _____

Relative Humidity _____

CHAPTER IV

RESULTS AND DISCUSSION

Results of Leaching Contaminated Parts

The scrap engine block parts, taken from the foundry scrap bins, were acid leached and aliquots of the leach solutions taken at timed intervals were analyzed for lead using an Instrumentation Laboratory, Model 157, atomic absorption spectrophotometer. The instrument was equipped with an automatic background corrector and a microprocessor to program in a concentration curve.

The solutions collected at the end of the first 15 minutes were analyzed for lead content. The results of these tests can be seen in line one of Table 3. The second set of samples, collected after 30 minutes of leaching, can be seen on line two of the same Table.

The results of the samples for aliquots obtained after the first hour and the remaining four aliquots, were noted to have large amounts of solid residue at the bottom of the glass beakers. Upon centrifuging the solution, the top clean upper layer was withdrawn and diluted before being introduced into the spectrophotometer. The results of those tests showed only trace amounts of lead. Trace amounts were classified as those with lead concentrations less than one microgram/mL.

The clear upper layer of the one-hour aliquot was pipetted off, and 20 milliliters of leaching solution was added to the

TABLE 3
LEAD DETECTION ON SCRAP ENGINE MATERIALS
EXPERIMENT NUMBER 1

Time	Cylinder Wall	Piston Connecting Rod
0.25 hour	0.46 mg/ml	0.48 mg/ml
0.50 hour	0.51 mg/ml	0.50 mg/ml
1.0 hour	trace	trace
2.0 hours	trace	trace
3.0 hours	trace	trace
4.0 hours	trace	trace
24.0 hours	trace	trace

thick lower residue. The beakers were agitated for 30 minutes, and a five milliliter sample was extracted and centrifuged to eliminate any remaining solid residue. A 2-mL sample was extracted and diluted 1:4 with deionized water before analysis. The results of these tests showed no lead levels greater than one microgram/mL.

Because of the problems encountered during leaching for prolonged periods of time, it was determined to reduce the leaching time to 15 minutes to prevent precipitation from occurring.

A second set of scrap samples was obtained from the foundry yard for analysis. The samples were returned to the lab, and handled as described previously, with the acid bath time restricted to 15 minutes. Results of the second leachings can be seen in Table 4.

Semi-quantitative analysis, specifically for lead, showed the parts having the highest leached-lead content to be the aluminium piston heads. The piston heads are made of aluminium and are not found in foundry feed material. However, the piston head was analyzed for lead as a large carbon deposit was noted on the head. It was believed that the carbon deposits contained large amounts of lead. The amount of lead detected was 14.71 mg/mL. The second highest leached-lead content was in the carbon residue located at the valve lifter head. The amount of lead detected was 6.4 mg/mL. The piston connecting rods showed leached-lead contents ranging from 0.48 mg/mL to 0.83 mg/mL. The lowest levels found during leaching were from the cylinder wall sections. The leached-lead contents ranged from 0.13 mg/mL to 0.46 mg/mL.

TABLE 4
LEAD DETECTION ON SCRAP ENGINE MATERIALS
EXPERIEMENT NUMBER 2

Part	Leached Lead Level
Cylinder Wall Section #1	0.46 mg/mL
Cylinder Wall Section #2	0.38 mg/mL
Cylinder Wall Section #3	0.13 mg/mL
Piston Connecting Rods #1	0.83 mg/mL
Piston Connecting Rods #2	0.52 mg/mL
Piston Connecting Rods #3	0.48 mg/mL
Carbon Deposit on Piston Head	14.71 mg/mL
Carbon Deposit on Valve Lifter	6.40 mg/mL

From the results of the tests, it was determined that the source of lead could be traced to the silvery flashing and carbon residue located on the inside of the internal combustion engine. The ultimate source of lead probably is the alkyl lead generally used as an antiknock reagent. Leaded gasoline contains as much as four grams of lead per gallon of gasoline.

The alkyl lead may be either tetraethyl or tetramethyl lead. The lead from the gasoline apparently accumulates in the flashings on the cylinder wall, and would also accumulate in the carbon residue.^{18,19,20}

Oil analysis, for cars using unleaded gasoline, has shown lead concentrations of 0.0085 mg/mL to 0.076 mg/mL, while using leaded gasoline has resulted in concentrations exceeding 8,474.8 mg/mL of lead. The American Society for Testing and Materials has determined the maximum lead concentrations in unleaded gasoline to be 0.05 grams per gallon and leaded gasoline to contain 4.2 grams per gallon.^{21,22}

Environmental Results for Lead in the Foundries

Environmental sampling was performed in the breathing zone of exposed employees to determine the time weighted average concentration of lead. Samples were collected at four foundries, two foundries with electric induction melting furnaces, and two foundries with cupola melt furnaces.

Personal sample results, for the first electric melt foundry, showed the highest exposures to lead occurring during the melting operation. The concentration for the furnace operator ranged from 0.22 mg/m³ to 1.44 mg/m³ and furnace charger's exposures range from 0.33 mg/m³ to 1.28 mg/m³. These sample results represent the same operator's and charger's exposures on various days. The noticeable decrease in exposure levels are a result of the company implementing procedures to lower airborne lead levels. Therefore, a statistical analysis of these exposure levels would be of no value. The results for the bull ladle operator and floor pourers showed lead levels which also exceed the present OSHA level of 0.05 mg/m³. The results of this survey can be seen in Table 5.

TABLE 5
 EMPLOYEE EXPOSURE TO LEAD IN
 ELECTRIC MELT FOUNDRY NUMBER 1

Operation	Test	TWA Concentration
Furnace operator	#1	1.44 mg/m ³
	#2	0.99 mg/m ³
	#3	0.85 mg/m ³
	#4	0.84 mg/m ³
	#5	0.43 mg/m ³
	#6	0.22 mg/m ³
Furnace charger	#1	1.14 mg/m ³
	#2	1.28 mg/m ³
	#3	0.76 mg/m ³
	#4	0.33 mg/m ³
Bull ladle operator	#1	0.22 mg/m ³
	#2	0.07 mg/m ³
Iron pourer	#1	0.29 mg/m ³
	#2	0.33 mg/m ³
	#1	0.02 mg/m ³

Sample results from the second electric melt foundry indicate that the furnace operator was exposed to lead at a concentration of 0.53 mg/m³ and the floor pourers to levels averaging 0.33 mg/m³. Results of this survey are seen in Table 6.

The breathing zone particulate lead concentrations were also determined for a cupola melting process. The first cupola foundry studied showed the cupola tender's exposure to lead to be 0.08 mg/m³, the average cupola charger's exposure at 0.05 mg/m³, the transfer ladle operator 0.11 mg/m³, and the average iron pourer's exposure at 0.06 mg/m³. The exposures at this foundry were the same as or exceeded the present OSHA standard of 0.05 mg/m³. Results may be seen in Table 7.

TABLE 6

EMPLOYEE EXPOSURE TO LEAD IN
ELECTRIC MELT FOUNDRY NUMBER 2

Operation	TWA Concentration
Furnace operator	0.53 mg/m ³
Iron pourer #1	0.30 mg/m ³
Iron pourer #2	0.36 mg/m ³

TABLE 7

EMPLOYEE EXPOSURE TO LEAD IN CUPOLA MELT
FOUNDRY NUMBER 1

Operation	TWA Concentration
Cupola tender	0.08 mg/m ³
Cupola charger #1	0.06 mg/m ³
#2	0.05 mg/m ³
#3	0.04 mg/m ³
	0.05 mg/m ³ average
Transfer ladle operator	0.11 mg/m ³
Iron pourer #1	0.07 mg/m ³
#2	0.07 mg/m ³
#3	0.06 mg/m ³
#4	0.06 mg/m ³
	0.06 mg/m ³ average

The second cupola foundry studied was very small in comparison to the first. The results of environmental sampling indicated that the cupola charger's exposure was 0.02 mg/m^3 , cupola operator-bull ladle operator's exposure was 0.01 mg/m^3 , and the average iron pourer's exposure was 0.02 mg/m^3 . Results are in Table 8.

Table 8

EMPLOYEE EXPOSURE TO LEAD IN CUPOLA MELT FOUNDRY NUMBER 2

Operation	Concentration
Furnace charger	0.02 mg/m^3
Furnace operator/Bull ladle operator	0.01 mg/m^3
Iron pourer #1	0.02 mg/m^3
Iron pourer #2	0.03 mg/m^3

Comparison of Environmental Results from the Various Foundries

In comparing the results of the electric melt foundries, it can be seen that the highest lead concentration occurred during the melting operation. This operation consisted of transferring the scrap from a pre-heater and depositing it into the furnace. A noticeable amount of metal fume was evolved during this process. The pre-heat temperature was usually maintained around 1000°F , and the scrap remained in the heater for approximately ten to 15 minutes. After the scrap has been deposited into the furnace, the furnace operator must then load the necessary additives of silicon and carbon. The scrap and additives are then heated in the furnace to 2700°F . The furnace charger and operator are working on the melting platform approximately 75 per cent of the day. The remainder of the time was spent in the furnace control room.

It can be seen from Table 9 that the melting point of pure lead is lower than that of the lead salts. However, the boiling points of the lead salts is much lower than pure lead. Since the lead contamination in this research may be a lead salt, lead bromide, and/or lead chloride, the evolution of lead fume would be expected to increase as the furnace temperature increases, and the concentration of lead would be more noticeable than expected.

TABLE 9
PROPERTIES OF LEAD^{1,19,23}

Atomic number	82			
Atomic weight	207.21			
Density	11.34 gram/milliliter			
Valence state	+2, +4			
	MP°F	BP°F	MP°C	BP°C
Metallic lead	619	2775	327	1509
Lead bromide	701	1679	373	916
Lead chloride	932	1747	501	954

Temperature vs Concentration

Temperature (°F)	Vapor Pressure (mm)	Concentration (mg/m ³)
944.6°	0.000016	0.18
980.6°	0.000033	0.37
1176.8°	0.001	11.3
1805.0°	1.0	900.0

The results of tests taken in the cupola melt foundries indicate high levels of lead exposure to the cupola tender. The cupola

tender's responsibility is the operation of the cupola and the loading and unloading of the furnace. The tender usually positions himself at the pouring spout during the unloading process.

In comparing the results of the four foundries, it can be seen that the cupola melt foundries have much lower airborne lead levels than do the electric melt foundries. In determining why such a difference in exposures occurs, one must first evaluate the different melting processes.

In the cupola foundries, the metal and other additives are entered in layers. The metal is preheated at the top of the cupola, and gradually melts and drains through the coke into the well. In the electric furnace melt process, the metal and additives are melted all at one time. Since the metal remains in the cupola furnace for a longer period of time, the lead fumes will be drawn up the stack into the collecting system. The better the draft on the stack, the more the lead fumes will be drawn away.

It should be noted that most electric melt foundries are equipped with canopy-type collecting hoods. The disadvantage of this type of hood is twofold. The first problem is most systems rely on the natural convection to add in the flow upward to the collector, and secondly, the employees breathing zone is often located between the source of contamination and the collecting hood.

CHAPTER V

CONCLUSIONS

The results of the acid leaching show that one source of airborne lead can be traced to the scrap engine block material, used in the foundry feedstock. The scrap parts containing carbon residue were found to contain the highest lead values. This source of lead may be traced to the introduction of lead into gasoline as an anti-knock ingredient.

The procedure for acid leaching of the scrap parts was restricted to fifteen minutes to avoid precipitation. The purpose of leaching was to determine if lead residue was present on the feedstock and not the actual amount present.

The results of the airborne lead sampling indicate that the gray iron industry has a potentially serious health problem occurring during the melting and pouring of molten metal. In comparing the results of the two foundries using different melting processes, it can be concluded that the employees working in the electric melt foundry are being exposed to higher levels of lead than the employees working in the cupola melt foundry. The reason for the difference in exposure is that the cupola melt process will cause the lead salt to vaporize much more readily and the lead will be drawn up the long stack into the dust collector. The electric melt process will release the lead into the breathing zone of the employees, due to poor ventilation control measures. It should be noted that all samples collected were over the present time weighted average standard of

fifty micrograms per cubic meter of air. Other studies by the author have shown that other sources of lead contamination may be present such as galvanized products and oily pressed steel scrap. The source of lead on the pressed scrap steel may be traced to lead soaps used as a friction reducing lubricant. Studies similar to the ones done here are very much needed as potentially serious health hazards may exist at foundries that use these various feedstocks.

Since unleaded gasoline contains a small percentage of lead, 0.05 grams per gallon, and there are still a substantial number of automobiles using leaded gasoline, it would be hard to speculate just when this problem may resolve itself.

The views and opinions expressed herein are the author's and do not necessarily reflect official Department of Labor opinion.

6. *Lett. No. 27-29*.
7. Bureau of Labor Statistics, *Lead Contamination in the Smelting and Refining of Lead*, Bulletin No. 147 (Washington: Government Printing Office, 1941), Appendix I, pp. 85-87.
8. A.E. Russell, et al., *Public Health Bulletin*, No. 295, 1933.
9. *Am. Inst. Public Health Administration, Report of Committee on Lead Poisoning*, New York, N.Y., 1943.
10. G.S. Wain and G. Sawyer, *Journal of Industrial Hygiene and Toxicology*, (1947), 28, p. 261.
11. Subcommittee Reports, *Ind. Hyg. and Surg.*, (Sept. 1965), 78, p. 10.
12. American National Standards Institute, Inc., *ISA Standards Acceptable Concentration of Lead and Its Compounds*, 1945 Z-11.1-1969 (Revision of Z-11.1-1937), New York, 1969.
13. *Federal Register*, Part 1910-83, Vol. 36, No. 157, pp. 13101-13107, Washington, D.C., Aug. 13, 1971.
14. *Federal Register*, Part 1910-1025, Vol. 43, p. 10001-53104, Washington, D.C., Nov. 16, 1978.

REFERENCES

1. "Lead," Encyclopedia Americana, 1980 ed., Vol. XVII.
2. M.R. Moore, B.C. Campbell, and A. Goldberg, "Lead," Environment and Man. Edited by John Lenihan and William W. Fletcher, Academic Press, New York, NY, 1977, Vol. VI, pp. 64-92.
3. L. Tanquerel des Planches, "Lead Diseases," A Treatise (from Traite des Maladies de plomb, ou Saturines, Paris, 1839), as cited in D. Hunter, The Disease of Occupations, 4th ed., Little, Brown, and Co., Boston, MA, 1969, p. 330.
4. H. Burton, Med-Chir Tr, London, 1840, XXIII, p. 63-79, as cited by F. H. Garrison, "An Introduction to the History of Medicine with Medical Chronology Suggestions for Study and Bibliographic Data," ed. IV, W.B. Saunders Co., Philadelphia, PA, 1929, p. 444.
5. Edgar Collins, "Lead Smelting. Special Report on Dangerous or Injurious Processes in the Smelting of Materials Containing Lead and in the Manufacture of Red and Orange Lead and Flaked Litharge." Reported by Great Britain, Home Department, London, 1910, pp. 24-27.
6. Collins, pp. 27-29.
7. Bureau of Labor Statistics, Lead Poisoning in the Smelting and Refining of Lead, Whole No. 141 (Washington: Government Printing Office, 1941), Appendix II, pp. 85-87.
8. A.E. Russell, et al, Public Health Bulletin, No. 205, 1933.
9. American Public Health Administration, Report of Committee on Lead Poisoning, New York, NY, 1943.
10. G.S. Winn and C. Shroyer, Journal of Industrial Hygiene and Toxicology, (1947), 29, p. 351.
11. Subcommittee Reports, Ind. Med. and Surg., (Sept. 1969), 38, p. 10.
12. American National Standards Institute, Inc., USA Standard Acceptable Concentration of Lead and Its Inorganic Compounds, USAS Z 37.11 - 1969 (Revision of Z 37.11 - 1943), New York, 1969.
13. Federal Register, Part 1910.93, Vol. 36, No. 157, pp. 15101-15107, Washington, D.C., Aug. 13, 1971.
14. Federal Register, Part 1910.1025, Vol. 43, No. 220, pp. 53007-53104, Washington, D.C., Nov. 14, 1978.

15. J. Gerin Sylvia, Cast Metals Technology, Addison-Wesley Publishing Co., Reading, MA, 1972, p. 9.
16. U.S. Department of Labor, Industrial Hygiene Field Operations Manual, OSHA Instruction CPL 2-2.20, Washington, D.C., April 2, 1979.
17. U.S. Department of Health, Education, and Welfare, NIOSH Manual of Sampling Data Sheets, 1977 ed., Washington D. C., GPO, DHEW (NIOSH), Pub. No. 77-159.
18. P.D.E. Biggins and R.M. Harrison, "Identification of Lead Compounds in Urban Air," Nature, April 6, 1978, 272, pp. 531-532.
19. "Lead, Alkyl Compounds," Occupational Health and Safety Encyclopedia, Vol. II, McGraw-Hill Book Company, New York, N.Y., 1974.
20. J.A. Robbins and F.L. Snitz, "Bromine and Chlorine Loss from Lead Lead Halide Automobile Exhaust Particulate," Environ. Sci. Tech., (1972), 6, p. 164.
21. C.P. Gilmore, "Oil Analysis for Your Car," Popular Science Mag., Vol. 211, (Aug. 1977).
22. J. Clausen and S.C. Rastog, "Heavy Metal Pollution Among Auto-workers. I. Lead," British Journal of Industrial Medicine, 1977, 34, p. 208-215.
23. Frank A. Patty, "Lead," Toxicology, John Wiley and Sons, Inc., New York, NY, 1963, Vol. II, pp. 941-987.