DEMONSTRATIONS OF CONTROL TECHNOLOGY FOR SECONDARY LEAD REPROCESSING

Final Report
Volume Two

September, 1983

Submitted to:
Centers for Disease Control
National Institute for Occupational Safety and Health
Division of Physical Sciences and Engineering
Cincinnati, Ohio 45226

RADIAN
CORPORATION

NIOSH Contract No. 210-81-7106

FINAL REPORT

DEMONSTRATIONS OF CONTROL TECHNOLOGY FOR SECONDARY LEAD REPROCESSING

September, 1983

VOLUME TWO

Submitted to: National Institute for Occupational Safety and Health
Parklawn Building
5600 Fishers Lane
Rockville, Maryland 20857

Submitted by: D. Jeff Burton
Ann V. Simonson
Barbara B. Emmel
Darrell B. Hunt
Radian Corporation
1864 South State Street, #200
Salt Lake City, Utah 84115-2082
(801) 487-4901

TABLE OF CONTENTS

VOLUME I

	GLOSSARY	viii
1.0	INTRODUCTION	1
	1.1 Objectives	2
	1.2 Overview of the Industry	3
	1.3 New Technology Prospects	3
	1.4 Overview of the OSHA Lead Standard	3
	1.5 Feasibility of Compliance at Existing Facilities	8
2.0	MAJOR CLASSES OF CONTROL	11
	2.1 Source Characterization	11
	2.2 Control Approaches	11
3.0	DEMONSTRATION PROJECT SUMMARIES	18
4.0	RECOMMENDATIONS	34
5.0	REPORTING	35

TECHNICAL REPORTS

- Demonstration Project No. 1, "Battery Breaking Emission Controls Using a Saturn® Shredder and Palletized Battery Handling"
- Demonstration Project No. 2, "Progress Report: Retrofit Application of a Controlled-Environment Operator's Cab to a Rubber-Tired Front-End Loader"
- Demonstration Project No. 3, "Construction and Evaluation of a Supplied-Air Island at the Casting Skimmer's Work Station"
- Demonstration Project No. 5, "Dross Emission Controls Using a Screw Drossing Machine"

TABLE OF CONTENTS (Continued)

VOLUME II

TECHNICAL REPORTS

- Demonstration Project No. 6, "Evaluation of Central Vacuum Systems for Exposure Control in Secondary Lead Smelters"
- Demonstration Project No. 7, "Control of Emissions by Screw Conveying Flue Dust Directly to a Reverberatory Furnace"
- Demonstration Project No. 10, "Evaluation of Airshowers and Shoecleaners as Exposure Controls in Secondary Lead Smelters"
- Demonstration Project No. 11, "Use of Supplied-Air Control Rooms and Stand-by Pulpits to Control Airborne Lead Exposure"
- Demonstration Project No. 13, "Construction and Evaluation of Emission Controls on Blast Furnace Tuyeres"
- Demonstration Project No. 14, "Evaluation of Pavement Cleaning Methods and Equipment for Exposure Control in Secondary Lead Smelters"

APPENDIX

REPORTS, VOLUME 2

- Demonstration Project No. 6, "Evaluation of Central Vacuum Systems for Exposure Control in Secondary Lead Smelters"
- Demonstration Project No. 7, "Control of Emissions by Screw Conveying Flue Dust Directly to a Reverberatory Furnace"
- Demonstration Project No. 10, "Evaluation of Airshowers and Shoecleaners as Exposure Controls in Secondary Lead Smelters"
- Demonstration Project No. 11, "Use of Supplied-Air Control Rooms and Stand-by Pulpits to Control Airborne Lead Exposure"
- Demonstration Project No. 13, "Construction and Evaluation of Emission Controls on Blast Furnace Tuyeres"
- Demonstration Project No. 14, "Evaluation of Pavement Cleaning Methods and Equipment for Exposure Control in Secondary Lead Smelters"

Demonstration
No. 6

EVALUATION OF CENTRAL VACUUM SYSTEMS FOR EXPOSURE CONTROL IN SECONDARY LEAD SMELTERS

Final Technical Report
Demonstration Project Number Six

Ann V. Simonson
Radian Corporation
Division of Occupational Safety and Health
Salt Lake City, Utah 84115

NIOSH 210-81-7106

Centers for Disease Control
National Institute for Occupational Safety and Health
Division of Physical Sciences and Engineering
Cincinnati, Ohio 45226

September, 1982

TABLE OF CONTENTS

Section		Page
1.0	INTRODUCTION	1
2.0	CENTRAL VACUUM EQUIPMENT	2
	2.1 Manufacturers of Central Vacuum Equipment	3
	2.2 Application	5
	2.3 Design Parameters	6
	2.4 Central Vacuum Equipment for Secondary Lead Smelters	7
	2.5 Costs	16
3.0	DESCRIPTION OF CENTRAL VACUUM SYSTEM AT TONOLLI NORTH AMERICA'S NESQUEHONING PLANT	20
	3.1 Specifications	21
	3.2 Operating and Maintenance Requirements	23
	3.3 Employee Acceptance	24
	3.4 Employee Exposure	24
	3.5 Effectiveness	25
4.0	DESCRIPTION OF CENTRAL VACUUM SYSTEMS AT GENERAL BATTERY CORPORATION'S READING AND HAMBURG PLANTS	26
	4.1 Industrial Plant	26
	4.2 Ball Mills	30
5.0	RECOMMENDATIONS FOR SUCCESSFUL APPLICATION	35
	5.1 Determining A Need For A Central Vacuum System	35
	5.2 Design Guidelines	36
	5.3 Equipment Selection	38
	5.4 Employee Education	40

LIST OF TABLES

Table		Page
2-1	Estimated Costs for Central Vacuum Systems. . . .	18
3-1	Summary of Data for Central Vacuum System at Tonolli North America's Nesquehoning Plant. . . .	22
4-1	Summary of Data for Central Vacuum System at General Battery Industrial Plant.	29
4-2	Summary of Data for Central Vacuum System at General Battery Ball Mill Plant, Reading, Pennsylvania.	32
4-3	Summary of Data for Central Vacuum System at General Battery Ball Mill Plant, Hamburg, Pennsylvania.	33

LIST OF FIGURES

Figure		Page
2-1	Diagram of Central Vacuum System.	4
2-2	Vacuum Producer	9
2-3	Bag Separator	10
2-4	Cyclone Separator	11
2-5	Vacuum Producer, Motor, and Separators.	12
2-6	Container Collection for Central Vacuum System System.	14
2-7	Use and Storage of Central Vacuum Equipment . .	17
3-1	Use of Central Vacuum Equipment To Clean Smelter Building at Tonolli Corporation	21
4-1	Photographs Illustrating Use of Central Vacuum System at General Battery Corporation	27

1.0 INTRODUCTION

Lead-containing dusts which accumulate in the workplace are potential sources of lead exposure for employees. Vehicle traffic, foot traffic, and equipment vibration can shake settled dust loose and reintroduce it into the plant atmosphere. Skin and workclothing can become contaminated through contact with dust accumulations. To reduce these sources of lead exposure, settled dust must be removed from the workplace.

Housekeeping requirements of the OSHA lead standard (29 CFR 1910. 1025) require that all plant surfaces be kept as free as practicable of accumulations of lead. The standard further requires that vacuuming methods be employed for housekeeping. Where vacuuming has been tried and found ineffective, other housekeeping methods (shoveling, dry or wet sweeping and brushing) may be employed. This study presents an evaluation of central vacuum systems and their utility in secondary lead smelters.

Site visits to evaluate central vacuum systems were made to Tonolli North America's plant in Nesquehoning Pennsylvania and General Battery Corporation's plants in Reading and Hamburg, Pennsylvania. Other secondary smelters were contacted by telephone. Manufacturers and suppliers of central vacuum equipment were contacted by telephone or letter and asked to supply information regarding their products. This report presents the results of the field evaluation and summarizes product information. The report is intended to provide useful technical, cost, and operational information to secondary lead smelter operators to aid them in determining appropriate applications for central vacuum systems and in developing specifications for their purchase, installation, and use.

2.0 CENTRAL VACUUM EQUIPMENT

A central vacuum system is a permanent installation designed to provide ready access to vacuum exhaust in all plant areas served by the system. A typical central vacuum system installation includes the following components:

- Drive motor
- Vacuum producer
- Air cleaning devices
- Vacuum line (rigid pipe or tubing)
- Vacuum inlet valves
- Flexible connecting hose
- Cleaning tools

The system may include auxiliary equipment such as an electronic bleed control, automated bag shaker, air discharge silencer, waste separator, or calibrated ammeter (to indicate airflow changes).

The central vacuum system is designed so that the vacuum line extends throughout the plant with inlet valves at convenient locations. The worker connects the flexible hose and cleaning tool to the inlet valve when performing clean-up work in an area served by the central system. The air-cleaning device (a baghouse) is located immediately upstream from the vacuum producer. Cleaning requirements typical of secondary lead smelters require that an additional air-cleaning device (a cyclone separator) be located immediately upstream from the bag separator. The cyclone separator removes large particles from the airstream going to the bag separator. Depending upon the service duty of a particular system, additional cyclone separators may be located further upstream from the vacuum producer. These mid-stream cleaning devices remove large particles at points along the vacuum line and help to prevent clogged lines. Figure 2-1 illustrates a central vacuum system.

2.1 MANUFACTURERS OF CENTRAL VACUUM EQUIPMENT

We have identified three companies in the United States that manufacture central vacuum systems of the type needed for use in secondary lead smelters. These companies are:

- Hoffman
  A Division of Clarkson Industries, Inc.
  6035 Corporate Drive
  East Syracuse, N.Y. 13057
  (315) 437-0311

- Lamson Corporation
  P.O. Box 4857
  Syracuse, N.Y. 13221
  (315) 432-5510

- The Spencer Turbine Company
  600 Day Hill Road
  Windsor, Connecticut 06095
  (203) 688-8361

These companies operate through manufacturer's representatives who are located throughout the United States. The manufacturer's representative can provide assistance in system design, equipment selection, and service requirements.

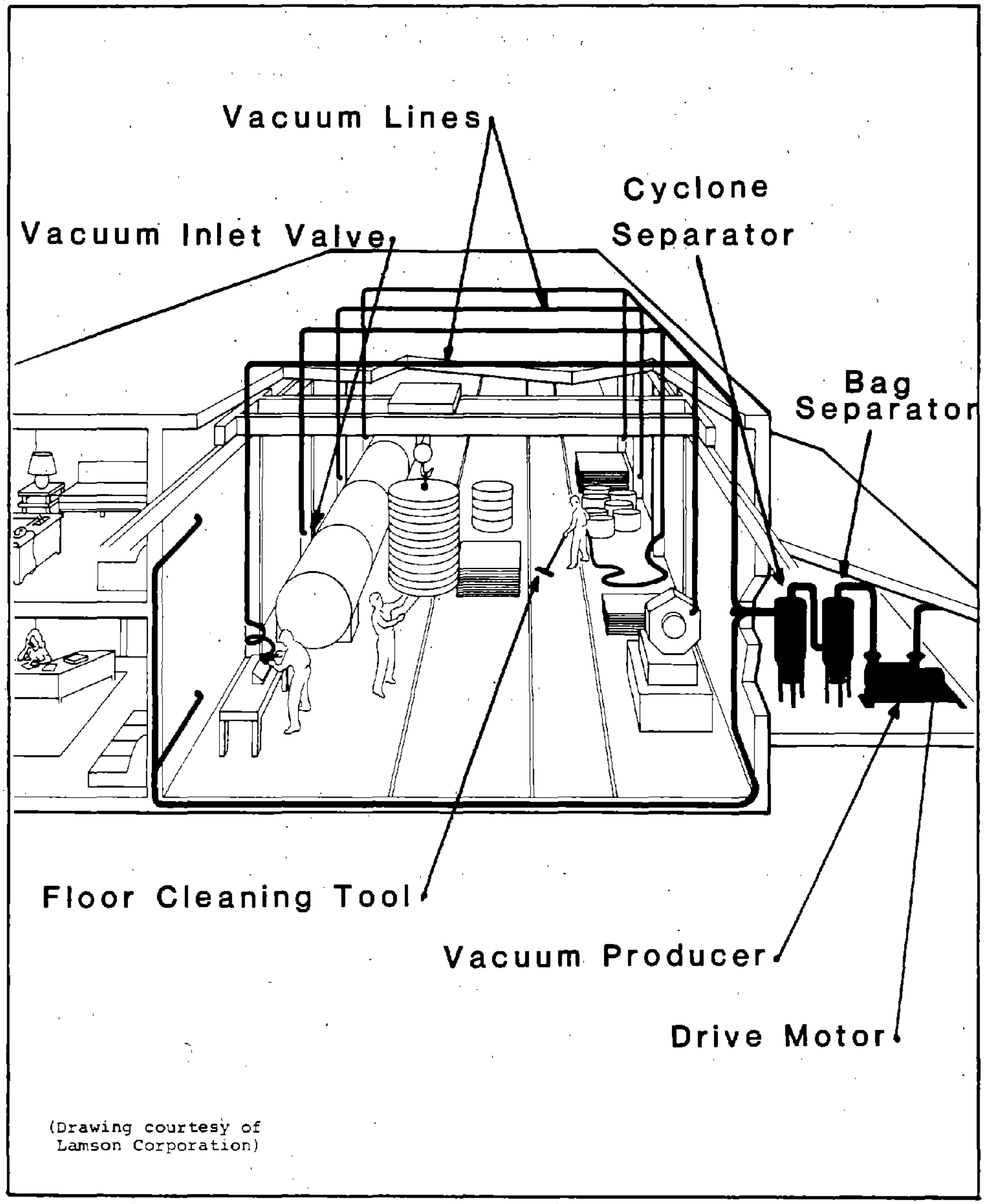


FIGURE 2-1. DIAGRAM OF CENTRAL VACUUM SYSTEM

2.2 APPLICATION

A central vacuum system is a convenient and efficient method of removing settled dust from the workplace. Dust removal by vacuuming can help reduce employee lead exposure potential by:

- Reducing the opportunity for reintroduction of lead-containing dusts into breathing air. Removing settled dust from plant surfaces prevents its becoming airborne again as a result of vehicle or foot traffic, machinery vibration, or sweeping.

- Reducing the opportunity for skin and clothing contamination. Removing settled dust from plant surfaces reduces the opportunity for contamination of skin and clothing through worker contact with dusty surfaces.

- Removing dust from employee clothing. Convenient brush/vacuum and shoecleaner/vacuum units make it possible for workers to clean dust from protective clothing before entering lunchrooms and breakrooms.

There are many opportunities for use of a central vacuum in routine plant cleanup:

- Floors
- Work stations
- Tools
- Vehicles
- Machinery

- Pipes and railing
- Shoes
- Workclothing
- Yard areas
- Office, breakrooms, lunchrooms

A central system is especially useful in event of spills since it provides an opportunity for immediate clean-up.

2.3 DESIGN PARAMETERS

Design parameters for central vacuum systems depend upon the expected application. For general use in a secondary lead smelter, it is recommended that a vacuum pressure of at least -3 inches Hg be maintained at the head of the cleaning tool located most distant from the vacuum producer. The recommended airflow at this point should be 85-95 SCFM for a 1-1/2" diameter hose line and 160-180 SCFM for a 2-inch diameter hose line. The vacuum line system should be designed to maintain a conveying velocity of 3800 to 5000 feet per minute. These guidelines were provided by T.C. Koester, Inc., and are based upon that firm's experience in designing central vacuum systems for secondary lead smelters and battery manufacturing plants. These guidelines may require adjustment, depending upon the specific plant application and material to be handled.

Given these basic design parameters, detailed specifications are developed considering the following:

- The size and design of the building or area to be served by the central system. Larger buildings or areas require larger systems. The length of the longest tubing run in the system is a major factor in determining the required rating for the vacuum producer. Ideally, the vacuum producer should be located centrally with respect to the area to be served. This will minimize the distance from vacuum producer to the furthest inlet valve.

- The number of operators who will be using the system at the same time. This is the single most important factor to consider at the design stage. The number of simultaneous operators greatly influences system volume requirements and pipe sizing and indirectly influences proper vacuum system rating.

2.4 CENTRAL VACUUM EQUIPMENT FOR SECONDARY LEAD SMELTERS

Central vacuum equipment is manufactured and marketed for a variety of applications. In this section, individual system components are discussed as applied to secondary lead smelting.

2.4.1 Drive Motor

Selection of a particular vacuum producer will determine drive motor power requirements. In vacuum system installations studied for this report, horsepower requirements ranged from 20 HP for a relatively small light-duty application to 150 HP for a large, heavy-duty application.

2.4.2 Vacuum Producer

A vacuum producer is selected on the basis of vacuum requirements and volume (CFM). Once the design requirements for these two parameters are known a particular vacuum producer is selected from charts or graphs which relate static pressure, exhaust volume, and horsepower requirements. The exhauster is selected so that satisfactory airflow and pressure are maintained over the range of expected operating conditions. Figure 2-2 illustrates a typical vacuum producer.

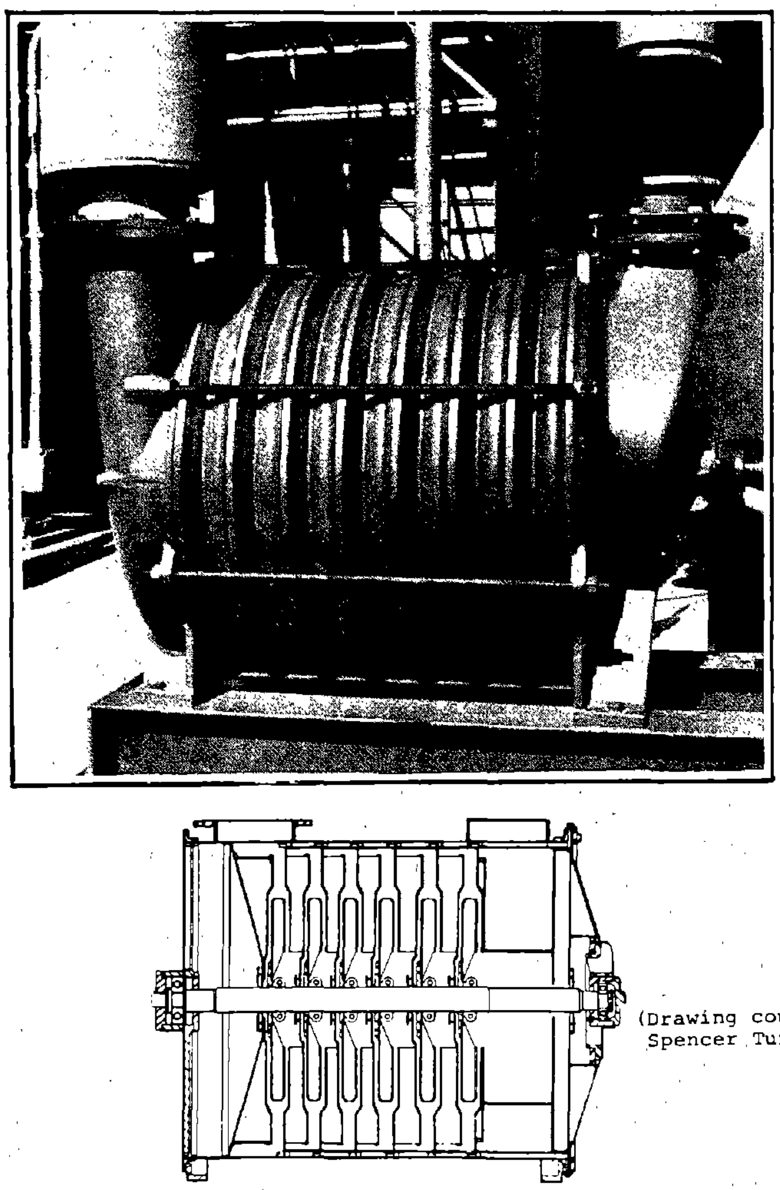
2.4.3 Separators

Separators for central vacuum systems are installed ahead of the vacuum producer. For service in a secondary lead smelter, two separators are used in tandem: a bag separator and a cyclone separator. The bag separator is selected on the basis of required bag area and the cyclone separator is selected to match the dimensions of the bag separator.

The function of the cyclone separator is to remove the bulk of the material, especially the larger particles and heavier dust, from the airstream which continues through the bag separator where final filtering of the airstream occurs while passing through the cloth bag surface. The inlet to the cyclone separator enters horizontally on a tangent near the top, and the centrifugal force imparted to the particles throws them against the inside surface of the separator. This impact, along with the drastic drop in conveying velocity, removes about 90% of the conveyed material and delivers it to a hopper where it is held for subsequent disposal.

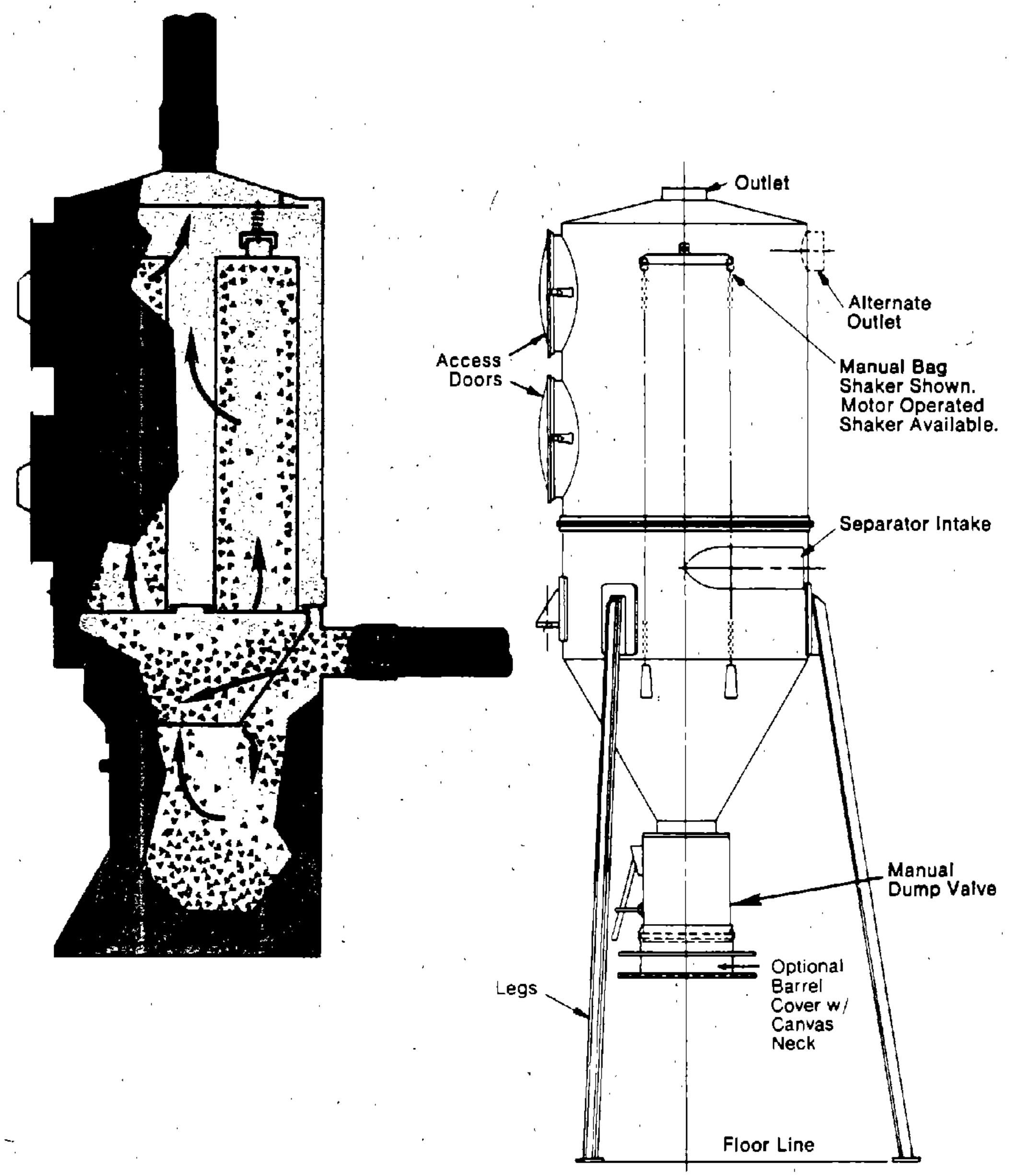
Figure 2-3 illustrates a typical bag separator unit. Figure 2-4 illustrates a typical cyclone separator unit. Figure 2-5 illustrates a typical placement of separators, vacuum producer, and drive motor.

Various types of bottom discharge dumping arrangements are available for both types of separators. Where storage in the separator is adequate, manual hinge-type valves may be used for



(Drawing courtesy of the Spencer Turbine Company)

FIGURE 2-2. VACUUM PRODUCER



(Drawings courtesy of the Spencer Turbine Company)

FIGURE 2-3. BAG SEPARATOR

19<

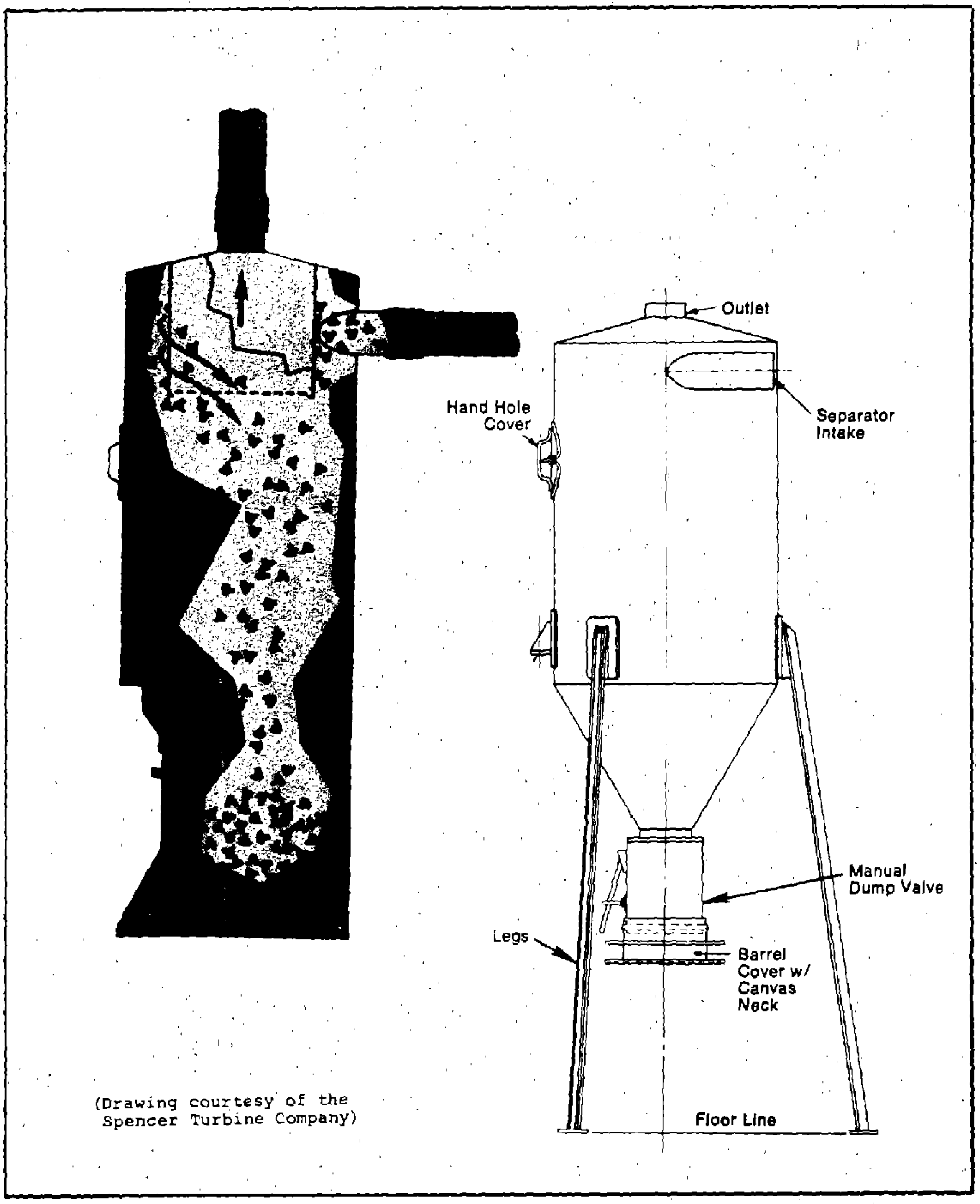
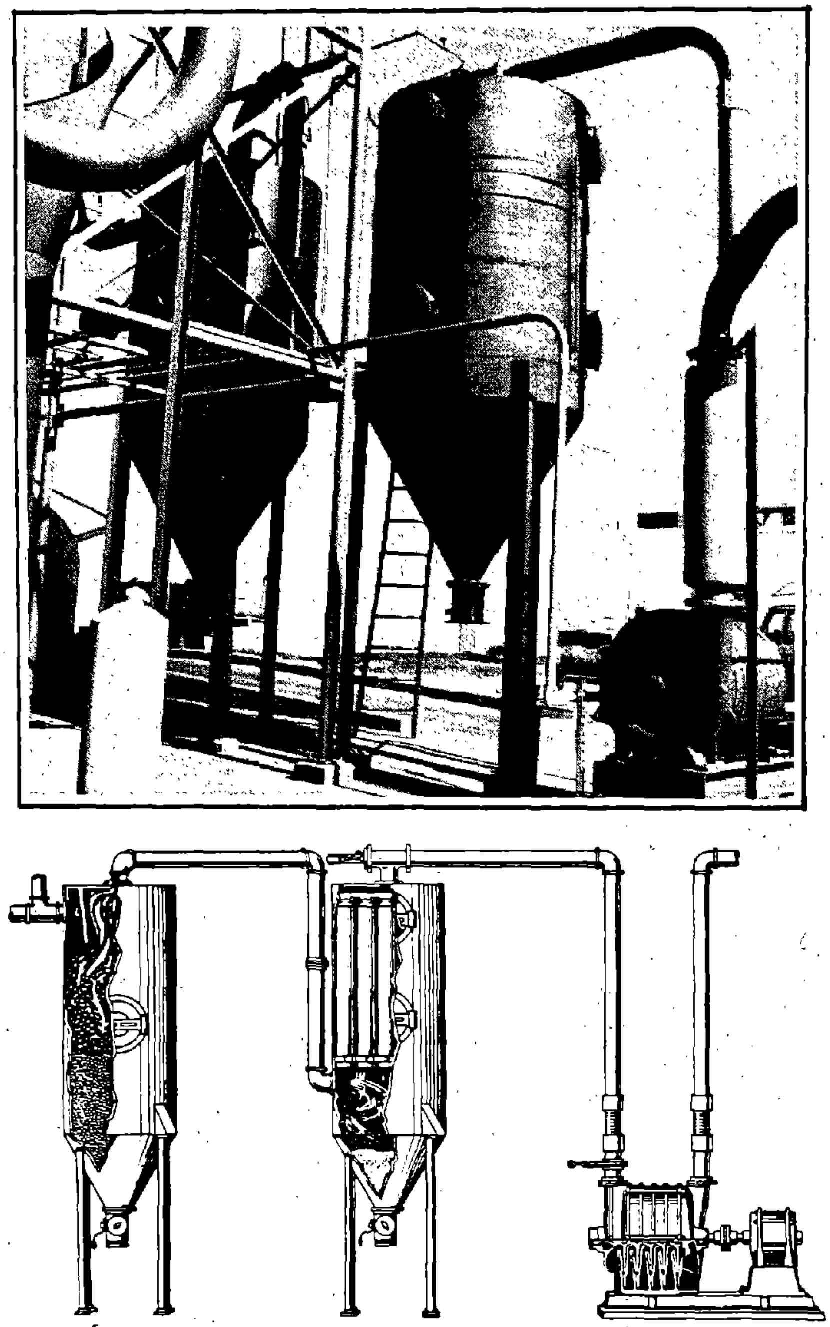


FIGURE 2-4. CYCLONE SEPARATOR



(Drawing courtesy of
Hoffman Air Systems)

FIGURE 2-5. VACUUM PRODUCER, MOTOR, AND SEPARATORS periodic dumping into tote boxes or barrels. Continuous discharge may be obtained with motor driven valves, double hinge valves, or a peristatic valve. All of the dumping arrangements seen during this study consisted of a manual dump valve into a closed waste transport container. Figure 2-6 illustrates a typical dumping arrangement for a secondary lead smelter.

Dust bags are usually fabricated from cotton but may be constructed of a special fabric such as Gortex. Both automatic and manually operated bag shakers are available. The vacuum producer must be shut down during the brief bag-shaking cycle.

2.4.4 Vacuum Line

Vacuum lines in secondary lead smelter applications are constructed of smooth-flow tubing or, for heavy-duty applications, schedule 40 pipe may be used. The goal of laying out a tubing, (or piping) system for a central vacuum system is to achieve a smooth and continuous flow of air. Tubing should be arranged so that there are no connections into which heavier material will drop by gravity or which can build up into a line obstruction.

Sections of tubing are joined by slip fit or by slip coupling. For a slip fit, connections are made by slipping the end of one section of tubing into an expanded end of another section of tubing. The joint is sealed by welding or brazing. For a slip coupling, two sections of tubing are slipped into a coupling which is sealed by welding or brazing. Couplings are available which use a mechanical seal and do not require welding or brazing.

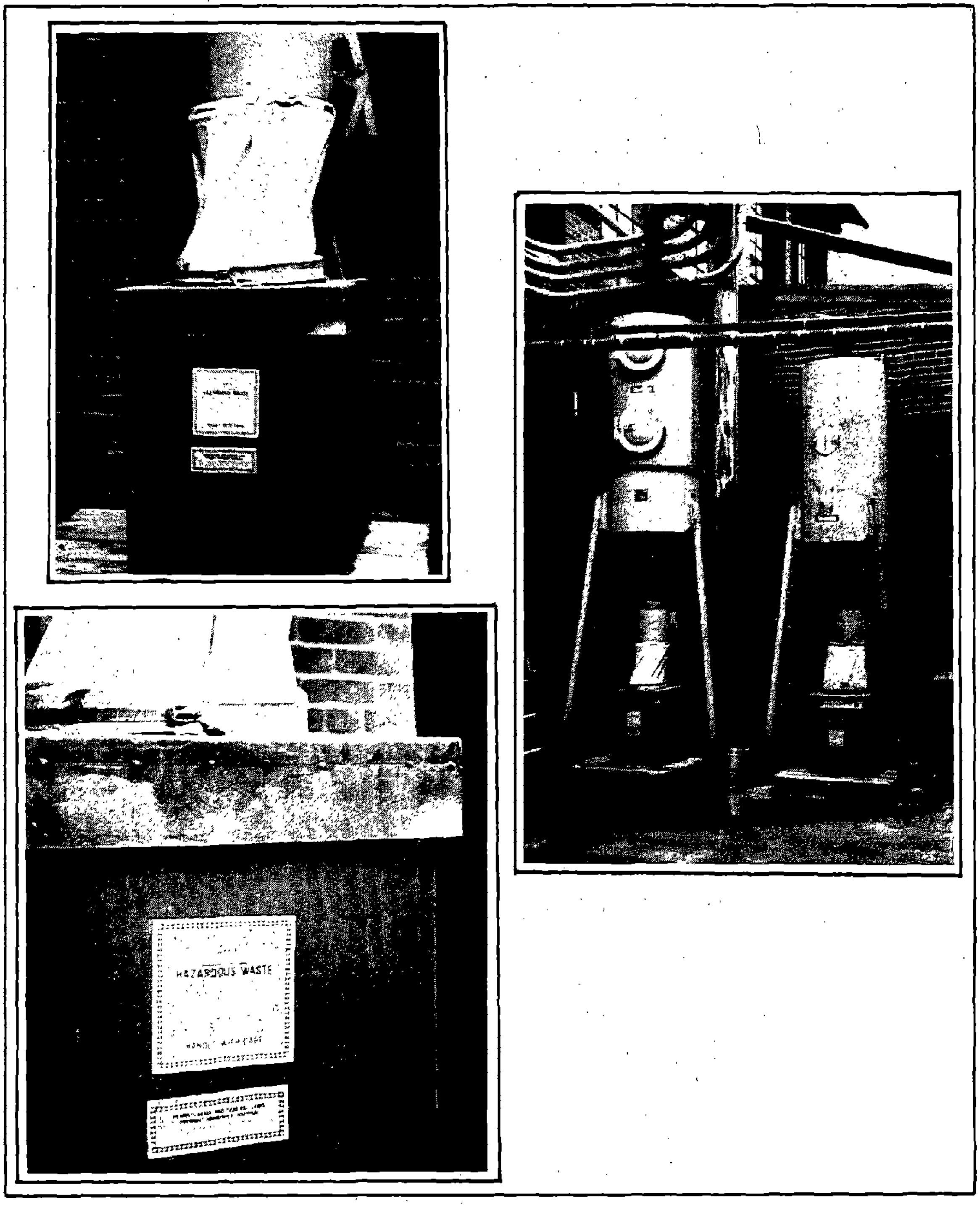


FIGURE 2-6. PHOTOGRAPHS ILLUSTRATING CLOSED-CONTAINER COLLECTION FOR CENTRAL VACUUM SYSTEM

Tubing that is sealed by welding or brazing requires installation of clean out plugs at appropriate locations. Sections of pipe that are joined with mechanical-seal couplings may be removed by section, cleaned, and then recoupled.

2.4.5 Vacuum Inlet Valves

Vacuum inlet valves are installed along with vacuum line drops at convenient locations in the plant so that vacuum exhaust is available where and when needed. The inlet valve is a hinged cap that seals off the end of a vacuum line drop when it is not in use. A typical inlet valve installation is shown in Figure 2-7.

2.4.6 Flexible Connecting Hose

Flexible vacuum hose is used to connect the cleaning tool to the permanent vacuum line installation. This connection is made by opening the inlet valve and inserting the hose coupling into the vacuum line drop. The other end of the hose is connected to an appropriate cleaning tool. Connecting hose is made from a variety of materials and is sized in 1 1/2 and 2-inch diameter. Since most smelter applications subject connecting hose to rough, abrasive surfaces, care should be taken to select a grade of hose that will provide a satisfactory service life. Spring tube steel bands which slip around connecting hose are available to reduce abrasive wear. These bands raise the hose off the floor and transfer wear from the hose to the bands.

2.4.7 Cleaning Tools

A variety of cleaning tool attachments are manufactured. Most smelter applications will require a selection of hand tools and floor tools that are designed for heavy-duty cleaning. Floor tool handles can be purchased in different lengths for use by

24/25

operators of differing heights. Typical hand and floor cleaning tools are illustrated in Figure 2-7.

2.5 COSTS

The cost of purchasing and installing a central vacuum system varies according to the size and service duty required. For costing purposes, three categories of service duty are noted:

<u>LIGHT DUTY</u> General cleaning, with a small amount of lead dust being picked up - 1-1/2 diameter hose - piping (tubing) run does not exceed 100' from equipment location to furthest work station outlet.

<u>MEDIUM DUTY</u> General Cleaning, small piles and moderate concentration of floor material - 1-1/2" diameter hose - piping (tubing run) does not exceed 200' from equipment location to furthest work station outlet.

<u>SEVERE DUTY</u> General cleaning, piles with small lead pieces - heavy floor dust concentration - 2" diameter hose piping (tubing) run does not exceed 300' from equipment location to furthest work station outlet.

Table 2-1 presents cost estimates for a variety of applications. These cost estimates are current (June, 1982) and are based on the following assumptions:

- <u>Operators</u>. This represents the number of operators expected to be using the system at the same time. It is assumed that each operator is supplied with 50 feet of hose (1 1/2 inch for light and medium

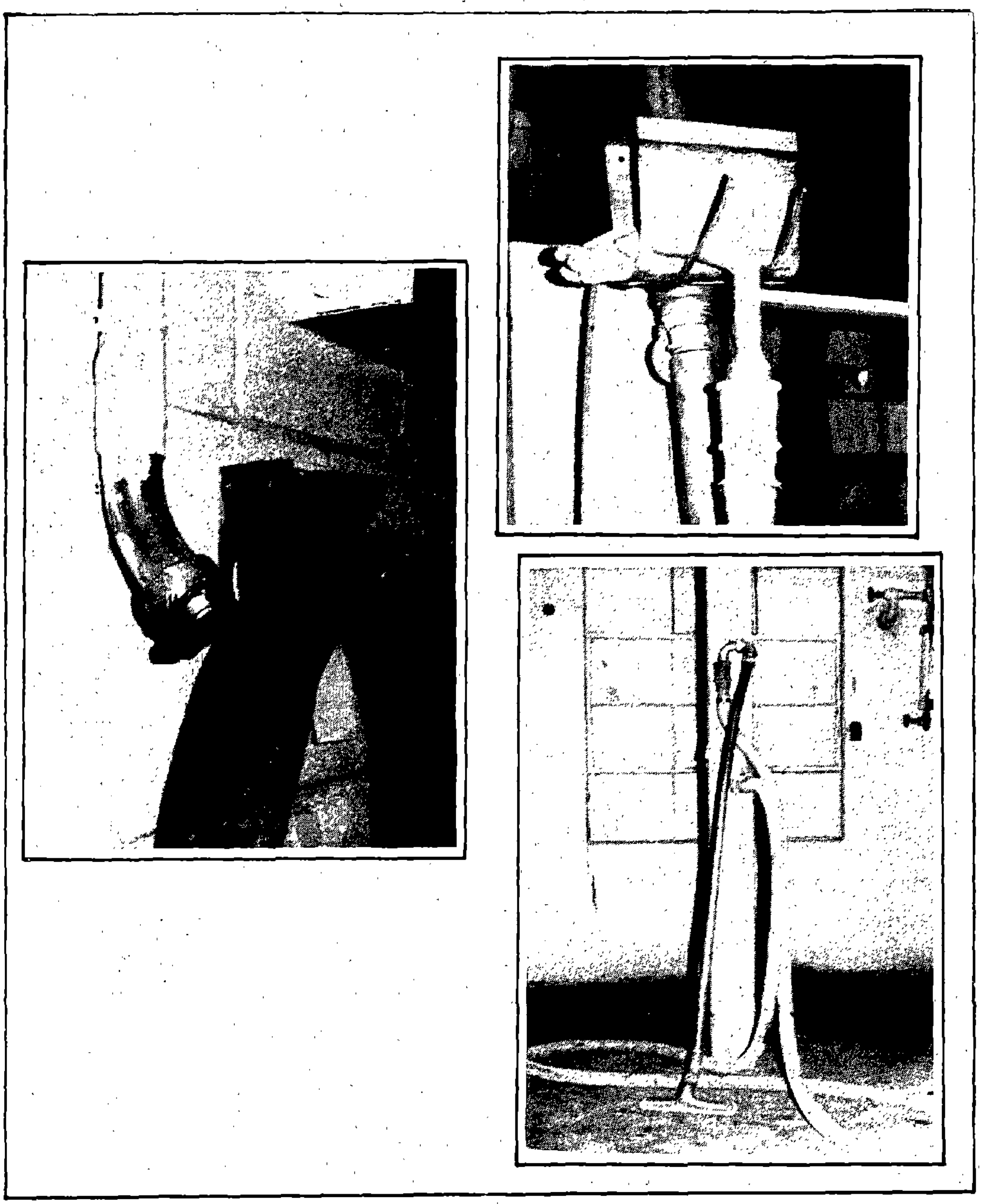


FIGURE 2-7. PHOTOGRAPHS ILLUSTRATING USE AND STORAGE OF CENTRAL VACUUM EQUIPMENT

TABLE 2-1: ESTIMATED COSTS FOR CENTRAL VACUUM SYSTEMS

LIGHT DUTY
8" Hg

OPERATORS	HORSEPOWER	EQUIPMENT COSTS	INSTALLATION COSTS
2	10	$ 8,900.00	$11.25/Ft.
4	20	11,500.00	14.25/Ft.
6	25	13,600.00	22.00/Ft.
8	30	15,300.00	45.00/Ft.
10	40	16,600.00	59.00/Ft.

MEDIUM DUTY
10" Hg

OPERATORS	HORSEPOWER	EQUIPMENT COSTS	INSTALLATION COSTS
2	15	$12,300.00	$11.25/Ft.
4	25	15,000.00	14.25/Ft.
6	30	17,000.00	22.00/Ft.
8	40	18,500.00	45.00/Ft.
10	50	20,000.00	59.00/Ft.

SEVERE DUTY
12" Hg

OPERATORS	HORSEPOWER	EQUIPMENT COSTS	INSTALLATION COSTS
2	25	$17,000.00	$11.25/Ft.
4	50	21,500.00	14.25/Ft.
6	75	25,000.00	22.00/Ft.
8	100	30,500.00	45.00/Ft.
10	125	35,000.00	59.00/Ft.

Source: Cost estimates provided by T.C. Koester, Inc., Lafayette Hill, Pennsylvania, May 1982. T.C. Koester, Inc., is a representative for the Spencer Turbine Company.

duty and 2 inch for severe duty applications). Each operator is supplied with appropriate cleaning tools.

- Equipment Costs. Vacuum producer, motor, electric surge control, primary centrifugal collector, secondary tubular bag collector and appropriate number of hose and attachments are included in the equipment cost estimate. Cost of vacuum line is included in installation cost estimate.

- Installation Costs. Installation costs are shown as cost per foot of vacuum line. The cost includes tubing, fittings, work station inlet valves, labor, hangers, etc. for complete installation. Costs are based on a minimum of 16 gauge steel tubing at a minimum of 2-1/8 inch diameter. A larger main run is specified, depending upon the number of operators. Welded joints are assumed for cost estimating. The cost per foot listed applies to total systems tubing length, not just the furthest work station outlet.

3.0 DESCRIPTION OF CENTRAL VACUUM SYSTEM AT TONOLLI NORTH AMERICA'S NESQUEHONING PLANT.

A large central vacuum system was installed in Tonolli North America's Nesquehoning plant in 1981. The system serves the smelter, refinery, warehouse, solder department, and outside storage areas. The system is used for general surface cleanup and spill removal. A station is provided where employees can vacuum dust from their clothing and clean their shoes with a mechanical brush/vacuum shoecleaner before entering the washroom and lunchroom.

The plant cleanup crew is the primary user of the central vacuum system. Routine cleanup takes place daily and spills are cleaned up as they occur. Figure 3-1 illustrates use of the vacuum system.

3.1 SPECIFICATIONS

The central vacuum system serves approximately 76,000 square feet of floor and yard areas. There are 52 inlet valves distributed throughout plant areas served by the vacuum system. The system is designed for simultaneous use by ten operators. The vacuum producer is rated at 1950 SCFM at 12 inches of mercury vacuum pressure and is powered by a 150 horsepower motor. A 50-inch diameter tubular bag separator is used in series with a 42-inch diameter centrifugal separator. The bag separator has 300 square feet of filter bag area (cotton twill) and discharges to a bottom hopper. An automatic bag shaker is installed on the separator. The centrifugal separator also discharges to a bottom hopper. Bottom hopper for both separators empty through a sleeve into closed containers. Approximately 3,000 pounds of material are collected each week. This material is recycled through the rotary furnaces. Table 3-1 contains equipment specifications in summary form.

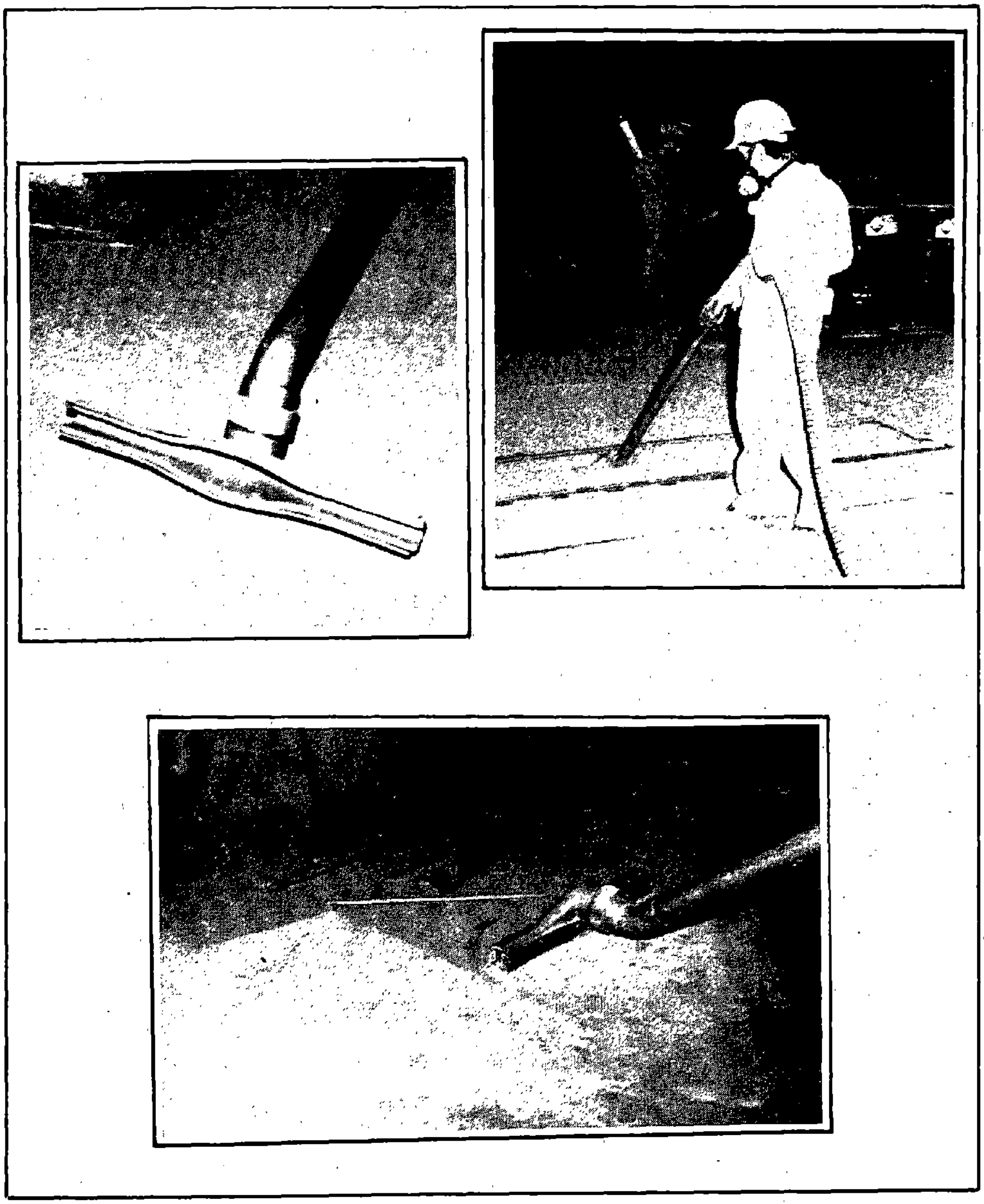


FIGURE 3-1. USE OF CENTRAL VACUUM EQUIPMENT TO CLEAN SMELTER BUILDING AT TONOLLI CORPORATION

TABLE 3-1: SUMMARY OF DATA FOR CENTRAL VACUUM SYSTEM AT TONOLLI NORTH AMERICA'S NESQUEHONING PLANT

PLANT AREA SERVED:	76,000 ft^2
NUMBER OF VACUUM INLET VALVES:	52
NUMBER OF SIMULTANEOUS OPERATORS (DESIGN)	10
AMOUNT OF MATERIAL COLLECTED PER WEEK	3,000 lbs.
DISPOSAL OF COLLECTED MATERIAL:	Recycled
DATE OF INSTALLATION:	1981
MANUFACTURER:	Spencer Turbine
VACUUM PRODUCER	
HORSEPOWER REQUIREMENT:	150 HP
EXHAUST VOLUME:	1950 SCFM
STATIC PRESSURE:	12 inches Hg
BAG SEPARATOR	
SIZE:	50-inch diameter
BAG AREA:	300 square feet
BAG TYPE:	Cotton Twill
SHAKER TYPE:	Automatic
CYCLONE SEPARATOR	
SIZE	42-inch diameter
COSTS:	
MAJOR EQUIPMENT:	$56,000
MISC. MATERIALS:	17,000
INSTALLATION AND START-UP:	27,000

Exhaust from the vacuum system discharges to the main plant baghouse. This was done to take advantage of an existing permit for atmospheric discharge.

The central vacuum is designed for severe duty. Two-inch diameter inlet lines are used and separators are supplied with heavy-duty liners. Heavy-duty, abrasive-resistant flexible hoses are used. Vacuum lines are constructed from schedule 40 pipe. The piping sections are connected with mechanical couplings at elbows and at the end of pipe lengths. These couplings provide for easy change out of elbows and simplify unplugging clogged lines.

A portable wet separator was purchased as an accessory for occasional cleanup of wet floor areas. The collector is connected in line with the floor tool and removes moisture from the airstream before it enters the inlet valve.

3.2 OPERATING AND MAINTENANCE REQUIREMENTS

3.2.1 Labor Requirements

As part of an overall housekeeping improvement program, two employees were added to the payroll and assigned to full-time clean-up duties. For accounting purposes, it is assumed that the employment of these two individuals represents the labor costs of operating the central vacuum system. In practice, these individuals do not spend all of their time vacuuming with the central vacuum system and workers other than the regular cleanup crew use the vacuum system as well. Two people were assigned to plant cleanup duties before installation of the central vacuum system.

3.2.2 Maintenance Requirements

Since the system's installation in 1981, maintenance costs have been limited to replacement of floor tools and hoses. In regular service, floor tools and extension handles wear out in about four month's time. Hoses have been replaced because they have been broken by trucks driving over them but not yet because they have worn out.

Central vacuum systems are highly reliable and require very little preventative maintenance. Routine preventative maintenance consists of:

- o Checking for leaks in the vacuum line system. A higher-than-normal amperage draw indicates system leakage.
- o Proper lubrication.
- o Daily cleaning (shaking) of bags.

3.3 EMPLOYEE ACCEPTANCE

Workers who use the vacuum system report that it works well and is relatively easy to use. A full day of vacuuming is, nonetheless, considered a tiring, monotonous job.

3.4 EMPLOYEE EXPOSURE

Exposure measurements were taken to see if vacuum cleaner operation posed an additional exposure burden. A personal monitoring pump was worn by a worker while cleaning floors in the warehouse and the smelter. This measurement represents operator exposure. Another individual (who was not vacuuming) wore a sampling pump and stood in the same general area but at least fifteen feet from the vacuum operator. This measurement represents background level. The results from 2-1/2 hours of sampling showed an average operator exposure of 250 ug Pb/m^3 and an average background exposure of 260 ug Pb/m^3. It was concluded that vacuum operation does not contribute to employee exposure in excess of background levels.

3.5 EFFECTIVENESS

The central vacuum system is an effective cleaning tool. We observed that only one pass of the cleaning tool was needed to remove accumulated dust and dirt. Vehicles travelling over newly cleaned floor areas stirred up relatively little dust. A direct-reading dust monitoring instrument was used to measure the dust concentration increase that occurred when a truck drove by over a floor area that had been recently cleaned with the vacuum. An increase of 5-25 ug $dust/m^3$ was recorded. Before this section of floor had been cleaned, the passing of a truck resulted in an increase of 50-100 ug $dust/m^3$ over background levels.

4.0 DESCRIPTION OF CENTRAL VACUUM SYSTEMS AT GENERAL BATTERY CORPORATIONS'S READING AND HAMBURG PLANTS.

Central vacuum systems have been installed at various locations at General Battery plants in Reading and Hamburg, Pennsylvania. The following paragraphs contain descriptions of three systems that were evaluated for this study. Figure 4-1 illustrates use of the central vacuum systems at General Battery.

4.1 INDUSTRIAL PLANT

The central vacuum system in the Industrial Plant was installed in 1978. It is the largest central system used at the Reading plants. The system serves assembly, finishing, oxide production, and warehousing operations. The system is used for general surface cleanup and spill removal. A station is provided where employees can vacuum dust from their workclothing and clean their shoes with a mechanical brush/vacuum shoecleaner before entering the washroom and lunchroom.

The system is used by workers in the Industrial Plant to clean work areas before break periods and at the end of shift. Spills are cleaned up as they occur. A janitorial staff of three (two for day s ft, one for afternoon shift) use the central vacuum system fo most of their cleanup tasks.

4.1.1 Specifications

The Industrial Plant central vacuum system serves approximately 130,000 square feet of floor area. There are 110 inlet valves distributed throughout the plant. The system is designed for simultaneous use by 12 operators. The vacuum producer is rated at 1125 SCFM at 12 inches of mercury vacuum pressure and is powered by a 75-horsepower motor. A 42-inch diameter tubular bag

FIGURE 4-1. PHOTOGRAPHS ILLUSTRATING USE OF CENTRAL VACUUM SYSTEM AT GENERAL BATTERY CORPORATION

separator is used in series with a 36-inch diameter centrifugal separator. Two additional 30-inch diameter centrifugal separators are located at mid-line points remote from the central collectors. These two separators were installed to remove particles from distant vacuum lines to help prevent line blockages en route to the central collectors. The bag separator discharges to a bottom hopper. Gortex-brand bags are used. A manual bag shaker is used and standard operating procedures require that the system be shut down and the bags shaken once each shift. The centrifugal separators discharge to bottom hoppers. Bottom hoppers for bag and cyclone separators empty through a sleeve into closed containers. Weekly, the system collects approximately 2,000 pounds of material which is recycled through the reverberatory furnace. Exhaust from the system is discharged to atmosphere. Table 4-1 contains equipment specifications in summary form.

4.1.2 Operating and Maintenance Costs

General Battery Corporation estimates that 7360 labor hours are expended annually to operate the central vacuum system in the Industrial Plant. Of these hours, 3840 are used by the janitorial staff for plant cleanup and 3520 are used by department workers for work area cleanup. This represents an annual labor cost of $70,000, using an average labor rate of $9.50 per hour.

Annual maintenance costs are estimated at $2,100 for repair and replacement equipment and $1,600 maintenance labor.

TABLE 4-1: SUMMARY OF DATA FOR CENTRAL VACUUM SYSTEM AT GENERAL BATTERY INDUSTRIAL PLANT, READING, PENNSYLVANIA

PLANT AREA SERVED	130,00 ft^2
NUMBER OF VACUUM INLET VALVES	110
NUMBER OF SIMULTANEOUS OPERATORS (DESIGN)	12
AMOUNT OF MATERIAL COLLECTED PER WEEK	2,000 lbs.
DISPOSAL OF COLLECTED MATERIAL	Recycled
DATE OF INSTALLATION	1978
MANUFACTURER	Spencer Turbine
VACUUM PRODUCER	
HORSEPOWER REQUIREMENT:	75 HP
EXHAUST VOLUME:	1125 CFM
STATIC PRESSURE:	12" Hg
BAG SEPARATOR	
SIZE:	42" diameter
BAG TYPE:	Gortex
SHAKER TYPE:	Manual
CYCLONE SEPARATORS	
SIZE:	1, 36" diameter 2, 30" diameter

4.1.3 Employee Acceptance

Users of the central vacuum system report that it greatly simplifies work station cleanup. Supervisors report that use of the central vacuum is well integrated into the daily work routine and complaints are registered when the system is down for repairs.

4.1.4 Effectiveness

We observed end-of-shift cleanup at the Industrial Plant.

Floor tools were used to clean floors in the immediate work area and hand tools were used to clean machinery and work tables. The cleanup was quick and thorough.

4.2 BALL MILLS

General Battery Corporation operates two lead oxide plants, which use ball mills. One of these plants is located at the Reading smelter, the other is located at the Hamburg plant. Both of these plants are served by central vacuum systems. In Reading, the vacuum system also serves a battery assembly plant. In Hamburg, the system also serves a grid casting plant.

In the oxide plants, the vacuum system is used by the plant operator for general cleanup of control rooms, machinery, plant surfaces, and yard areas. The vacuums are also used for immediate cleanup of oxide spills. In the assembly and casting plants, the vacuum systems are used by workers for general surface and machinery cleaning at their individual work stations.

4.2.1 Specifications - Reading Plant

The central vacuum system for the ball mill and assembly plants serves approximately 3,700 square feet of plant area. There are 25 vacuum inlet valves; 18 of these are located in the ball mill plant. The vacuum producer is rated at 350 SCFM at 8 inches of mercury vacuum pressure and is powered by a 20-horsepower motor. A cyclone separator is used in series with a tubular bag separator. Both separators discharge to bottom hoppers which empty through a sleeve into a closed container. Material collected by the system is recycled through the reverberatory furnace. Exhaust air from the bag separator discharges to atmosphere. A manual bag shaker is used. Table 4-2 contains a summary of equipment specifications.

4.2.2 Specifications - Hamburg Plant

The central vacuum system for the ball mill and casting plants serves approximately 8,100 square feet of plant area. There are 26 vacuum inlet valves; 12 of these are located in the ball mill plant. The system is designed for simultaneous use by six operators. The vacuum producer is rated at 600 SCFM at 8 inches of mercury vacuum pressure and is powered by a 25-horsepower motor.

A 30-inch diameter cyclone separator is used in series with a 36-inch diameter tubular bag separator. A manually-operated bag shaker is used. Separators discharge to bottom hoppers which empty through sleeves into closed containers. Collected material is recycled through the reverberatory furnace at Reading. In accordance with hazardous waste regulations, collection containers are labeled as containing hazardous wastes before shipment to Reading. Exhaust air from the bag separator discharges to atmosphere. Table 4-3 contains a summary of equipment specifications.

TABLE 4-2: SUMMARY OF DATA FOR CENTRAL VACUUM SYSTEM AT GENERAL BATTERY BALL MILL PLANT, READING, PENNSYLVANIA

PLANT AREA SERVED	3,700 ft^2
NUMBER OF VACUUM INLET VALVES:	25
DISPOSAL OF COLLECTED MATERIAL	Recycled
DATE OF INSTALLATION	1977
MANUFACTURER	Spencer Turbine
VACUUM PRODUCER	
HORSEPOWER REQUIREMENT:	20 HP
EXHAUST VOLUME:	350 CFM
STATIC PRESSURE:	8" Hg
BAG SEPARATOR	
SIZE:	36" diameter
BAG TYPE:	Gortex
SHAKER TYPE:	Manual
CYCLONE SEPARATOR	
SIZE:	30" diameter

TABLE 4-3: SUMMARY OF DATA FOR CENTRAL VACUUM SYSTEM AT GENERAL BATTERY BALL MILL PLANT, HAMBURG, PENNSYLVANIA

PLANT AREA SERVED	8,100 ft^2
NUMBER OF VACUUM INLET VALVES	26
NUMBER OF SIMULTANEOUS OPERATORS (DESIGN)	6
DISPOSAL OF COLLECTED MATERIAL	Recycled
DATE OF INSTALLATION	1977
MANUFACTURER	Spencer Turbine
VACUUM PRODUCER	
HORSEPOWER REQUIREMENT:	25 HP
EXHAUST VOLUME:	600 CFM
STATIC PRESSURE:	8" Hg
BAG SEPARATOR	
SIZE:	36" diameter
BAG TYPE:	Gortex
SHAKER TYPE:	Manual
CYCLONE SEPARATOR	
SIZE:	30" diameter

4.2.3 Operating Requirements

In the ball mill oxide plants, the plant operator is in charge of cleanup and is the primary user of the central vacuum system. Plant cleanup requires from 15 to 20 minutes each shift. In the assembly and casting plants, vacuum inlet valves are located at individual workstations and cleanup is the responsibility of the worker assigned to that workstation. About 15 minutes are devoted to cleanup at the end of each shift.

4.2.4 Employee Acceptance

Oxide plant operators report that the central vacuum system works well, is easy to use, and makes their jobs easier. Before the central system was installed at Reading, a portable vacuum was used. The operator at Reading reported that the portable unit was cumbersome and didn't provide as good of pick-up as the system now in use.

4.2.5 Effectiveness

We observed use of the central vacuum system at both oxide plants. The system appeared to work well and provided quick removal of accumulated dust.

The central vacuum system is instrumental in maintaining the cleanliness of the control rooms at the oxide plants. These supplied-air control rooms are specifically designed as exposure controls for lead exposure. Frequent use of the vacuum in these control rooms quickly removes dust and prevents its accumulation.

5.0 RECOMMENDATIONS FOR SUCCESSFUL APPLICATION

A central vacuum system can provide an effective, convenient means of removing dust and dirt from the workplace. Central systems have been installed in some secondary smelters and have proven useful. This section contains a number of recommendations presented as "points to consider" when planning a central vacuum system. These recommendations are taken from literature supplied by vacuum manufacturers, from experience reported by lead smelter operators using central vacuum systems, and from our observation of the systems in use.

5.1 DETERMINING A NEED FOR A CENTRAL VACUUM SYSTEM

The OSHA lead standard (29 CFR 1910.1025) requires that vacuuming methods be used for surface cleaning. Other cleaning methods may be used if vacuuming has been tried and found ineffective.

A central vacuum system is a convenient installation. It is especially useful when:

- It is desirable to have vacuum equipment available at several different locations at different times. A central vacuum system offers this flexibility because it is an integral part of plant structure.

- It is desirable to be able to clean up spill immediately. The convenience of having a vacuum inlet valve nearby allows spill cleanup to take place immediately.

- The area to be cleaned is large. Central vacuum systems are especially well suited to the cleanup of large areas.

- A separate clean-up crew is not available. Conveniently located vacuum inlet valves make it possible for cleanup to be a part of any worker's job routine.

- It is desirable to have a number of people vacuuming at the same time. A central vacuum system is specifically designed to offer this flexibility.

5.2 DESIGN GUIDELINES

The central vacuum system must operate effectively if it is to fulfill its function in exposure control. If pickup velocities are too low, much of the system's value is lost because cleaning tools cannot remove dust effectively. Many passes of the cleaning tool are required and significant amounts of dust may be left behind. Much time is lost and workers can become discouraged. Poor design of vacuum lines and inadequate transport velocities can result in line blockages and frequent downtime for the system. Again, much time is lost and workers can become discouraged. The goal of good design is to provide a system that works well, requires little maintenance, and (most importantly) gets used.

5.2.1 Location of Vacuum Inlet Valves

Vacuum inlet valves should be located where they are convenient to use. This requires careful study of the workplace. In congested areas or areas requiring frequent cleaning, inlet valves should be located so that a relatively short piece of flexible hose can be used. Unwieldly lengths of heavy connecting hose present a storage and mobility challenge. When this challenge must be met frequently and in the midst of traffic or equipment congestion, the central system ceases to be a convenience.

Yard areas, offices, lunchrooms, maintenance shops, upper level platforms, and flue dust handling systems may benefit from ready access to the central vacuum system and should not be overlooked.

5.2.2 Location of the Vacuum Producer

The vacuum producer should be located centrally with respect to the location of vacuum inlet valves in order to reduce friction losses associated with long runs of vacuum lines. The vacuum producer and drive motor may be significant noise sources and should be located so that they do not present a noise hazard. The vacuum exhaust should be located so that it does not present a lead exposure hazard should there be a failure in aircleaning equipment.

5.2.3 Location of Separators

The bag separator and cyclone separator should be located immediately upstream from the vacuum producer. Additional cyclone separators may be used further upstream if vacuum line runs are long and dust loading is heavy. Ready access to collection containers should be provided so that it is easy to collect and replace them. Adequate space should be provided so that inspection doors and cleanouts can be used without obstruction.

5.2.4 Design of Vacuum Line

Vacuum lines should be designed to provide adequate transport velocity for the materials being conveyed. Access for easy cleanout of blocked lines should be provided. Elbows, bends, and connections should promote smooth, even airflow. Since elbows and bends are especially subject to abrasive wear they should be reinforced and constructed for easy changeout.

5.2.5 Sizing the Vacuum Producer

The velocity of air sweeping across the surface being cleaned and into the inlet of the cleaning tool is the true cleaning agent. This inrush of air scours loose dirt deposits and picks up dust and dirt. The central vacuum system should be sized so that it provides an adequate pick-up velocity. Once dust and dirt enter the system, adequate transport velocity needs to be maintained so that material does not settle out and plug lines. Correct sizing for a central vacuum system is critical to its success. The services of a professional design engineer (with experience in designing central vacuum systems for lead smelter applications) should prove a worthwhile investment.

5.3 EQUIPMENT SELECTION

Central vacuum equipment is manufactured for a variety of applications ranging from cleaning hospitals to cleaning nuclear power plants. It is important that equipment suitable for service in a smelter environment be selected from the many available options.

5.3.1 Cleaning Tools

A variety of floor and hand tools are available. The plants visited in this study used all-metal floor and hand tools. Tools with brushes have been used but they proved unsatisfactory for most applications. Tools with brushes are used, however, in cleaning lunchrooms, control rooms, and other areas with tile floors and light dust loadings.

Extension handles for floor tools are available in different lengths to accommodate workers of different heights. Selection of a handle that "fits" the worker is especially important if that worker is expected to operate the vacuum for a whole shift.

Cleaning tools and elbow joints constructed of aluminum may not wear well. At the Tonolli smelter, aluminum cleaning tools are used because they are lightweight and easy to handle. The use of aluminum elbow joints was, however, discontinued because they wore out quickly.

5.3.2 Connecting Hose

A compromise must be struck between durability and ease of handling. This may involve some experimentation with different materials and weights of construction. In the plants visited, the hose types that worked out best were a heavy duty plastic hose and a corregated rubber hose. One plant used circular steel spring bands around the hose to lift it off the floor and reduce abrasive wear.

5.3.3 Vacuum Lines

Vacuum lines at General Battery plants are constructed of 16 gauge steel tubing. This material has provided satisfactory wear, except at some elbows. Vacuum lines at the Tonolli plant are constructed of schedule 40 pipe. To date, this material has provided satisfactory wear. Mechanical couplings are used at the Tonolli plant to facilitate cleanout and changeout. This arrangement has worked out extremely well. Slip fit, welded couplings are used at General Battery plants to connect tubing. This arrangement has worked well, but maintenance personnel report that the industrial plant vacuum line lacks sufficient clean out access points.

5.3.4 Separators

General Battery Corporation has experienced a problem with manually-operated bag shakers: they may not be used. Automatic bag shakers are available and may present an advantage in situations where the task is subject to neglect.

5.4 EMPLOYEE EDUCATION

Central vacuum systems are easy to use and their method of operation is essentially self-explanatory. There are a couple of operating points, however, that should be stressed:

- It is the inrush of air into the cleaning tool that is the true cleaning agent. It is counter-productive to bear down on cleaning tools or hold them so that the inrush of air is sealed off.

- Vacuum pick up should be limited to materials that will not jam or clog tubing, fittings, and separators. Paper towels, plastic bags, welding rod ends, nails, wet or oil-soaked material, etc., need to be removed by means other than the central vacuum system.

Demonstration
No. 7

CONTROL OF EMISSIONS BY SCREW CONVEYING FLUE DUST DIRECTLY TO A REVERBERATORY FURNACE

Final Technical Report
Demonstration Project Number Seven

Darrell B. Hunt
Radian Corporation
Occupational Safety and Health Division
Salt Lake City, Utah 84115

Contract No. NIOSH 210-81-7106

U.S. Department of Health and Human Services
Centers for Disease Control
National Institute for Occupational Safety and Health
Division of Physical Sciences and Engineering
Cincinnati, Ohio 45226

CONTENTS

Section			Page
1.0		Introduction	1
2.0		Background	2
	2.1	General Methods of Handling and Disposing of Flue Dust	2
	2.2	Methods of Flue Dust Reclamation	3
3.0		General Aspects of Screw Conveying/Recycling Flue Dust	5
4.0		Description of General Battery Corporation Plant Operations - Reading, PA	8
	4.1	General Plant Description	8
	4.2	Screw Conveying/Recycling of Flue Dust	10
5.0		Operation and Maintenance	17
6.0		Environmental Considerations	19
7.0		Costs	29
8.0		Discussion	31
	8.1	Application	31
	8.2	Problems	32
	8.3	Design Considerations	34

FIGURES

Figure	Title	Page
1.	Screw Conveyor Components	6
2.	Conveyor Screw Types	7
3.	Smelter Plot Plan for General Battery	9
4.	Flue Dust - Flow Diagram	11
5.	Charge Configuration	13
6.	Screw Conveyors and Main Bucket Elevator	15
7.	Open Flue Dust Screw Conveyor Cover, Trough and Screw	16
8.	Cleaning Screw Conveyor Transfer Points	20
9.	Replacing Broken Hanger Bearing and Coupling	21
10.	Ventilation Tie-in at Main Bucket Elevator	23
11.	Flue Dust Leaks Around Motor Drive Shaft	24
12.	Flue Dust Leaks at Cracks and Seams on the Bucket Elevator	25
13.	Chute and Collection Bin for Dust Collected from Charge Ram	26
14.	Overflow Point at Top of the Flue Dust Feed Chute	28
15.	Flue Dust Trap Door Recommendation	37

ACKNOWLEDGEMENT

This study was conducted at the General Battery Corporation (GBC) plant located at Reading, Pennsylvania. Without the assistance and cooperation of GBC management and staff, this study would not have been possible. Special appreciation is extended to Mr. John Bitler, Mr. Neil Lebo, and Mr. Carl Petzold of GBC for their support.

1.0 INTRODUCTION

This report describes the results of a project funded by the National Institute for Occupational Safety and Health (NIOSH) to investigate exposure and emission control technologies with potential application to the secondary lead smelting industry. This particular project investigates the employment of a screw conveyor system to recycle lead flue dust at the General Battery Corporation (GBC) secondary lead smelter in Reading, Pennsylvania.

The project was conducted by the Occupational Safety and Health Division of Radian Corporation. The information in the report was obtained by Radian through visits to the General Battery plant in October and December, 1981 and through contact with vendors and designers of screw conveying equipment following those visits.

The information developed and presented in this report is not intended to provide a definitive solution to the problem of handling of leaded flue dust. The study is, however, a review of GBC's attempts to solve this problem and the experience gained in this effort. This report (1) provides a technical description of the system and it's operation, (2) reviews operation and maintenance requirements, (3) describes financial costs and advantages, (4) assesses environmental variables, (5) describes problems experienced, and (6) suggests some recommended design considerations to help alleviate operational problems.

57<

2.0 BACKGROUND

Secondary lead smelters typically capture lead and other particulate airborne material in air cleaning devices to reduce emissions to the ambient environment. Equipment used to capture and control these emissions generate large volumes of high lead content flue dust.

2.1 GENERAL METHODS OF HANDLING AND DISPOSING OF FLUE DUST

The actual collection of flue dust poses few exposure problems, other than during maintenance of collection equipment. It is during the handling and disposing of collected flue dusts that exposure problems occur. Several optional methods exist for handling collected flue dust and are currently being practiced. Among these are:

- Selling flue dust to other users, e.g. secondary or primary smelters.
- Disposing of the flue dust in an approved landfill.
- Recycling of the flue dust for the purpose of reclaiming the lead content.

GBC does not consider the selling or disposing of flue dust to be viable options because (1) the flue dust represents a substantial economic value to the smelter due to its lead content, (2) suitable landfills are not available in the area, and (3) shipment of flue dust to other users presents potential environmental problems. Furthermore, potential buyers are becoming scarce because of the difficulties associated with the handling of flue dust. For these reasons, GBC has elected to recycle captured flue dusts through their reverberatory furnaces.

58<

2.2 METHODS OF FLUE DUST RECLAMATION

A number of different methods for handling and recycling flue dusts have been developed in the secondary smelter industry. This section provides an overview of these methods and introduces GBC's approach of conveying flue dust directly to a furnace.

The major approaches to flue dust reclamation are presented below:

- Open Storage and Transport. This simple approach allows flue dust to be piled up in the vicinity of the baghouse. Front-end loaders then transport the flue dust to the charge preparation area for mixing with other charge materials, or to storage This method creates high exposures due to wind erosion, spills, rubber-tired vehicle traffic, vibration, and the general contamination associated with open transport.

- Container Transfer. In some plants, flue dust is collected in containers, both open and closed. These may include barrels, steel bins, boxes, or large canvas bags. While more environmentally protective than open transport, this approach also results in considerable emissions and exposures, usually as the result of poor work practices, spills, and during dumping of the container. Collection and transfer of flue dust in tote bins also create emission and exposure problems during removal of the bin from the collection device and during charging at the furnace. One problem is that the flue dust must either be dumped or shoveled all at once into

59<

the charging device within an exhausted protective enclosure. This operation potentially creates additional fugitive emissions and exposures. Exposures are especially affected if the dusty material is manually shoveled. Another container transfer method has been developed at a plant in Denver, involving the filling of disposable cardboard containers with flue dust, and charging the containers directly to the furnace.

- Modifying the Form of the Dust. Some smelters alter the dusty characteristics of the flue dust so as to reduce emissions. This is accomplished by wetting, e.g. with a pug-mill, or by agglomerating, e.g. with a Bergsoe-type hearth furnace or a Tonolli-type rotary furnace. This technique* can reduce emissions but usually requires a restrictive set of metallurgical parameters and still requires handling of the agglomerated dust. Further, the cost of the approach can be high, typically $100-200K, or more.

- Conveying Flue Dust to Point of Furnace Charge. This approach, which is described in detail in this report, keeps flue dust in an enclosed system, which theoretically eliminates the potential for emission.

---

* Agglomeration of flue dust has been studied and is reported by Radian in "Emissions and Emission Controls at a Secondary Lead Smelter," January 1981 and in "Control Technology Assessment: The 'Secondary Nonferrous Smelting Industry,'" NIOSH Publication 80-143, October 1980.

60<

3.0 GENERAL ASPECTS OF SCREW CONVEYING/RECYCLING FLUE DUST

Automatic and continuous recycling of flue dust at secondary lead smelters might be accomplished by any one of the previously described handling methods; however, screw conveying of leaded flue dust has several advantages. According to one manufacturer, designer, and installer of various types of conveying systems, screw-conveying is the most economical method for handling lead oxide or flue dust. Screw conveyor systems can be totally enclosed from the point of flue dust collection (usually at a baghouse hopper) to the furnace charge point, and they can be held at negative pressure to prevent emissions.

The properties of lead flue dust typically collected in secondary smelters are such that some special considerations must be taken into account when selecting a material handling system. The flue dust is not significantly corrosive but possesses moderate abrasive qualities. Most significantly, lead flue dust has a high density and may pack under normal conditions. Finally, it may become like cement if it collects moisture.

Some screw conveyor system components are shown in Figure 1. Conveyor screws are available in different configurations to serve different functions, as shown in Figure 2. Standard pitch screws (upper left corner, Figure 2) are normally selected for flue dust handling in main sections. Trough enclosures are generally selected over tubular types because of maintenance access. Hanger bearings and shafts made of hardened (abrasive resistant) materials are recommended by most manufacturers for systems handling lead oxide or flue dust.

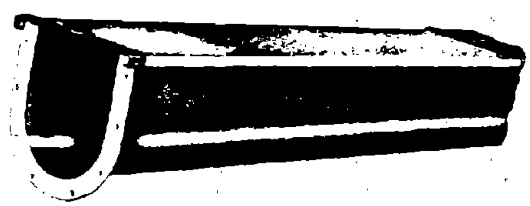
FIGURE 1 SCREW CONVEYOR COMPONENTS

The Conveyor Screw imparts a smooth positive motion to the material as it rotates within the trough.

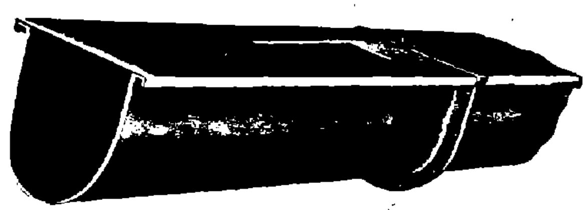
Couplings and Shafts connect and transmit motion to subsequent screw conveyors. Held in place by self-locking Tem-U-Lac bolts.

Hangers provide support, maintain alignment and serve as bearing surfaces.

Troughs and Covers completely enclose the material being conveyed and the rotating parts. Covers are available in various types and are secured to the trough by Spring, Screw, Tite-Seal or quick-acting Barron Clamps depending on the trough cover combination used.



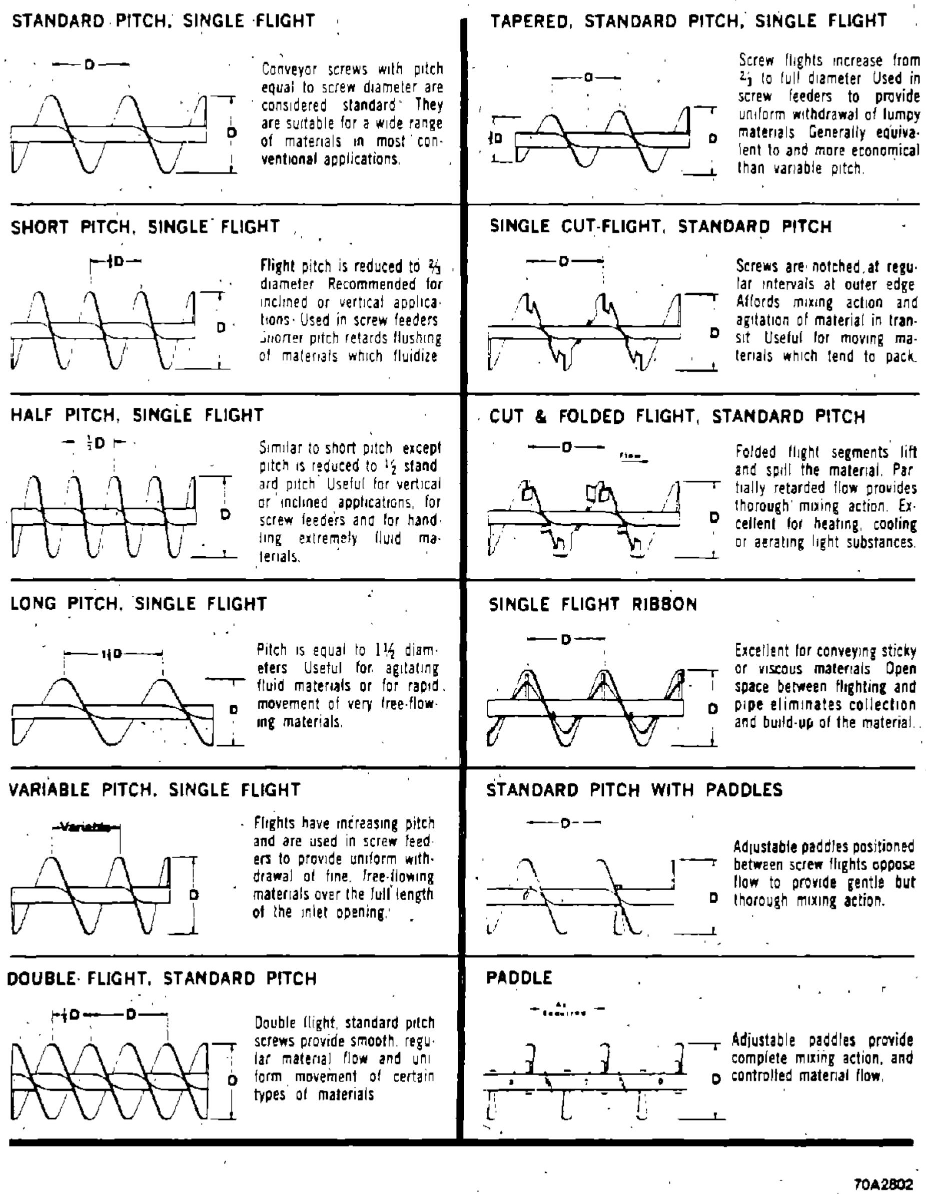
Inlet and Discharge Openings may be located wherever needed, discharge spouts may be without slides or fitted with either flat or curved slides. These slides may be operated by hand, rack and pinion gears, or by power.



SOURCE: SCREW CONVEYOR CORPORATION 70A2801

62<

FIGURE 2 CONVEYOR SCREW TYPES



SOURCE: CONVEYING MACHINERY COMPANY

4.0 DESCRIPTION OF GENERAL BATTERY CORPORATION PLANT OPERATIONS - READING, PA.

4.1 GENERAL PLANT DESCRIPTION

General Battery Corporation's (GBC) facility in the Reading, PA Metropolitan area is located in Muhlenberg Township and the Burrough of Laureldale. The plant produces hard and soft lead ingots and antimonial alloys in two (almost) identical blast furnace-reverberatory furnace installations. Scrap industrial and SLI batteries are the major raw materials. When the plant was constructed in 1971, it had two blast furnaces, a reverberatory furnace and ten kettles. In 1976-1978 reverb No. 2 and additional process gas handling and sanitary ventilation/gas treatment systems were added. The plant layout is shown in Figure 3.

This plant is among the largest U.S. secondary smelters. In addition to smelting operations, GBC manufactures SLI, industrial, and motorcycle batteries at this facility.

This plant charges entire (crushed) plastic-cased batteries and tops (grids and posts) of rubber-cased batteries to two blast and reverberatory furnace trains, each of which has a rated output capacity of 65-80 tons/day. Batteries and flue dust are charged to the reverb furnaces and reverb slag is charged to the blast furnaces.

As shown in Figure 3, material flow through the smelter occurs generally from the north to the south end. The operations occur in the following order from north to south: raw material receiving and storage, battery breaking, charge storage and preparation, smelting/refining/casting operations, and slag storage. Reverb furnace slag is transported from the south storage area back to the charge storage area for blast furnace feed and flue dust from baghouses is recycled back to the

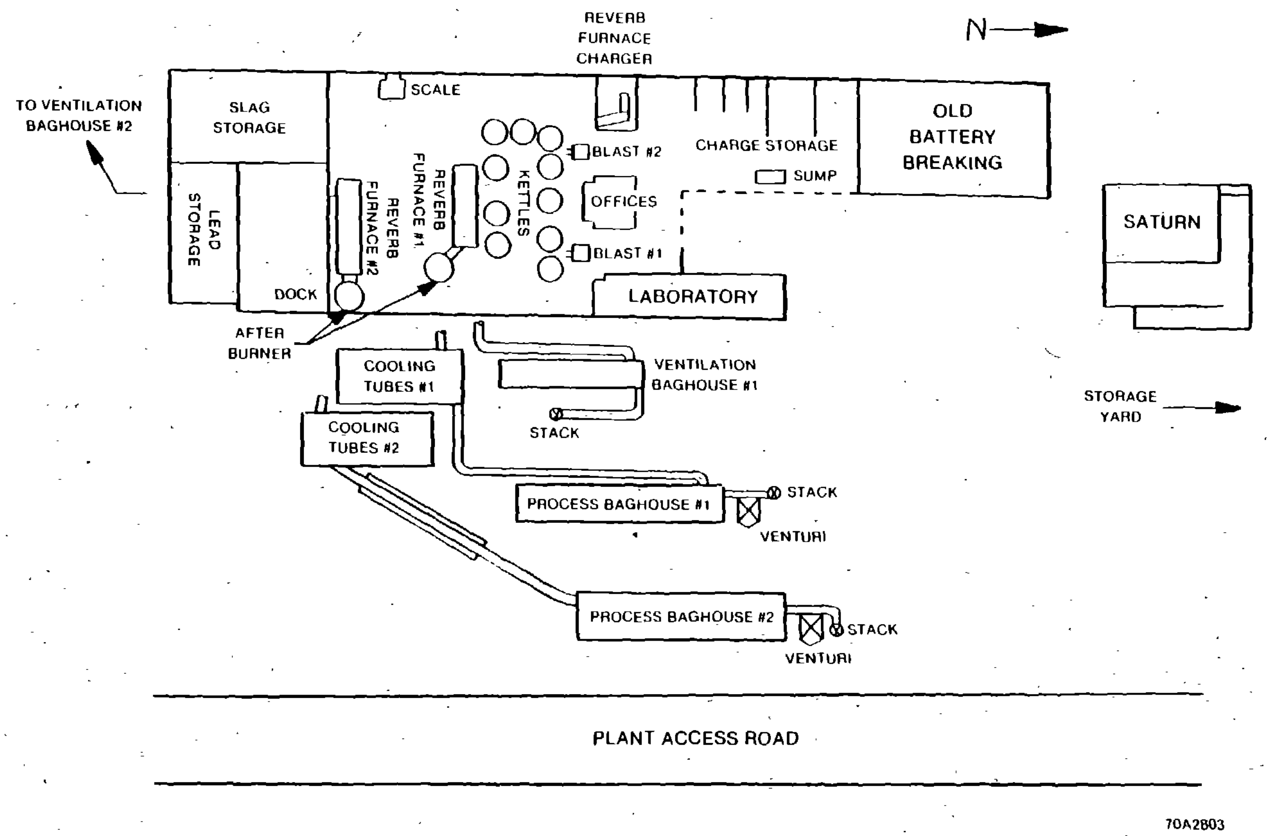


FIGURE 3 SMELTER PLOT PLAN FOR GENERAL BATTERY

65

reverberatory furnace feed.

4.2 SCREW CONVEYING/RECYCLING OF FLUE DUST

As described above, GBC recycles its flue dust, containing high concentrations of lead material, in an enclosed screw conveying system. GBC incorporated the system in the original Reading Plant design built in 1971 and expanded the system in 1978.

Each of the two process trains has its own air handling and cleanup systems, consisting of one ventilation (hygiene) system and one process gas system each. The ventilation system for each process train collects particulate gaseous emissions from the slag and lead taps at the blast furnace, slag and lead taps at the reverb furnace, raw material discharge and charging points at the reverb furnace, and the refining kettles. The process gas system for each process train collects hot process gas and particulate from the top of the blast furnace, process gas from the reverb furnace, and fugitive emissions and heat from the top of the reverb furnace. The ventilation systems discharge directly through ventilation baghouses. The process gas systems discharge through after-burners, cooling tubes, process baghouses, and then a venturi and scrubber. The combined collection of all systems is estimated to average 2500 to 3000 pounds of flue dust per hour.

Lead flue dust is collected via trough screw conveyors, as shown in Figure 4, from the bottom of each of the two sets of cooling tubes, the bottom of each of the four baghouses (two process houses and two ventilation houses), and from the bottom of the #2 process gas duct (between the cooling tubes and the #2 process baghouse). The dust from the #1 process and ventilation baghouses and the #2 process gas duct and process baghouse are collected individually and fed to a main gathering screw at ground level. The #2 ventilation system baghouse is handled

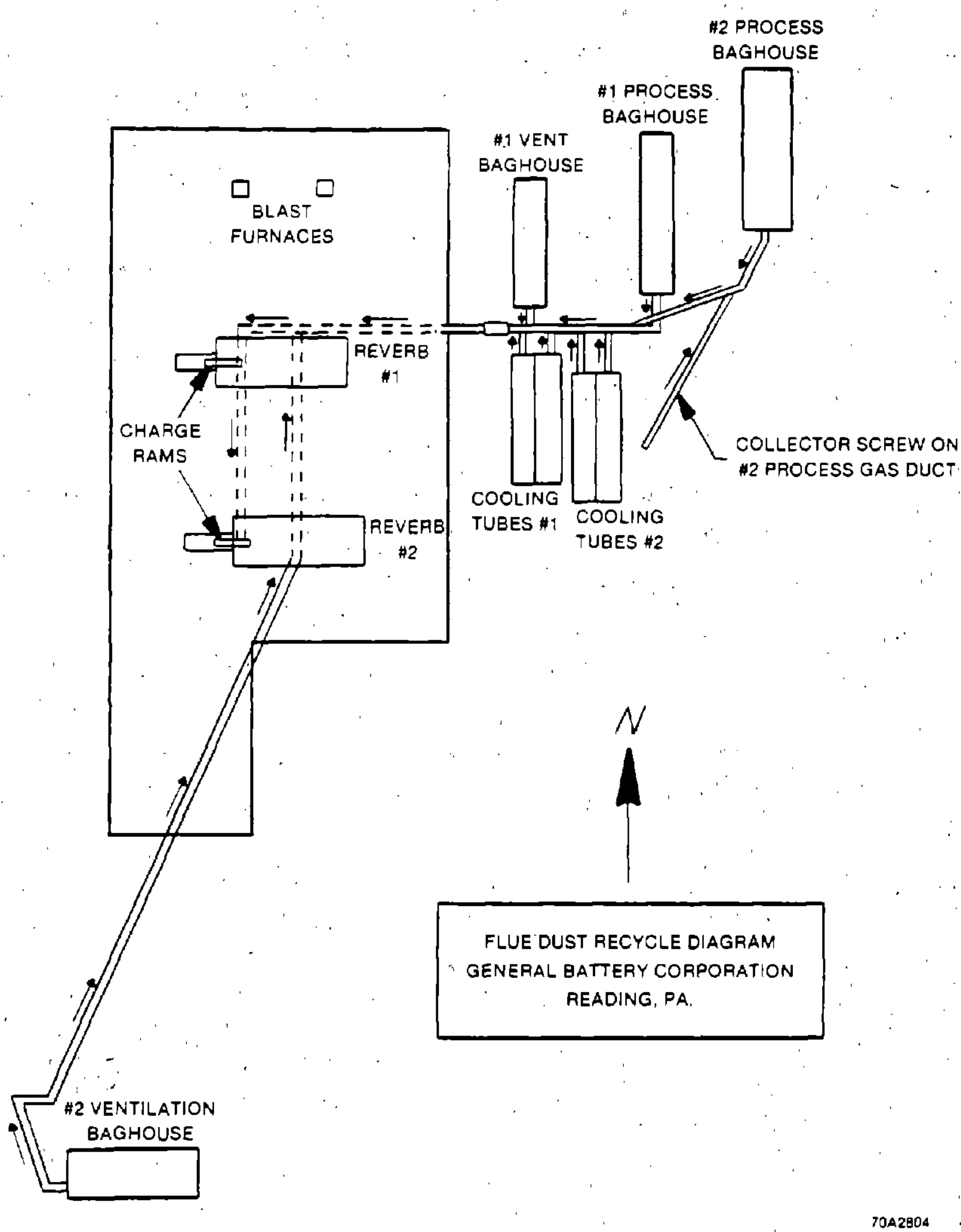


FIGURE 4 FLUE DUST-FLOW DIAGRAM

by a separate screw conveyor system. Both screw conveyor systems dump into bucket elevators at locations outside the smelter building, which in turn dump back into overhead screw conveyor systems running into the building. These two overhead systems converge above the #1 reverb furnace to form a single feed stream. The feed stream screw conveyor feeds the flue dust charging chute at either the #1 or #2 reverb furnace, one at a time, alternately.

The flue dust chutes allow the dust to flow separately from the other charge materials by gravity to the charging ram. The flue dust chute feeds into the ram compartment at a point between the raw materials charging chute and the entrance of the ram into the furnace. The flue dust and raw materials are fed separately to the ram to control moisture entering the dust handling system from the wet raw charge materials. Figure 5 shows a general representation of the feed/charge arrangement.

The screw conveyor system was constructed in two phases. The first phase was part of the original plant construction in 1971 and included the collection system from the #1 process cooling tubes, the #1 process baghouse, and the #1 ventilation baghouse and the conveyor system from that area to the #1 reverberatory furnace. The remainder of the system was installed during a plant expansion in 1978. The two segments comprise a total system which is designed for a maximum surge loading of 54,000 pounds of flue dust per hour (900 lbs/min). Although it is estimated that the system handles an average of 2500 to 3000 pounds per hour (based on long term data), the maximum surge load experienced in a short period of time is unknown.

All sections of the screw conveyor system employ 12-inch diameter screws in the main runs and mostly 9-inch diameter screws at gathering points. All screw sections are contained in troughs

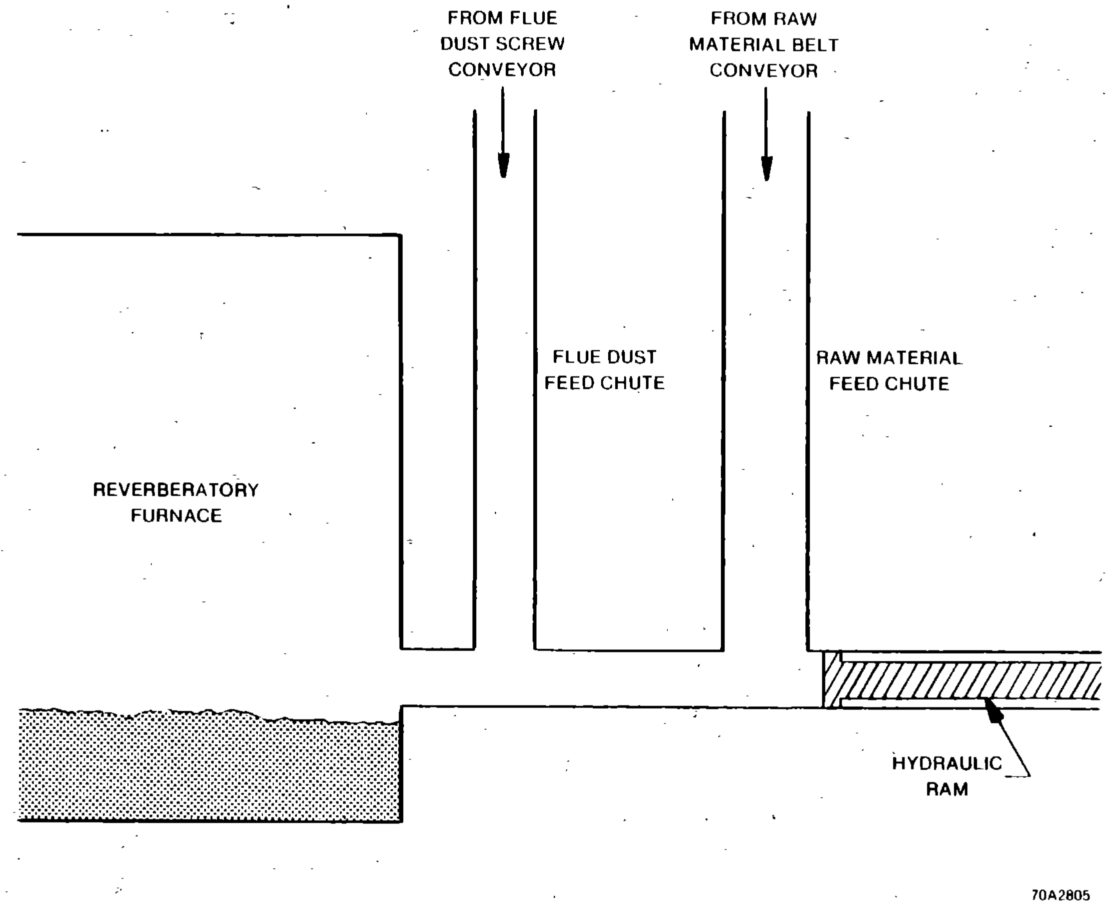


FIGURE 5 CHARGE CONFIGURATION.

with screw-down covers. Cleanout doors are provided at each transfer point throughout the system. In total, there are approximately 1300 feet of screws and troughs and two bucket elevators. Figures 6 and 7 show typical sections of the system.

70<

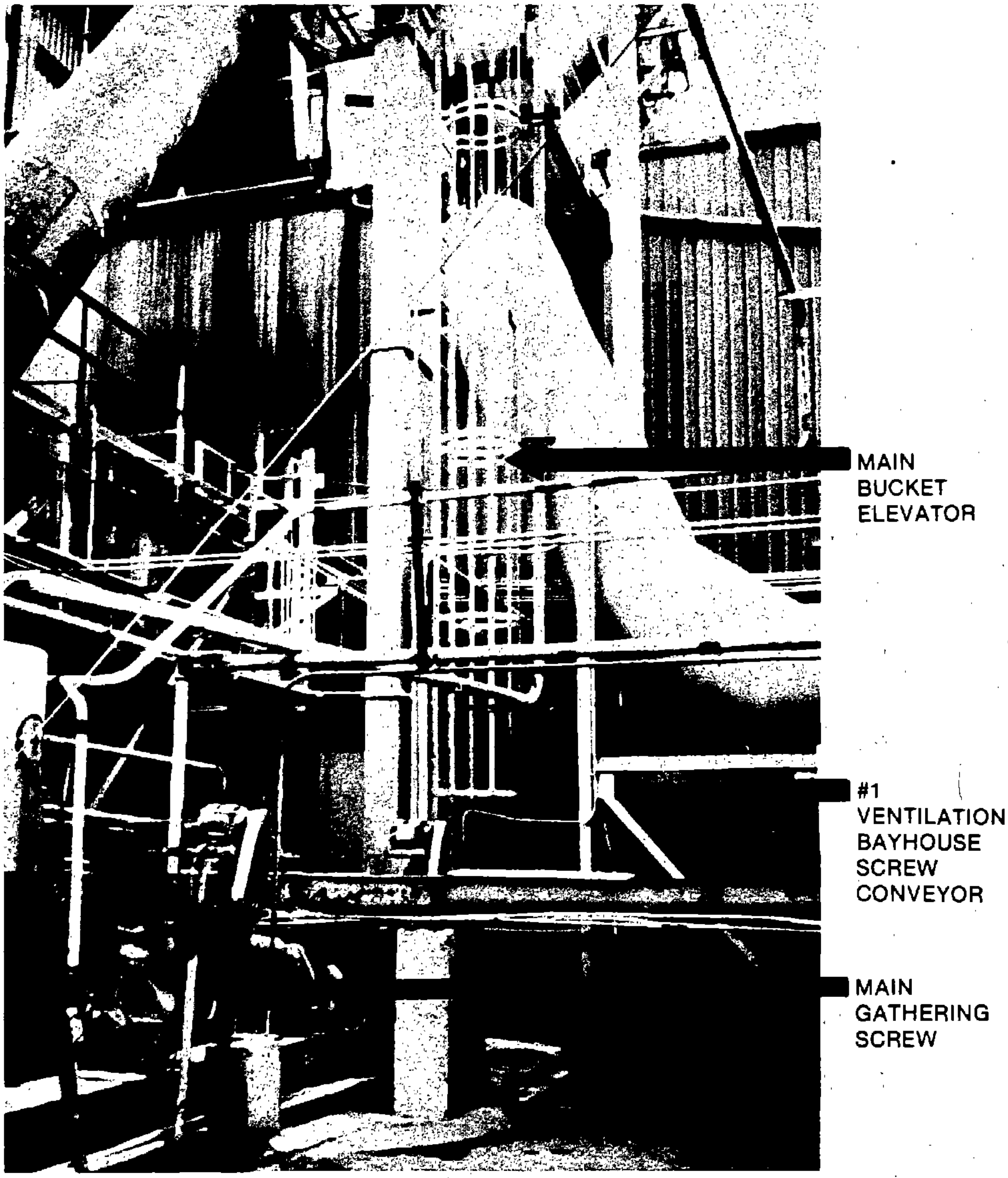


FIGURE 6 SCREW CONVEYORS AND MAIN BUCKET ELEVATOR

71<

FIGURE 7 OPEN FLUE DUST SCREW CONVEYOR COVER, TROUGH, AND SCREW

72<

5.0 OPERATION AND MAINTENANCE

This section describes requirements for the operation and maintenance of the screw conveyor/recycle system. Most of these requirements result from problems in the GBC system. (A description of these problems and potential solutions are discussed in Section 8.)

Because of problems incurred with blockage at different points in the system (see discussion in Section 8.2) an operational requirement has been established. Pollution control personnel (those maintaining pollution control systems) spend approximately 2 man-hours each shift cleaning out transfer points. Prior to adopting this practice, overflows in the system occurred approximately once a shift and required 2 to 3 man-hours to clean up. Clogs in the system seem to occur most frequently at the end of the feed screws where the flue dust is fed to the charge chutes and less frequently at other transfer points, such as that dumping into the bucket elevator boots.

Maintenance requirements, both scheduled and unscheduled, are estimated to average approximately 3 man-hours per day or 1 man-hour per operating shift. Scheduled maintenance includes weekly greasing and oiling of drive and screw assemblies.

Unscheduled maintenance primarily consists of replacing broken shaft couplings, hanger bearings and worn out screws. The frequency of these requirements is unpredictable. One maintenance worker stated that there may be no failures in a given week and then as many as eight in another. Maintenance time is increased by the presence of screw-down trough covers rather than the clamp type.

The majority of unscheduled maintenance requirements experienced with this system are considered to be avoidable at new installations. See Section 8 on the analysis of system problems and recommended design modifications and considerations. Scheduled maintenance will be necessary with any system and some degree of unscheduled maintenance will occur from time to time.

6.0 ENVIRONMENTAL CONSIDERATIONS

Although the objective of this evaluation is to assess the application of this technology for control of worker exposures to lead, other aspects of environmental concern are mentioned here. This operation produces no additional solid or hazardous waste, and actually reduces the volume that might be generated under other approaches. There is no water involved in the process nor any washdown or liquid discharge points. Noise is also not a problem since the only potential noise sources are the electrically driven motors and the screws being mechanically rotated. Emission of leaded flue dust to the air is the only major environmental consideration.

There is no easy way to quantitatively evaluate the impact of emissions on personnel exposure or on the ambient environment. Measurement of air concentrations or exposure levels before and after the installation of this technology was impossible, since it was part of the original plant installation. Major exposure and emission problems only occur if the system is opened, or during upset conditions.

At GBC, or at any other operation of a screw conveying system, some scheduled maintenance of internal components is required and is an unavoidable exposure condition. Upsets can also be expected to occur periodically, which may cause system shutdown and repair. However, routine cleaning-out of transfer points within the system and frequent repair and replacement of couplings at GBC, as described in the previous section, are operations in which exposures may be potentially reduced. These operation and maintenance exposure conditions are depicted in Figures 8 and 9. Such exposures are not expected to occur in new installations following the design considerations presented in Section 8.

FIGURE 8 CLEANING SCREW CONVEYOR TRANSFER POINTS

76

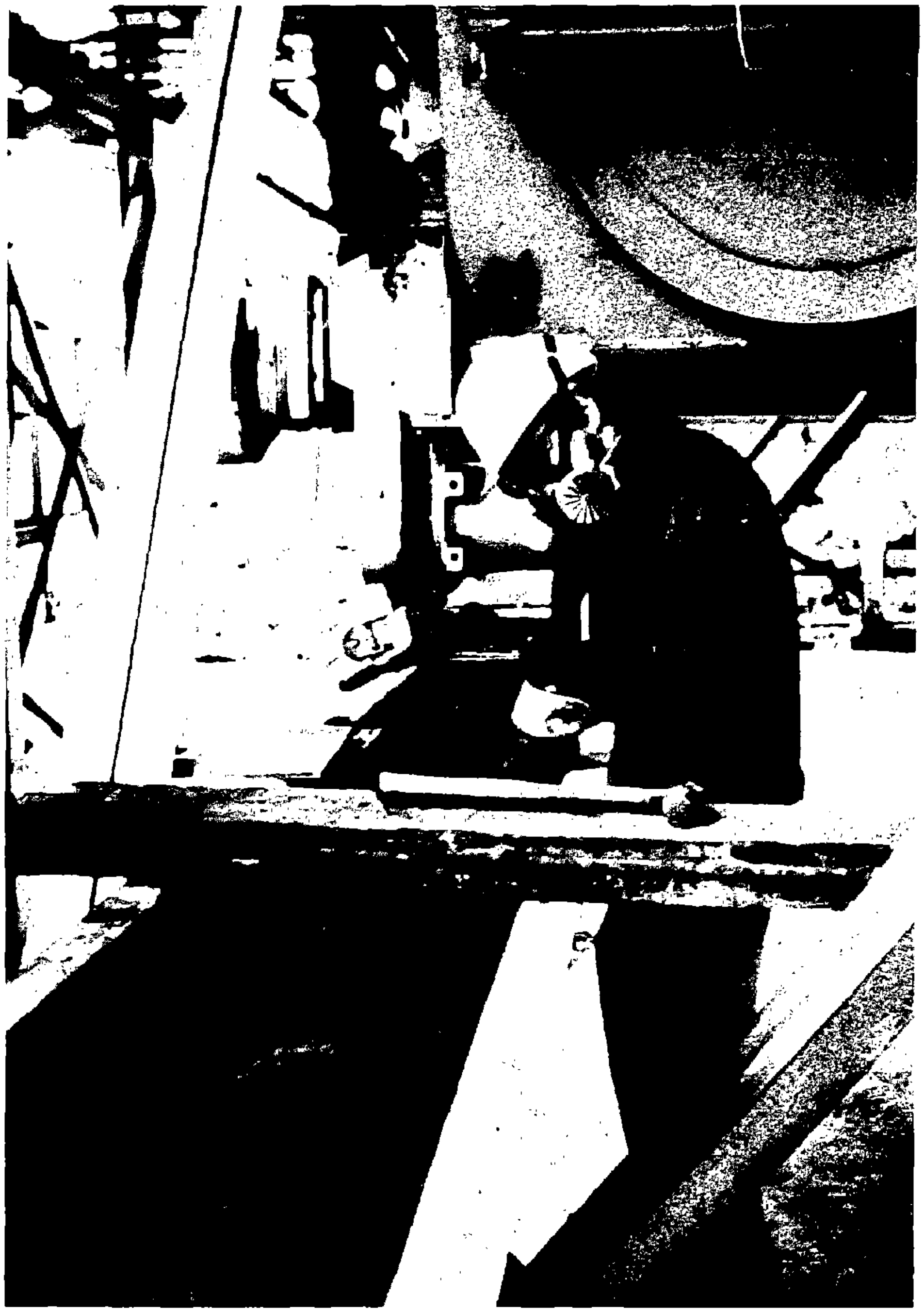


FIGURE 9 REPLACING BROKEN HANGER BEARING AND COUPLING

77<

Fugitive emissions are also expected to occur to some degree in most systems, which result from incomplete sealing during installation, wear and deterioration of equipment, and operational upsets. These emissions add to the overall emission to the atmosphere and create exposures where personnel are working in the area. At General Battery, fugitive emissions from the screw conveyor system do not appear major. They are controlled by maintaining the system and by keeping a slight negative pressure placed on flue dust conveyor troughs and handling equipment. Based on static pressure measurements taken during the site visit, it was found that a negative pressure is maintained on all outer portions of the two systems (between the baghouses and the bucket elevators). From the bucket elevators to the feed point at the furnaces (the inner portion of the system), the pressure was equal to atmospheric, i.e. no positive control of emissions. The negative pressure maintained on the outer reaches of the system is the result of the negative pressure of the attached baghouses. There is also one direct ventilation tie-in at the bucket elevator on the main gathering conveyor system that maintains a negative pressure on that system component (see Figure 10).

Minor emissions occur at points where drive assemblies enter the troughs (Figure 11), at cracks and openings on the main bucket elevator housing (Figure 12), and at the charging rams where dust is pulled out of the charging shaft on the ramslide mechanism. Dust pulled out on the ramslide mechanism is limited by a permanently installed rubber scraper which scrapes dust off the mechanism and down a slide into a tote bin (Figure 13).

A major source of occasional emissions, reported during the visits to GBC, is the occurrence of overflows from the overhead screw conveyor system. This reportedly occurs because of blockages in the flue dust charging chute, causing flue dust to back-up from

78<

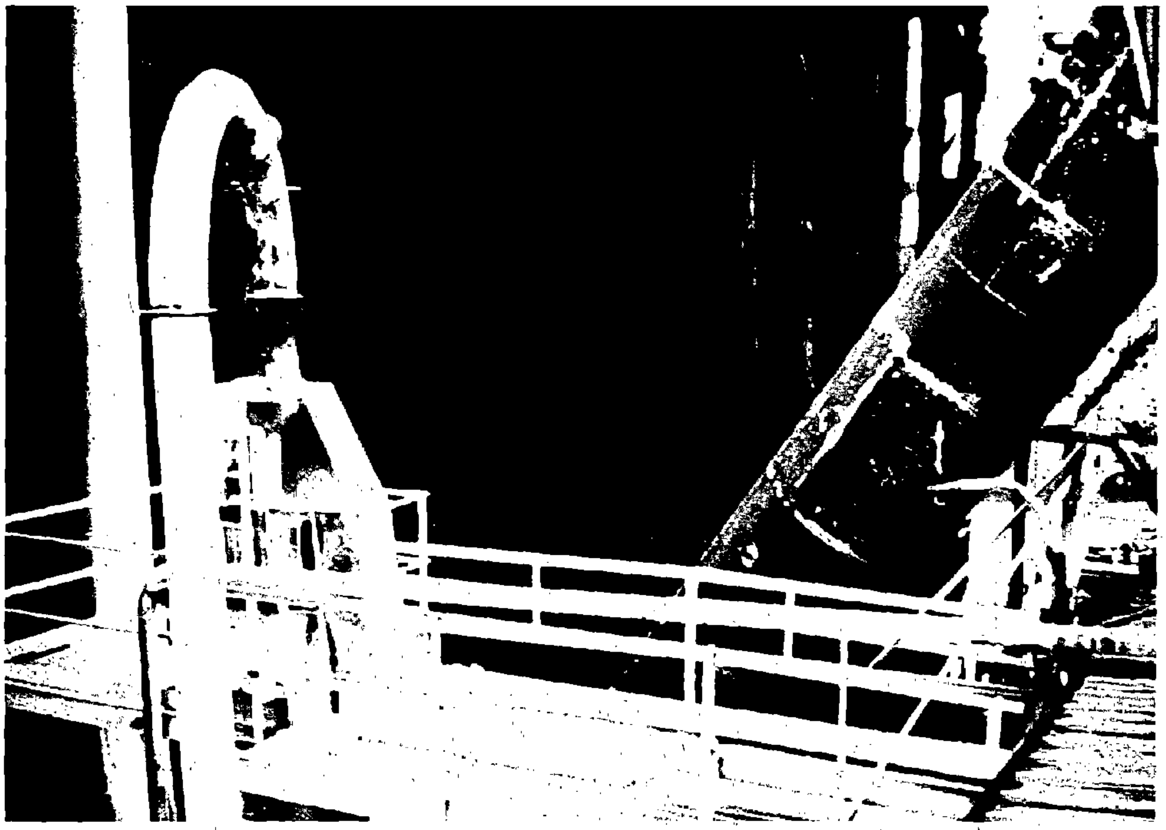


FIGURE 10 VENTILATION TIE-IN AT MAIN BUCKET ELEVATOR

79<

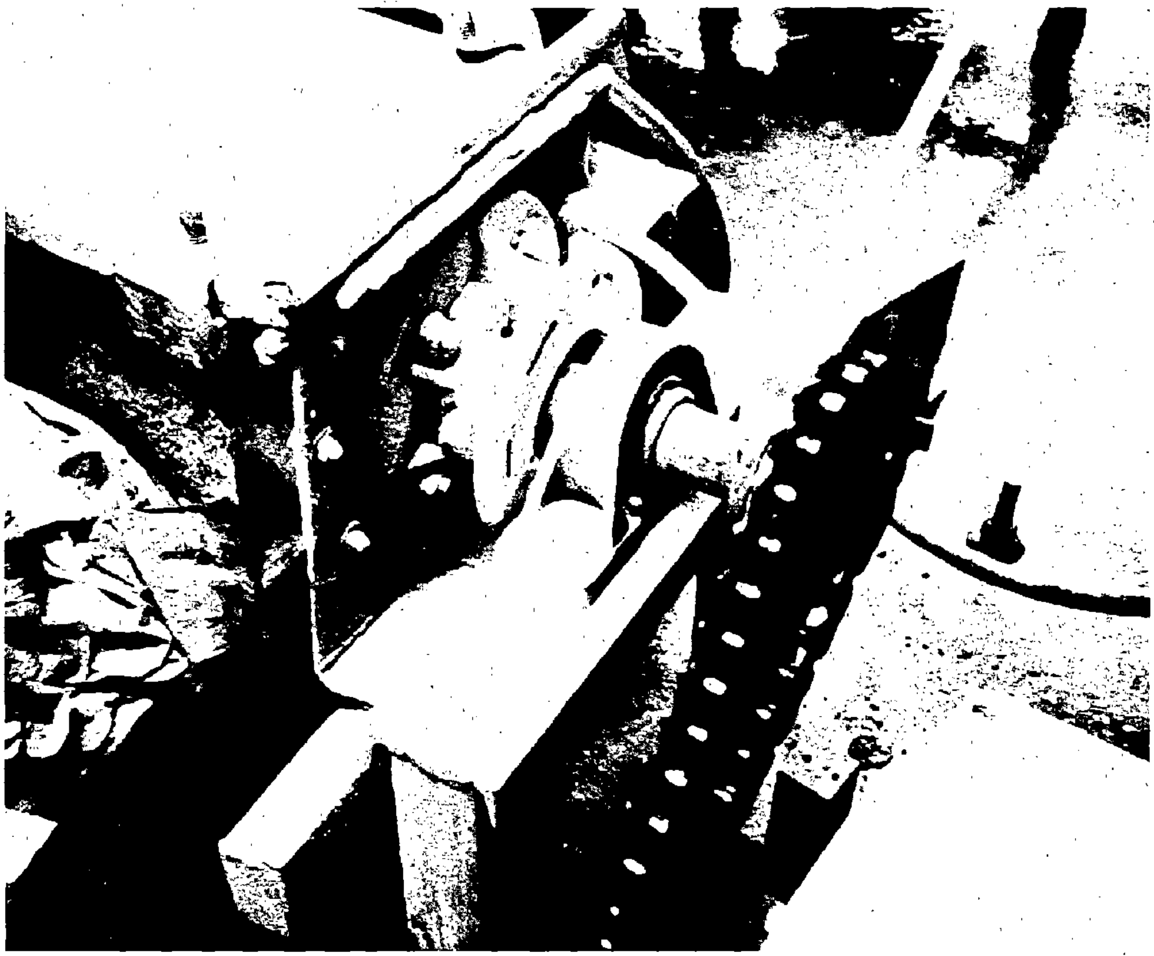


FIGURE 11 FLUE DUST LEAKS AROUND MOTOR DRIVE SHAFT

80<

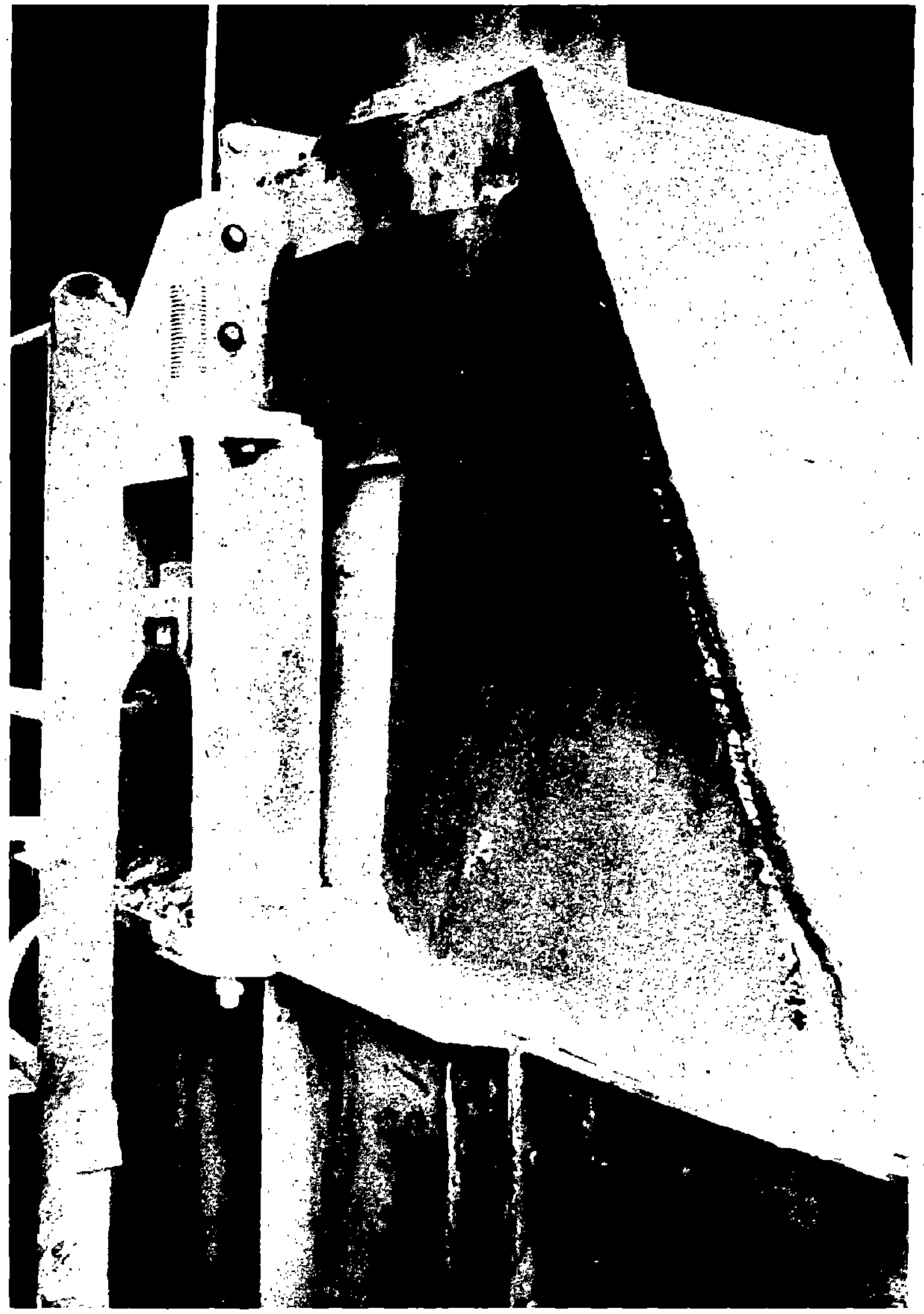


FIGURE 12 FLUE DUST LEAKS AT CRACKS AND SEAMS ON BUCKET ELEVATOR

81<

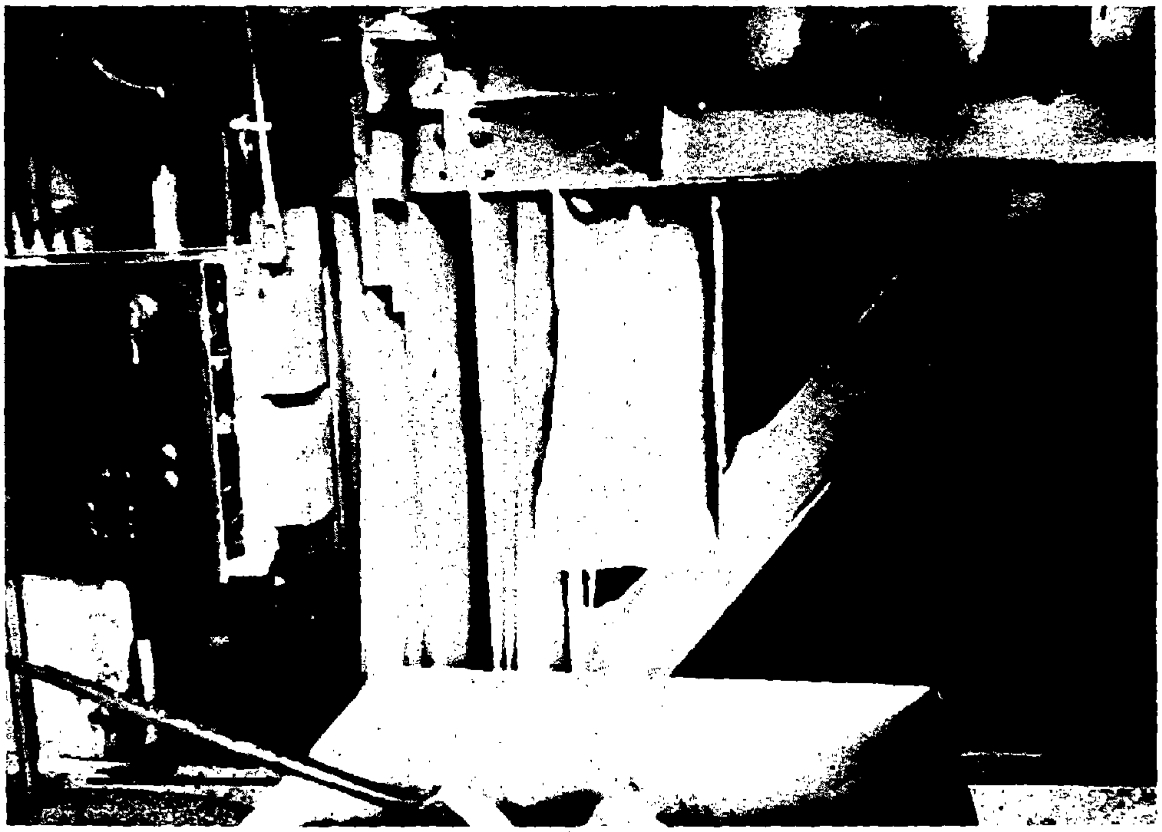


FIGURE 13 CHUTE AND COLLECTION BIN FOR DUST COLLECTED FROM CHARGE RAM

the charging chute through the screw conveyor troughs. When the backed-up dust places pressure on a weak point in the system (e.g. a loose cover or an access door) the dust breaks through and pours out over the smelter area, until someone shuts the system down. Figure 14 shows the end of the screw conveyor system at the flue dust charging chute, the access door where many overflows occur, and dust left over from past spills.

Since the time of the site visits, some additional control actions have been taken at GBC to limit continuous fugitive emissions and overflows from system upsets described above. These actions are discussed in Section 8.

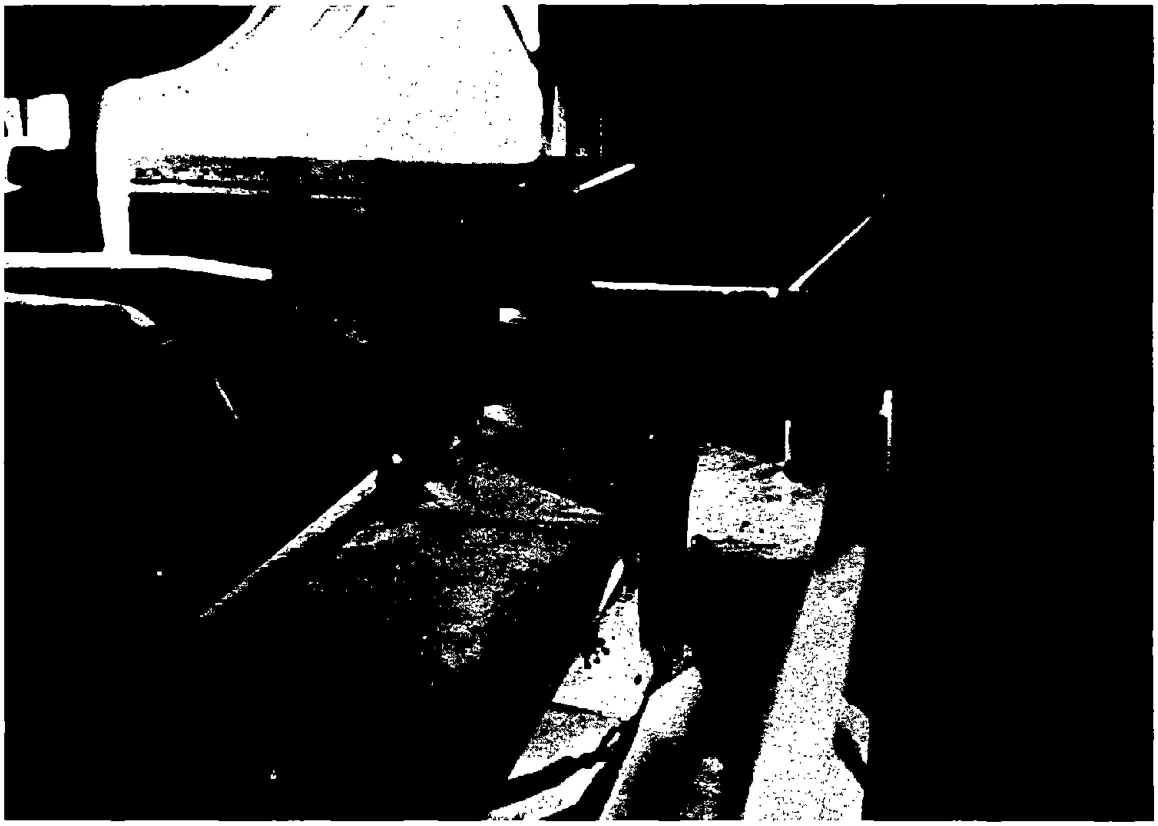


FIGURE 14 OVERFLOW POINT AT TOP OF THE FLUE DUST FEED CHUTE

7.0 COSTS

It is estimated that GBC may recycle as much as 30 to 40 tons of flue dust per operating day (24 hours). From assays of the flue dust, the lead content has been measured at 50 to 60%. This interprets to approximately 15 to 25 tons of lead per day recycled as flue dust. According to GBC, an approximate figure of 20 cents per pound of refined lead (30 cents per lb. market value minus 10 cents per lb. processing costs) may be realized in savings. At GBC-Reading this may equate to a total value of reprocessed lead of $6,000 to $10,000 per operating day.

The cost of the screw conveyor system at GBC is not available since it was a small portion of a much larger, phased engineering project. However, the designer and manufacturer of the screw conveying system at GBC, Hussong-Walker-Davis Company, provided the following general costing guidelines at 1981 prices to estimate equipment and construction costs. As a general guideline, a standard 50-foot long section comprised of 12-inch screws, troughs and covers, and a 10-horsepower rated motor, should be estimated at $250 per running foot or $12,500 total for equipment costs. Equipment costs for conveyor sections longer or shorter than 50 feet should be based on the 50-foot section price plus or minus $175 per running foot for each foot greater or less than 50 feet (e.g. cost of a 70-foot section = $12,500 + (20 ft.) ($175/ft.) = $16,000). Erection costs should be estimated at $30 per running foot of conveyor. Any walkways and handrails for access to sections above ground level should be estimated at an additional $150 per running foot of walkway. Approximately 6 months should be allowed for planning, design, manufacture, and installation of a total system.

Operating costs include the energy to run the system and any labor that might be involved. Although considerable O & M labor is required at GBC, it is not expected that new installations will have that extensive requirement. Energy costs were not available at GBC but a maximum cost may be estimated for new designs based on an average recommended design rating of 10 horsepower per 50-foot length. For example, assuming 500 feet of conveyor length, $0.05 per KWH, and an around-the-clock operation, the maximum energy cost would be $90 per day (10 HP/50 ft. x 500 ft. x 0.746 KW/1 HP x 24 hrs. x $.05/KWH) or $32,000 per year. Of course, this represents the maximum cost, and the average should be much less based on the average horsepower demand.

Maintenance and replacement costs include labor for scheduled and unscheduled maintenance and equipment costs. Labor costs at GBC are estimated to be approximately $8,500 per year. Experience at GBC indicated that the replacement frequency for most major system components (e.g. screws, troughs, etc.) is 4 to 5 years.

8.0 DISCUSSION

It is concluded that screw conveyor/recycling of lead flue dust to reverberatory furnaces has significant merits (e.g. closed transport, non-labor intensive, and good economic returns from reclaimed lead value). More importantly, a closed screw conveyor system, similar to that observed at GBC, should significantly reduce employee exposures in comparison to the use of other non-closed methods, if operational problems described in this report can be limited. Recycling of flue dust in other than an enclosed controlled system invariably contributes to airborne lead levels throughout the smelting area, adding to the overall exposure of all smelter area personnel (e.g. furnace operators, casting operators, and refiners).

This section discusses the potential application of screw conveying to other plants, problems associated with the system, and design considerations for new installations. These should be thoroughly evaluated before any endeavor is undertaken to install a screw conveyor system. Prime consideration should be given to the design and safeguards of conveying system components in the smelting area (within the building) to prevent fugitive emissions and overflows in populated areas. Without emissions in the smelting area the only personnel that should be potentially exposed are the maintenance personnel.

8.1 APPLICATIONS

From the experience at GBC it appears that screw conveying of flue dust may be applied to reverberatory furnace operations, in general, with little or no metallurgical or production impact. Continuous recycling of all flue dust at GBC to the reverberatory furnaces has resulted in no observable product changes under normal operating conditions. Under conditions where a build-up of flue dust occurs and a larger ratio of flue dust to raw material is charged to the furnaces, the slag may be more watery. Screw conveyor systems can be retrofitted to most existing gas clean-up/collection systems or installed as part of a new system installation. Charging of flue dust to the reverb furnaces may be accomplished by either feeding flue dust to the raw materials charge point at the furnace, as is done at GBC, or by feeding flue dust directly into the furnace via a water cooled chute. For application of this technology to existing smelters adequate overhead space for runs of conveying equipment must be considered.

The concept of screw conveying/recycling flue dust directly to blast furnaces draws varying opinions. To our knowledge this application has not been tried. Blast furnaces are established as batch operations and screw conveying is continuous. The screw conveying operation would probably have to be converted to a batching process. If flue dust is held near the furnace inlet for batching it may become molten. Flue dust introduced into the blast furnace may become entrained in the flue gases leaving the furnace, potentially short circuiting the recycle system.

8.2 PROBLEMS

The majority of the problems experienced at GBC with screw conveying of lead flue dust are due to clogging. Major emissions and exposures are attributed almost entirely to these upset conditions. Plugging or clogging occurs as a result of overloading or packing within the system.

At General Battery, overloading of the system was found to occur if all baghouses cycled at the same time, causing a massive flow through the system. Since the visits to GBC, changes have been made in the baghouse cleaning cycles which have reportedly helped reduce overloading of the system. The length of time each baghouse cell is shaken has been reduced, but the frequency of each cycle has been increased. Overloading also can occur when any portion of the system is shut down for maintenance and the built-up load is allowed to flow.

Clogs occur at transfer points between screw conveyor sections. Most of these points are located out of doors where moisture may enter the system due to negative pressure on the system. Packing may also occur at these points because of restricted discharge openings between sections. Packing at these locations is compounded by dents and disfiguration of the trough transfer points caused by pounding with a steel bar to dislodge any build-up.

Packing is also a major problem in the GBC system at the bucket elevators. Packing in the boot of the bucket elevators occurs to the point that it occasionally strips the buckets from the elevator drive. This may be due to moisture, undersizing of buckets, poor adjustment of bucket lips, or compaction from the vertical drop of dust into the boot.

Clogging in the GBC system occurs frequently at the charging chute. This may be attributed to several different factors: (1) Raw materials being charged to the furnace may be rammed into the dust charging chute causing blockage which allows dust to build-up back through the chute into the overhead screw conveyor system, or (2) moisture may be drawn or forced into the system from the raw charge materials, although no negative or positive pressure was detected in this section of the system. GBC has tried using vibrators on the charge chute, but it failed to stop the clogging. Since the visits to GBC, a limit switch has been installed at the top of the flue dust charge chute to deactivate the conveyor system and alarm the operator if a clog occurs. After a short trial period, this modification has been judged to be a major success in limiting major emissions within the smelter area.

The frequent replacement of hanger bearings and couplings on screw shafts and less frequent replacement of screws and other major components may be attributed to the heavy stress placed on them by frequent clogs in the system, selection of improper coupling and bearing materials, undersizing of components, or poor maintenance. The rigorous maintenance schedule at GBC would tend to dispell poor maintenance as a likely cause. It is believed that the problem is a result of the stress caused by clogs in the system and selection of standard bearings and couplings instead of hardened and strengthened components. GBC is in the process of installing load limit switches on the screw conveyor drive motors to shut down the system before couplings or screws break. It is suggested that it will be quicker (and obviously less expensive) to manually unclog the jammed screw section than to replace broken couplings and screws.

Fugitive emissions from the other sources mentioned in Section 6 are considered to be relatively insignificant or controllable through additional application of negative pressure to the system or enclosure. Since the visits to GBC, the slide and tote bin, collecting dust from the charge ram, have been enclosed and ventilated.

8.3 DESIGN CONSIDERATIONS

It appears that most of the problems described in the preceding section can be greatly reduced through improved design. The following items are recommended for consideration in the design of a screw conveyor system for handling lead flue dust:

- Arrange, if possible, for all gas cleanup systems (baghouses) to cycle at different times.

90<

- For periods when conveyor segments may be shut down for repair or maintenance and then restarted, provide a by-pass to handle the continuous build-up in the collection devices or design the conveyor system to handle a high flow in order to prevent overloading.

- Size the screw conveyor system to handle flue dust at a maximum trough depth of 15% (12-inch screws have been found to work best at GBC and are recommended by vendors).

- Use sealed covers on all conveyor sections and assure that all transition and junction points are sealed tight and protected from potential water infiltration.

- Specify spring-clamp type cover fasteners or equivalent for easy removal and replacement.

- Oversize discharge openings at all transfer points.

- Oversize bucket elevators or consider use of drag conveyor or inclined screw to elevate load, where room is available.

- Design a flue dust feed chute with a spring-loaded trap door if a ram charge configuration is used (see Figure 15). This should reduce the amount of dust deposited on the ram as well as prevent clogging in the feed chute.

- Design valves in the flue dust feed system to allow all furnaces to be fed simultaneously, individually, or alternately by remote selection.

- Install limit switches at points where maximum build up and clogging are likely.

- Use only hardened bearings and couplings.

- Provide negative pressure on all sections of the system, especially those inside the work area, to prevent fugitive emissions (this may be partially accomplished by the negative pressure placed on the system by the attached baghouses and by addition of an exhaust system tied in at the flue dust charging point).

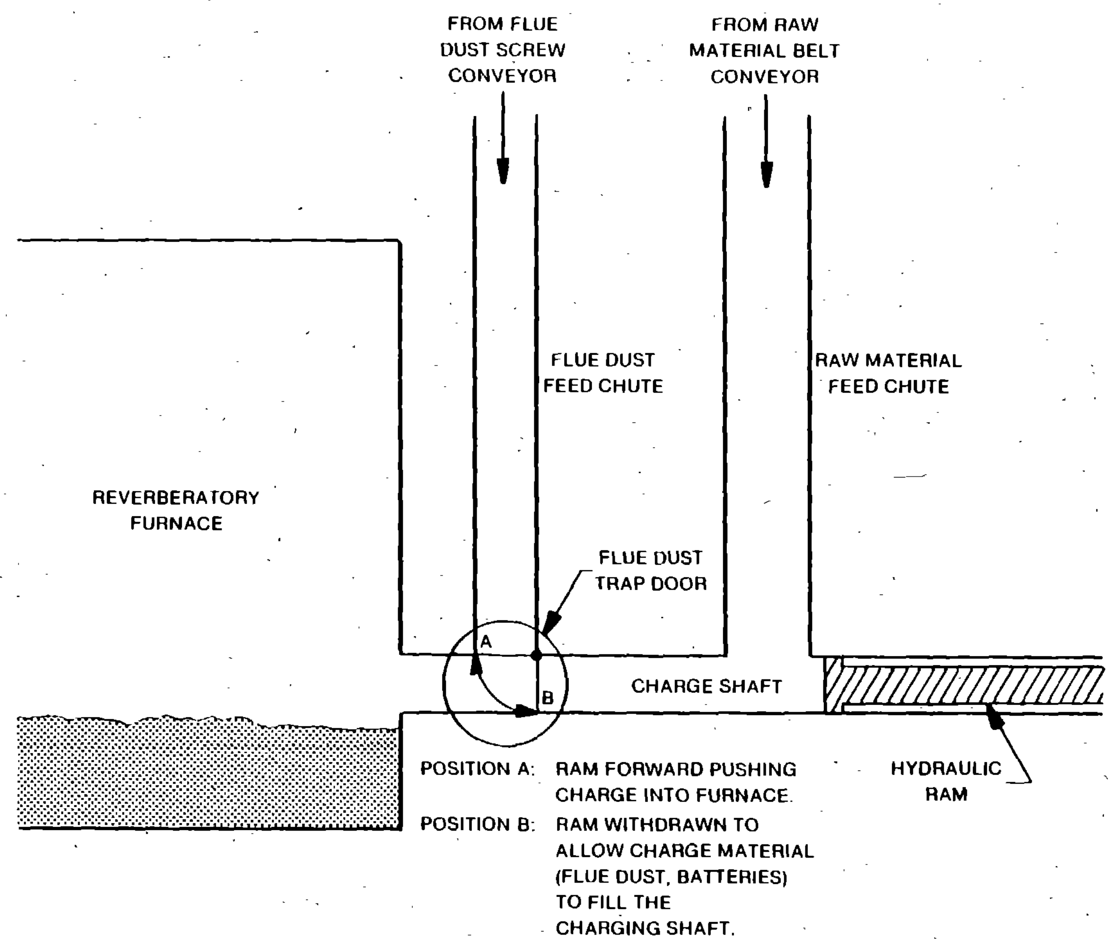


FIGURE 15 FLUE DUST TRAP DOOR RECOMMENDATION

Demonstration
No. 10

EVALUATION OF AIRSHOWERS AND SHOECLEANERS AS EXPOSURE CONTROLS IN SECONDARY LEAD SMELTERS

Final Technical Report
Demonstration Project Number 10

A. V. Simonson and C. C. Mecham
Radian Corporation
Division of Occupational Safety and Health
Salt Lake City, Utah 84115

NIOSH Contract No. 210-81-7106

Centers for Disease Control
National Institute for Occupational Safety and Health
Division of Physical Sciences and Engineering
Cincinnati, Ohio 45226

September 1983

DISCLAIMER

The contents of this report are herein as received from the contractor.

The opinions, findings, and conclusions expressed herein are not necessarily those of the National Institute for Occupational Safety and Health, nor does mention of company names or products constitute endorsement by the National Institute for Occupational Safety and Health.

NIOSH Project Officer: Robert T. Hughes

Project Technical Director: D. Jeff Burton
Radian Corporation

Demonstration #10 Task Leader: Ann V. Simonson
Radian Corporation

96<

FOREWORD

The National Institute for Occupational Safety and Health (NIOSH) is responsible for helping ensure that every person in the U.S. has safe and healthful working conditions. To accomplish this end, the Institute engages in research on occupational safety and health problems including evaluation of hazards and their control.

One of the hazards considered for evaluation and control is lead exposure in the secondary lead smelting industry. NIOSH therefore funded a study to demonstrate emission and exposure controls at secondary lead smelters.

This technical report presents the findings of one of the demonstration projects. It has been written primarily for the secondary lead smelter operator. We hope it will provide the basis for further exposure reductions in plants where the technology can be adopted.

EXECUTIVE SUMMARY

This demonstration project presents an evaluation of airshowers and automatic shoecleaners as employee exposure control options in secondary lead smelters. Radian performed the study under the sponsorship of the National Institute for Occupational Safety and Health.

Site visits were made to three smelter establishments to observe application and use of airshower equipment. Some smelter operators have installed airshowers and shoecleaners outside lunchrooms specifically to comply with hygiene facilities and practices requirements of the OSHA lead standard. Others use airshowers outside cleanroom facilities to keep the rooms as lead-free as possible and maximize their usefulness as exposure control measures.

Tests of airshower effectivieness were conducted on-site and in a laboratory simulation. The data show that airshowers are generally effective in lead dust removal. From 5-72% of lead (in the form of lead oxide) applied to fabric patches worn in an airshower field test was removed by use of the airshower. From 23 to 69% of lead oxide dust applied to fabric patches was removed during laboratory simulations of airshower operation. The amount of dust removal varied according to fabric weave and weight. All fabrics tested showed some degree of dust breakthrough during testing. The amount of breakthrough is small, but may present a significant source of skin contamination.

Employee use of automatic shoecleaners was observed during site visits to six smelter establishments. Both vacuum/brush and water/brush shoecleaners were observed. Both were effective in removing dust and dirt accumulations from worker's shoes. Employee diligence in using the shoecleaning equipment varied widely.

Dust containment practices (use of smocks and shoecovers) were observed at two smelter establishments. As a control for dust contamination from protective clothing, dust containment appears to be a reasonable alternative to dust removal.

TABLE OF CONTENTS

Name	Page
Disclaimer	i
Foreword	ii
Executive Summary	iii
Acknowledgements	vii
1.0 INTRODUCTION	1
2.0 AIRSHOWER EQUIPMENT	3
2.1 Manufacturers of Airshower Equipment	3
2.2 Airshower Costs	6
2.3.1 Cost of Equipment	7
2.3.2 Cost of Installation	7
2.3.3 Cost of Routine Maintenance	9
3.0 AIRSHOWER EVALUATION	10
3.1 Booth-Style Airshowers	10
3.1.1 Description	11
3.1.2 Employee Acceptance	17
3.1.3 Removal of Lead Dust from Workclothing	20
3.1.4 Contamination of Control Room	24
3.2 Tunnel-Style Airshower	24
3.2.1 Airshower Description	25
3.2.2 Employee Acceptance	25
3.3 Laboratory Simulation	29
4.0 SHOECLEANING EQUIPMENT	36
4.1 Manufacturers of Shoecleaning Equipment	36
4.2 Costs of Shoecleaning Equipment	38
5.0 SHOECLEANER EVALUATION	40
5.1 Shoecleaners at East Penn Manufacturing	40
5.2 Shoecleaners at General Battery Corporation	42
5.3 Shoecleaner at Tonolli Corporation	43
5.4 Shoecleaner at Schuylkill Metals	43
6.0 RECOMMENDATIONS	46
6.1 Airshowers	46
6.2 Shoecleaners	47
6.3 Employee Education	48
7.0 ALTERNATIVES	50
7.1 Containment of Surface Dust	50

LIST OF TABLES

Name		Page
Table 2-1	Cost Estimates for Three Size Categories of Airshowers	8
Table 3-1	Summary of Data for Airshower at General Battery Corporation, Reading, Pennsylvania	14
Table 3-2	Summary of Data for Airshower at General Battery Corporation, Hamburg, Pennsylvania	19
Table 3-3	Lead Removal Testing	22
Table 3-4	Summary of Data for Airshower at Schuylkill Metals, Baton Rouge, Louisiana	28
Table 3-5	Dust Removal - Airshower Simulation	33
Table 3-6	Dust Breakthrough - Airshower Simulation	34

LIST OF FIGURES

Name		Page
Figure 2-1	Typical Airshower	4
Figure 2-2	Use of Booth-Type Airshowers	5
Figure 3-1	Booth-Style Airshower at General Battery Corporation (Reading, PA)	12
Figure 3-2	Location of Airshower at GBC/Reading	13
Figure 3-3	Booth-Style Airshower at General Battery Corporation (Hamburg, PA)	16
Figure 3-4	Location of Airshower at GBC/Hamburg	18
Figure 3-5	Tunnel-Style Airshower at Schuylkill Metals (Baton Rouge, LA)	26
Figure 3-6	Drawing of Airshower Tunnel at Schuylkill Metals	27
Figure 3-7	Laboratory Simulation of Airshower	31
Figure 3-8	Before and After Comparison of Fabric Patches Used in Airshower Simulation Testing	32
Figure 4-1	Typical Shoecleaning Machine	37
Figure 5-1	Use of Vacuum/Brush and Wash/Brush Shoecleaners	41
Figure 5-2	Use of Vacuum/Brush Shoecleaner	44
Figure 6-1	Use of Floor Mats to Collect Dust from Work Shoes	49
Figure 7-1	Surface Dust Containment Practices at Tonolli North America's Nesquehoning, Pennsylvania Plant	52
Figure 7-2	Surface Dust Containment Practices at Tonolli North America's Nesquehoning, Pennsylvania Plant	53

ACKNOWLEDGEMENTS

Radian Corporation greatly appreciates the helpfulness of smelter operators and equipment manufacturers in providing information for this study. We especially appreciate the cooperation of smelter operators who allowed us to visit their plants. Special thanks to:

East Penn Manufacturing Company
General Battery Corporation
Schuylkill Metals
Tonolli Corporation

1.0 INTRODUCTION

Lunchrooms, breakrooms, and control rooms in secondary lead smelters can become contaminated with lead dust that is carried on employee workclothing and shoes. Contamination of a cleanroom facility interferes with its usefulness in reducing employee exposures and may, in fact, create an additional source of exposure. For this reason, it is important that some means be provided for employees to either remove or clean their protective clothing and gear before entering a cleanroom facility.

The OSHA standard for lead exposure (29 CFR 1910.1025) specifies that:

> "The employer shall assure that employees do not enter lunchroom facilities with protective workclothing or equipment unless surface lead has been removed by vacuuming, downdraft booth, or other cleaning method."

Downdraft booths (or airshowers) are widely used in a number of industries (e.g., electronics) to remove surface lint and dust from workclothing before employees enter cleanroom facilities. In this application airshowers are used primarily for manufacturing process control rather than any type of exposure control.

The use of airshowers for exposure control in heavy industry, such as secondary lead smelters, has been limited. This demonstration project presents an evaluation of airshowers as employee exposure control options in secondary lead smelters. In addition, the demonstration project includes an evaluation of shoecleaning equipment that may be used to remove surface lead from shoes.

Site visits were made to two of General Battery Corporation's plants in eastern Pennsylvania and to Schuylkill Metal's plant in Baton Rouge, Louisiana, to observe different types and applications of airshower equipment. Shoecleaners were studied during site visits made to Schuylkill Metals (Baton Rouge, LA), General Battery Corporation (Reading and Hamburg, PA), East Penn Manufacturing (Lyon Station, PA) and Tonolli North America (Nesquehoning, PA). Other secondary smelters were contacted by telephone. Manufacturers and suppliers of airshowers and shoecleaning equipment were contacted by telephone and asked to supply information about their products.

This report presents the results of field and laboratory evaluation and summarizes product information. The report is intended to provide useful technical, cost, and operational information to secondary lead smelter operators to assist them in determining appropriate applications for airshowers and shoecleaners and in developing specifications for their purchase, installation, and use.

2.0 AIRSHOWER EQUIPMENT

A typical airshower (or downdraft booth) is an enclosure with supply air jets located on the sides and ceiling and a return air plenum located beneath a metal grate which forms the floor. A high pressure, low velocity fan is used to circulate air through the airshower. In-line filters are used to clean the airstream as it circulates. Figure 2-1 is a drawing of a typical booth-style installation.

To use the airshower, the employee enters the enclosure, starts the blower (which may be interlocked to start when the door is opened), and remains in the enclosure to the end of the timing sequence (usually, about 20 seconds). In a booth-type airshower, the employee is generally instructed to raise the arms and slowly turn around while the airshower is in operation. In a tunnel-type airshower, the employee need only walk through the length of the tunnel. Respirators are always worn during use of the airshower to protect employees from inhaling dust that is stirred up by use of the airshower. Figure 2-2 shows employees using booth-type airshowers. One booth uses slots for air delivery; the other booth uses nozzles.

2.1 MANUFACTURERS OF AIRSHOWER EQUIPMENT

The following companies have been identified as manufacturers of airshower equipment. Although an attempt was made to identify as many manufacturers as possible, some companies may have been overlooked and, consequently, are not included in the list.

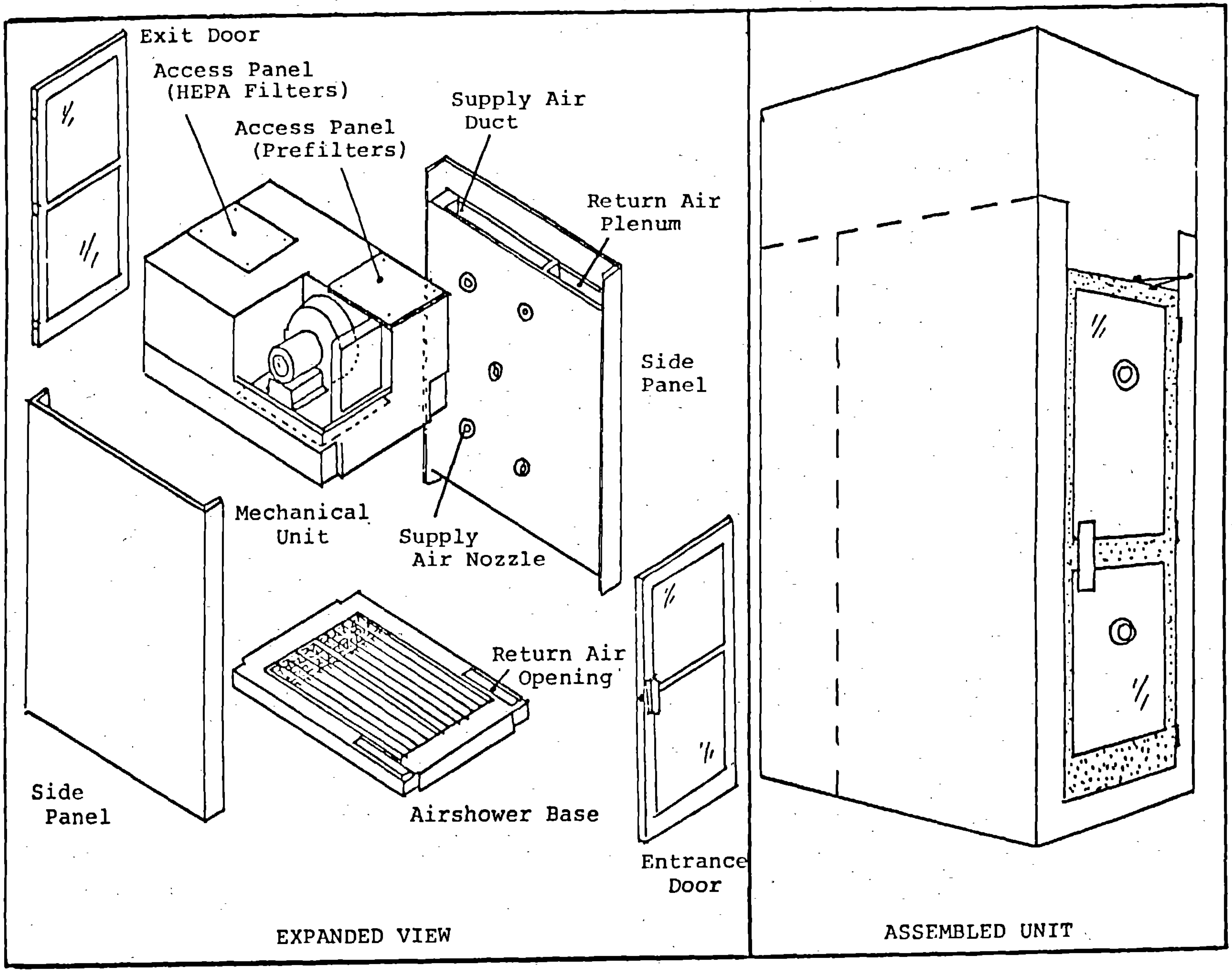


FIGURE 2-1. TYPICAL AIRSHOWER

Upper Left: Employee uses booth-style airshower to remove surface dust before entering control room. Note placement of supply air nozzles.

Lower Right: Worker uses booth-style airshower to remove surface dust from clothing. Note slot delivery of supply air jets.

FIGURE 2-2. USE OF BOOTH-TYPE AIRSHOWERS

- Advanced Purification Systems, Inc.
  40-9 Oser Avenue
  Hauppage, NY 11787
  (516) 273-2680

- Amos-Tech Industries
  204 Pinebrook Road
  Eatontown, NJ 07724
  (201) 542-1200

- Clean Room Products, Inc.
  56 Pentaquit Avenue
  Bay Shore, NY 11706
  (516) 968-8282

- Liberty Industries, Inc.
  133 Commerce Street
  East Berlin, CT 06023
  (203) 828-6361

- Moore and Hanks Co.
  9702 East Rush Street
  El Monte, CA 91733
  (213) 443-9337

All of these companies offer off-the-shelf equipment ready for assembly in the user's facility. Some companies offer custom design and installation services as well.

2.2 AIRSHOWER COSTS

This section contains cost information for airshower equipment (purchase, installation, and maintenance) obtained from equipment manufacturers and users.

2.3.1 Cost of Equipment

The cost of purchasing an airshower depends upon the size of airshower needed. Most manufacturers of airshowers offer a variety of sizes from which to choose. For costing purposes, three categories of airshowers, based on size, are noted:

- Standard airshower booth (accommodates 1-3 employees).
- Expanded airshower booth (accommodates 3-4 employees).
- Airshower tunnel (accommodates 4 or more employees).

Table 2-1 presents dimensions for each type of airshower along with cost estimates obtained from equipment manufacturers. These costs are for stock models that typically have a straight path entry and exit. Custom built airshowers are available which allow for right and left angles of egress or longer lengths of airshower tunnels.

2.3.2 Cost of Installation

Installation costs for airshowers typically range from 10 to 25% of the purchase price, depending upon who performs the work. The manufacturer is usually willing to provide installation for a fee. Costs of manufacturer's installation vary from company to company, and upon geographic location of the customer. In most cases, the installation can be performed at less cost by in-house plant personnel, with or without the supervision of a manufacturer representative. Airshower manufacturers estimate that in-house installation will take one to two days with the aid of a forklift truck and three or four workers.

Table 2-1. COST ESTIMATES FOR THREE SIZE CATEGORIES OF AIRSHOWERS

TYPE	APPROXIMATE INSIDE DIMENSIONS (FEET) (W x L x H)	CAPACITY-NUMBER OF EMPLOYEES	COST RANGE (1983 $)
Standard Airshower Booth	3x3x7 - 3x6x7	1 - 3	$5340 - $9000
	4x4x7 - 4x6x7		$7150 - $8400
Expanded Airshower Booth	5x5x7 - 5x6x7	3 - 4	$7550 - $8720
	6x6x7		$8350 - $9445
Airshower Tunnel (unit construction)	3x7x7 - 3x9x7	4 - 6+	$10996 - $22000
	4x15x10		$19840
Airshower Tunnel (modular construction)	3x4x7 (each module)		$9,000 (per module) +$1,200 (set of doors)

SOURCE: Cost estimates supplied by manufacturers of airshower equipment (Advanced Purification Systems, Inc.; Amos-Tech Industries; Clean Room Products, Inc.; Liberty Industries, Inc.; Moore and Hanks Co.)

2.3.3 Cost of Routine Maintenance

Routine maintenance of airshowers consists mainly of filter replacement. Air filtration systems typically use high efficiency particulate air (HEPA) filters and replaceable prefilters.

One manufacturer recommends that prefilters be changed every thirty days or oftener if service is heavy. If prefilters are replaced regularly, the HEPA filter should last 2-3 years. HEPA filters cost from $100.00 to $250.00 each. Prefilters cost approximately $40.00 for 12 filters. Prefilters may be used individually or in pairs for added protection of the HEPA filter.

3.0 AIRSHOWER EVALUATION

Airshowers are not used extensively by secondary lead smelter operators. Of twenty-four secondary lead smelting companies contacted by telephone, only five used airshowers in one or more of their plants. Management personnel at some of the companies not using airshowers said that they were considering using them in the future; others said that they did not plan to use airshowers at all because they did not consider them effective.

Site visits to test airshower effectiveness were made to two of General Battery Corporation's plants in Pennsylvania. One plant uses a booth-style airshower purchased as a prefabricated unit. This particular system uses nozzles for the supply air jets. The other General Battery plant uses a booth-style airshower that was custom designed and built, using slots for delivery of the supply air. Both airshowers are used to reduce lead contamination in oxide mill control rooms.

Another airshower application was seen at Schuylkill Metal's plant in Baton Rouge, Louisiana. This tunnel-style airshower is used to reduce lead contamination in the lunchroom used by smelter workers.

Additional tests of airshower effectiveness were conducted in the laboratory using a simulated airshower.

3.1 BOOTH-STYLE AIRSHOWERS

Booth-style airshowers are used to prevent contamination of positive-pressure, supplied-air control rooms at two of General Battery Corporation's plants. Operators use the airshower booths to remove surface dust from their workclothing prior to entering the control rooms. The airshowers were installed during 1979-81 (along with the supplied air control rooms) as a lead exposure reduction measure for operators of the oxide mills.

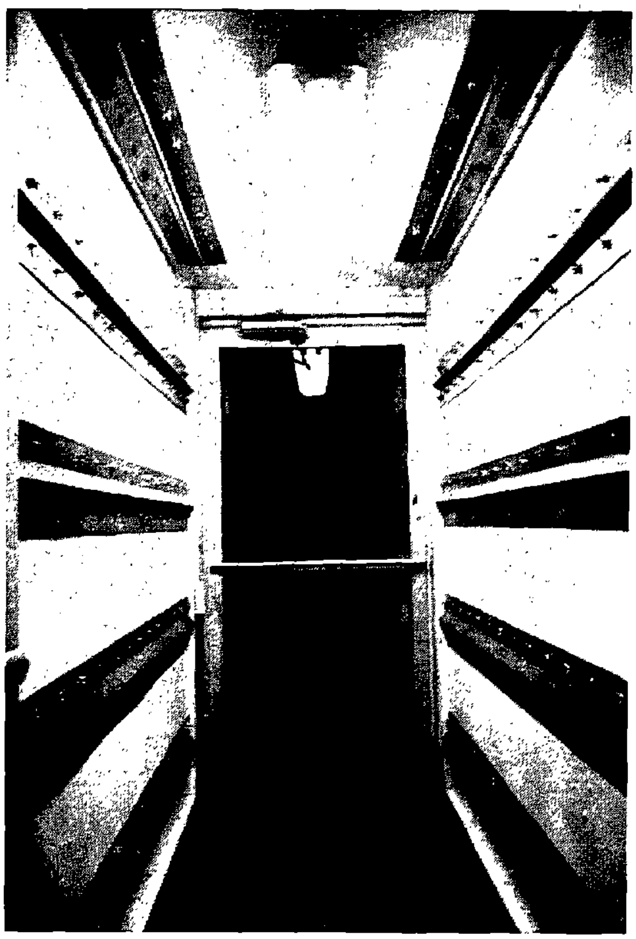
3.1.1 Description

Figure 3-1 shows the interior of the airshower booth at the Reading plant. The booth is a custom design built exclusively for the Reading plant by Saxon Air Systems, Harrisburg, Pennsylvania. Supply air is delivered to the airshower booth through four horizontal slots located on each side wall and two lengthwise slots in the ceiling. Two return air registers (40" x 7") are located at floor level on each of the side walls. The velocity of supply air at the slots was measured with an Alnor® Series 6000P velometer. Air velocity ranged from 2700 to 5800 feet per minute and was greatest near the entry door for the wall slots and near the exit door for the ceiling slots.

The airshower begins operation when the entrance door is opened. The user remains inside the booth through its cycle of operation (approximately 20 seconds) and then exits directly into the oxide mill control room. It is possible for the user to exit the shower before its cycle of operation is complete because the exit door does not automatically lock when the airshower begins operation. Users are required to wear respirators during airshower operation.

All personnel are required to pass through the airshower to enter the control room. The exit door from the control room leads directly to the oxide mill floor.

Figure 3-2 is a drawing showing the location of the airshower at the Reading plant. Table 3-1 contains summary data for the airshower.



Upper Left: Booth-style airshower at General Battery Corporation's Reading Plant. Photo shows exit door which leads to the oxide mill control room.

Below: Entrance to airshower. Sign cautions user to wear respirator during airshower operation.

FIGURE 3-1. BOOTH-STYLE AIRSHOWER AT GENERAL BATTERY CORPORATION (READING, PA)

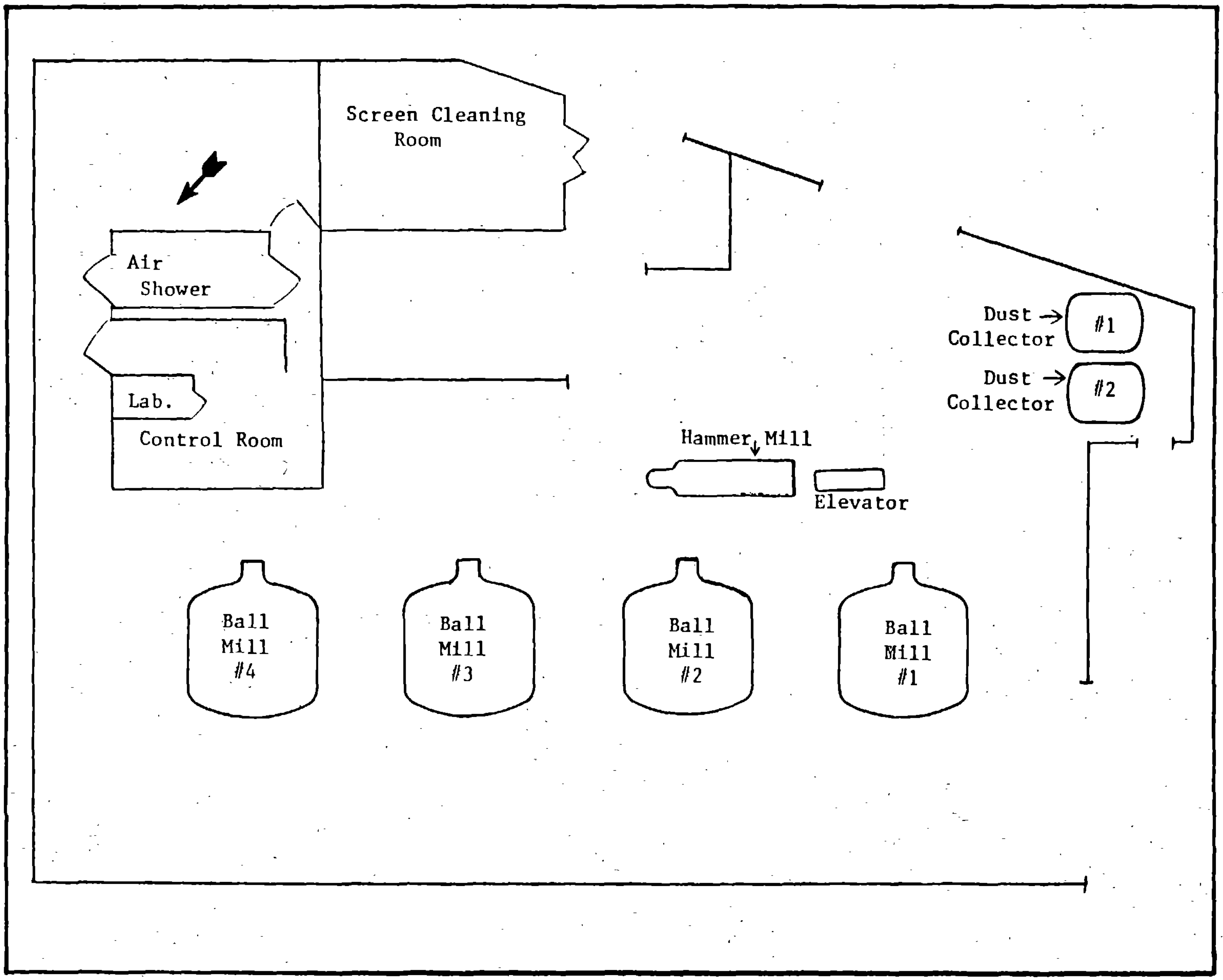


FIGURE 3-2. LOCATION OF AIRSHOWER AT GBC/READING

Table 3-1. SUMMARY OF DATA FOR AIRSHOWER AT GENERAL BATTERY CORPORATION, READING, PENNSYLVANIA

APPLICATION:	Removal of surface dust from workclothing before entry to oxide mill control room.
NUMBER OF PEOPLE SERVED:	1-2, per shift.
STYLE:	Walk-through booth, 20 second cycle.
AIR DELIVERY SYSTEM:	4 horizontal slots, each wall. 2 horizontal slots, ceiling.
AIR VELOCITY AT SUPPLY SLOT:	2700 - 5800 FPM.
AIR FILTRATION SYSTEM:	HEPA filter.
SIZE (L x H x W):	7'5" x 6'11" x 3'
MANUFACTURER:	Saxon Air Systems, Inc., Harrisburg, PA.
COST:	Not Available.

Figure 3-3 shows the interior of the airshower booth used at GBC's Hamburg plant. The booth is a prefabricated, off-the-shelf model manufactured by Liberty Industries, Inc., East Berlin, Connecticut. Supply air is delivered to the airshower through five nozzles located in each side wall and four nozzles located in the ceiling. The average velocity of air delivered to the booth through the supply nozzles was measured by Alnor® Series 6000P velometer at 5,500 feet per minute (range: 4,400 to 6,800 feet per minute). The return air plenum is located below the floor grating.

The airshower begins operation when the user pushes the START button. A prominent sign inside the airshower instructs the user to:

1. Enter and start unit.
2. Stand between air jets.
3. Raise arms shoulder high and slowly rotate one full turn.
4. Exit when cycle has completed.

Users are required to wear respirators during airshower operation.

The airshower is designed to permit one-way traffic only (from the oxide mill plant area into the control room). The airshower exit door is always locked and the entrance door is unlocked. When the blower motor is activated, the entrance door locks and the exit door remains locked. At the end of the cycle, the entrance door remains locked and the exit door unlocks. Once the user leaves the airshower, the exit door locks and the entrance door automatically unlocks. Personnel may leave the control room by a door which opens to the yard area or by a second door which leads directly to the oxide mill plant area. Entrance to the control room is permitted only through the airshower booth following the procedure described above.

Upper Left: Industrial hygienist measures air velocity from supply nozzle. Airshower is placed at entrance to ball mill control room.

Below: Industrial hygienist uses smoke tube to observe air flow patterns inside airshower during operation.

FIGURE 3-3. BOOTH-STYLE AIRSHOWER AT GENERAL BATTERY CORPORATION (HAMBURG, PA)

118<

Circulating exhaust air is filtered through a 35% (ASHRAE efficiency rating) prefilter and a HEPA filter (99.97% efficiency in removing particles to 0.3 microns, DOP test method) before its return to the airshower via supply nozzles.

A 3500 RPM, 5 HP blower circulates air through the system at a design air flow volume of 2,200 CFM.

Figure 3-4 is a drawing of the airshower booth location at the Hamburg plant. Table 3-2 contains summary data for the airshower.

3.1.2 Employee Acceptance

Oxide mill operators who regularly use the airshowers at GBC's Reading and Hamburg plants were asked for their opinions concerning airshower usefulness and effectiveness. Operators reported that, since they had to go in and out of the control room frequently, it was annoying to have to go through the airshower each time. The one-way door locking feature of the airshower at Hamburg was seen as especially annoying: the exit lock has been forced open and broken repeatedly. One operator reported that the air jets were uncomfortably chilling to him during hot weather when he had been working hard and had perspired heavily. Some operators said that the airshower seemed to blow dust through their workclothes and onto their skin. There seemed to be a general feeling among operators that the airshowers are not particularly effective clothing cleaning devices and that they are somewhat of a nuisance.

Management personnel are attempting to improve employee attitudes toward airshower use through information and training programs which emphasize the benefit of the airshower and the supplied air control room in lead exposure reduction.

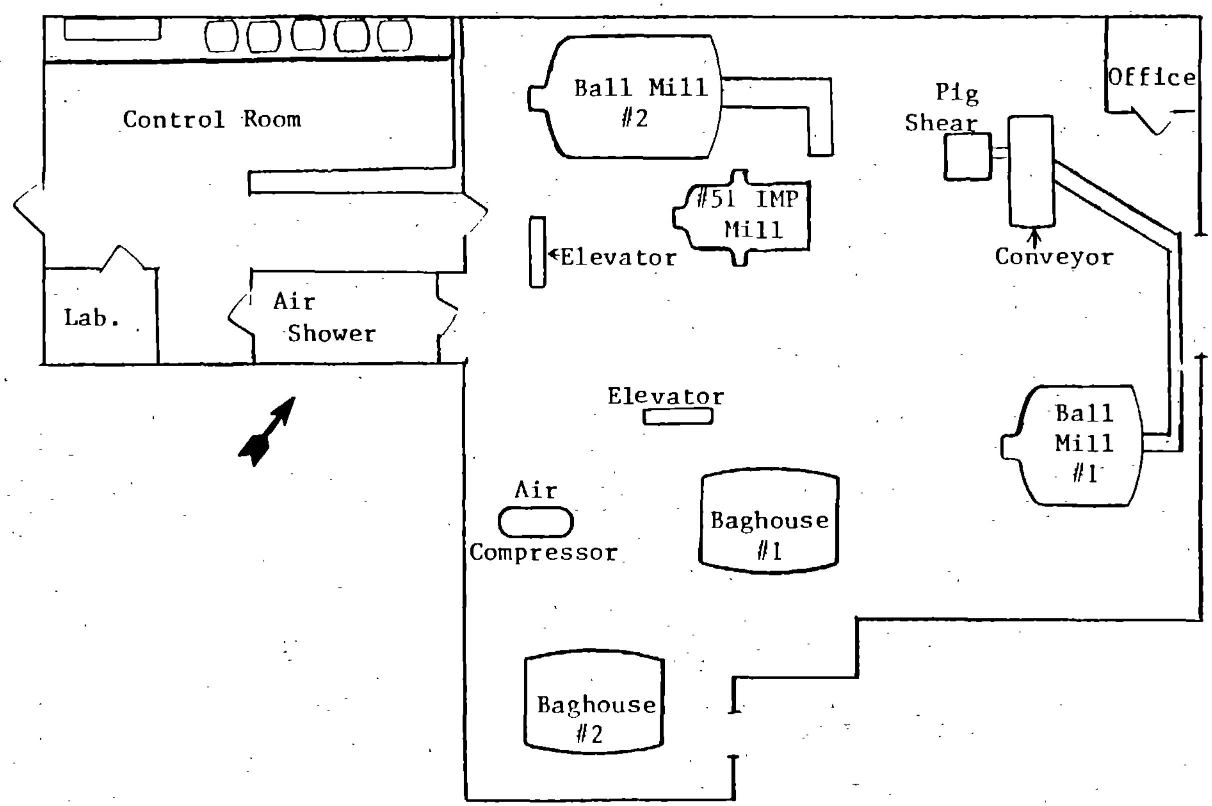


FIGURE 3-4. LOCATION OF AIRSHOWER AT GBC/HAMBURG

Table 3-2. SUMMARY OF DATA FOR AIRSHOWER AT GENERAL BATTERY CORPORATION, HAMBURG, PENNSYLVANIA

APPLICATION:	Removal of surface dust from workclothing before entry to oxide mill control room.
NUMBER OF PEOPLE SERVED:	1-2, per shift.
STYLE:	Walk-through booth, 20 second cycle.
AIR DELIVERY SYSTEM:	14 supply nozzles. 1 high-pressure blower (2,200 CFM).
AVERAGE AIR VELOCITY AT SUPPLY NOZZLE:	5,500 FPM.
AIR FILTRATION SYSTEM:	1 prefilter (35% ASHRAE). 1 HEPA (99.97% at 0.3 microns).
SIZE (L x H x W):	5'8" x 6'10" x 3'.
MANUFACTURER:	Liberty Industries, Inc.
COST:	$11,700 (1981 $).

3.1.3 Removal of Lead Dust from Workclothing

An evaluation procedure was established to test the effectiveness of airshowers in removing surface lead dust from workclothing. Tests were conducted at GBC/Reading and GBC/Hamburg.

<u>Evaluation Procedure</u>

Samples of two types of cloth commonly used for industrial workclothing were obtained. One of the fabric samples was a lightweight shirting material; the other fabric sample was a heavier twill coverall material. Fabric samples were cut into swatches measuring 2" x 3" for testing.

It was originally planned that the fabric patches would be affixed to employee workclothing and allowed to collect dust through the normal work routine before airshower testing. However, since employees were in and out of the control room so often and since so few employees actually used the airshowers, it was decided that lead dust should be loaded directly on the patches. For this purpose, a known mass of lead oxide (50 mg) was placed into small, screw-cap vials and transported to the smelter plants.

Fabric patches were loaded on-site by shaking the contents of the sample vial onto the fabric and distributing the material with the edge of a razor blade. All fabric patches were loaded in the same way, using the same number of strokes to distribute the lead dust. To check the consistency of lead loading, six loaded patches were selected from the group and analyzed as controls. The mean loading for these controls was 40 mg lead (SD = 0.75 mg). When computing percent lead removals, 40 mg was used as the standard lead loading for all fabric patches.

Fabric patches loaded with lead oxide and blank fabric patches were attached to the shoulders of the experimenter's jacket with double-stick tape. The experimenter then walked into the airshower and followed standard operating procedures for its use. The patches were removed after the airshower cycle was completed and placed in small plastic sample envelopes.

Patches were analyzed for lead content by a modification of NIOSH Method No. S-341.

Results

The data for airshower field testing are shown in Table 3-3. An analysis of these results shows:

- Airshowers are generally effective in removing surface dust. Tests show that from 5 - 72% of the lead (in the form of lead oxide) applied to fabric patches was removed during operation of the airshower.

- The nozzle-type airshower at GBC/Hamburg showed a higher percentage lead removal (in most cases) than did the slot-type airshower at GBC/Reading.

- Lead contamination of clean clothing can occur from dust stirred up during airshower operation. Blank fabric patches worn in either airshower picked up some lead during normal operation of the airshower. The heavier twill coverall fabric appeared to pick up and hold more lead than did the lighter weight shirting fabric.

During the airshower field tests, it was noted that some lead oxide dust was blown through the lighter weight shirting fabric. Also, it appeared that more dust was removed from the

Table 3-3. LEAD REMOVAL TESTING

Fabric Treatment	Fabric[1] Type	Post-Test Lead Content (mg)	Lead Removal[2] (%)
• Fabric patch loaded with lead oxide and worn through full cycle of airshower operation. (GBC/Hamburg)	1	14	65
	1	29	28
	1	31	22
	1	26	35
	2	29	28
	2	15	62
	2	*	*
	2	11	72
• Fabric patch loaded with lead oxide and worn through full cycle of airshower operation. (GBC/Reading)	1	37	8
	1	30	25
	1	37	8
	1	38	5
	2	36	10
	2	30	25
	2	38	5
	2	29	28
• None. (Fabric blank)	1	.007	N/A[3]
	2	<.005	N/A
• Blank fabric patch worn through full cycle of airshower operation. (GBC/Hamburg)	1	.038	N/A
	2	.017	N/A

(Continued on next page)

Table 3-3. LEAD REMOVAL TESTING (Continued)

Fabric Treatment	Fabric(1) Type	Post-Test Lead Content (mg)	Lead Removal(2) (%)
• Blank fabric patch worn through full cycle of airshower operation (GBC/Reading)	1	.034	N/A
	2	.017	N/A
• Fabric patch loaded with lead, shaken by hand.	1	29	28
	2	33	18
• Fabric patch loaded with lead, worn through airshower, airshower not operating (GBC/Hamburg)	1	40	-0-
	2	34	15

Notes: (1) Fabric type 1 = lightweight shirting; Fabric type 2 = twill weave coverall.
(2) Based on original lead loading of 40 mg.
(3) N/A = not applicable

* Sample lost during analysis.

shirting than the coverall fabric. A laboratory simulation test was designed to study these observations in greater depth. The results of this laboratory study are discussed in Section 3.3, Laboratory Simulation.

3.1.4 Contamination of Control Room

Area monitoring was conducted in control rooms at both airshower locations. Average lead-in-air concentrations in the two rooms were measured:

Location	Average Lead-in-Air Concentration (ug/m3)
GBC/Hamburg	7.0
GBC/Reading	2.0

These data indicate that the control rooms do remain relatively free of lead contamination, despite a fair amount of traffic in and out. No visible contamination of the control room by employee workclothing was observed. A direct-reading respirable dust monitor (Sibata P5) was used to detect changes in control room dust concentrations associated with traffic in and out. No changes in concentration were detected.

Since control room lead-in-air concentrations were low and no measureable change in control room dust concentrations were apparent when employees entered the control rooms, it was concluded that lead dust from workclothing was not a significant source of contamination for GBC's supplied air control rooms.

3.2 TUNNEL-STYLE AIRSHOWER

A site visit was made to Schuylkill Metal's secondary lead smelter in Baton Rouge, Louisiana, to observe its tunnel-style airshower. At the request of management, no airshower testing was conducted and no lead-in-air measurements were made.

3.2.1 Airshower Description

Figure 3-5 shows the interior of the tunnel-style airshower installed in 1979 at Schuylkill Metal's Baton Rouge Plant. The airshower leads from the smelter work area to the washroom located outside the smelter lunchroom. This washroom is also pictured in Figure 3-5. The tunnel is made up of eight pre-fabricated airshower modules manufactured by Liberty Industries, Inc., East Berlin, Connecticut.

Supply air is delivered to the airshower through a total of 72 nozzles located in three rows along each side wall and 32 nozzles located in two rows along the ceiling. The tunnel is 32 feet long and about 10 seconds are required to walk through it.

The airshower begins operation when the entrance door is opened. Each module begins operation in a timed sequence. Employees are required to wear their respirators when using the airshower. After walking through the airshower, users remove their respirators and store them in lockers located in the washroom. Employees then clean up and enter the lunchroom through a swinging door. All employees are required to use the airshower and wash before entering the lunchroom.

Figure 3-6 is a drawing of the airshower; Table 3-4 contains summary data for the airshower.

3.2.2 Employee Acceptance

Management personnel at Schuylkill Metals report that employee use of the airshower is 100%. They attribute the success of the airshower to its placement and ease of operation.

Upper Left: Tunnel-style airshower used at Schuylkill Metal's Baton Rouge Plant. Tunnel is constructed of eight modular units in series. Photo shows entrance door; airshower tunnel leads to washroom shown below.

Below: Washroom leading to smelter worker's lunchroom. Washroom is accessed through airshower tunnel shown above.

FIGURE 3-5. TUNNEL-STYLE AIRSHOWER AT SCHUYLKILL METALS (BATON ROUGE, LA)

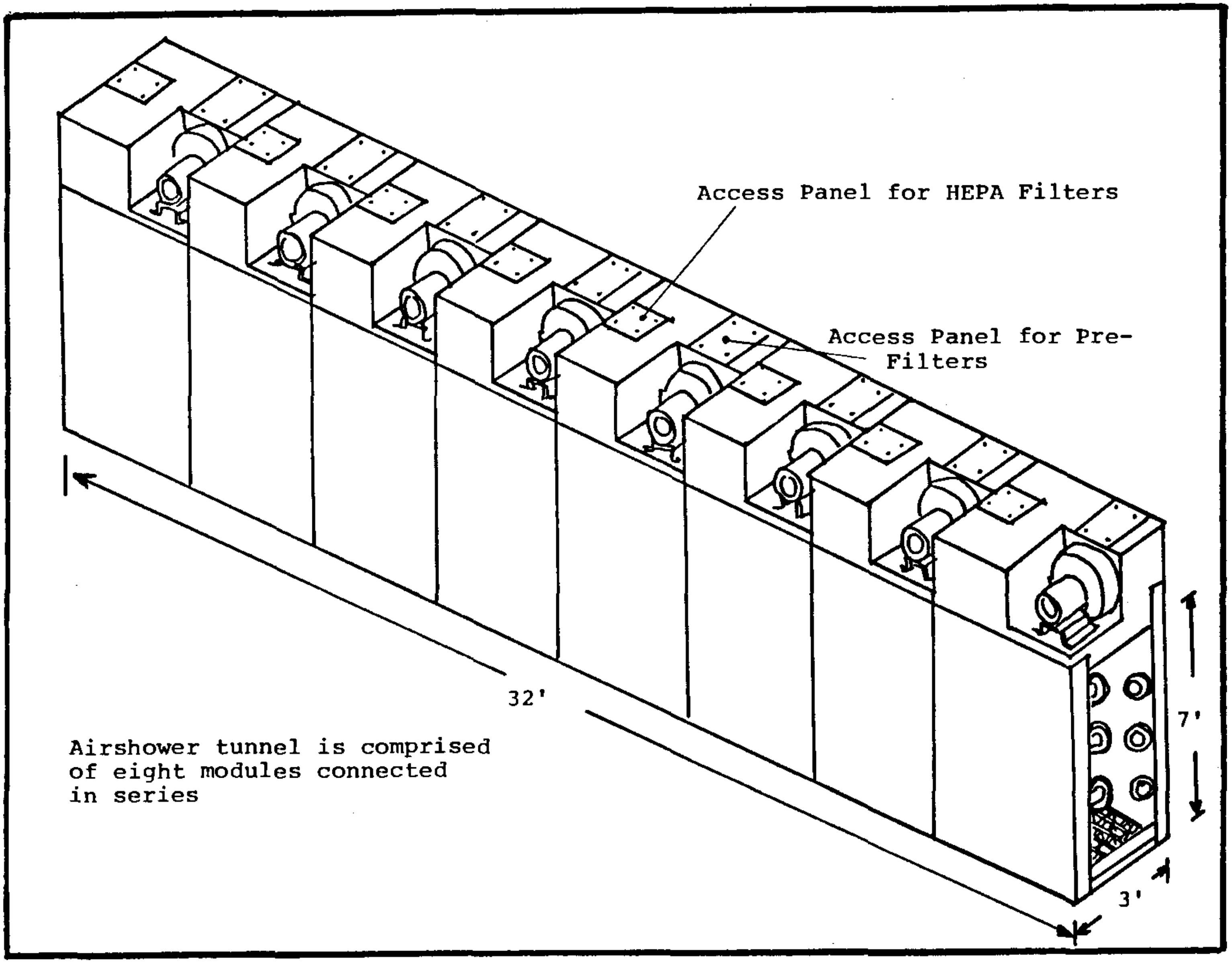


FIGURE 3-6. DRAWING OF AIRSHOWER TUNNEL AT SCHUYLKILL METALS

Table 3-4. SUMMARY OF DATA FOR AIRSHOWER AT SCHUYLKILL METALS, BATON ROUGE, LOUISIANA

APPLICATION: Removal of surface dust from workclothing before entry to smelter washroom and lunchroom.

NUMBER OF PEOPLE SERVED: Not available.

STYLE: Walk-through tunnel.

AIR DELIVERY SYSTEM: 176 supply nozzles.
8 high-pressure blowers (2200 CFM, each).

AVERAGE AIR VELOCITY AT SUPPLY NOZZLE: Not available.

AIR FILTRATION SYSTEM: 8 prefilters (35% ASHRAE).
16 HEPA filters (99.97% at 0.3 microns).

SIZE (L x H x W): 32' x 6'6" x 3' (inside dimentions).

MANUFACTURER: Liberty Industries, Inc.

COST:	$36,000	(Airshower)
	7,500	(Freight and miscellaneous parts)
	3,300	(Labor and overhead costs to install)
	$46,800	Total (December 1979 $'s)

The airshower was located to take advantage of an established traffic pattern from the smelter to the lunchroom. It requires no special effort on the part of employee to use it and it does not interfere with progress, i.e., the employee does not have to stand in one spot and wait for the airshower to complete its cycle of operation.

3.3 LABORATORY SIMULATION

From observations made during the field test of the airshowers, it appeared that lead oxide dust could be blown through the lighter weight shirt fabric and that the amount of dust removed in the airshower differed between the two fabrics that were tested. To look more closely at the effect of fabric type on dust breakthrough and overall dust removal, a laboratory airshower simulation was conducted. Three different fabric types were tested: a plain-weave shirting fabric, a twill-weave coverall fabric, and a non-woven disposable fabric (Tyvek®).

Evaluation Procedure

Nine circular patches, each measuring 50-mm in diameter, were cut from samples of each of the three fabrics tested. All fabric patches were weighed to the nearest tenth milligram. Every third patch was reweighed to assure the precision of the weighing procedure.

Patches were loaded with lead oxide dust. A cotton swab was used to distribute lead oxide dust on the surface of the fabric. All patches were loaded using the same procedure although no attempt was made to standardize loading weight.

After loading, the fabric patches were reweighed to determine the net loading. As before, every third patch was weighed twice to assure precision of the weighing procedure.

Fabric patches were then pinned on one of three boards, each board holding three patches of each fabric type. The center patch in each row covered a 47-mm, 0.45 micron pore-size filter backing. This filter was later submitted to an analytical laboratory for determination of breakthrough lead content.

Airshower supply air jets were simulated using a glass-tube nozzle connected by a rubber hose to a source of compressed nitrogen gas. The airflow velocity from this nozzle was adjusted to match that measured during the field test at GBC/Hamburg (5,500 FPM).

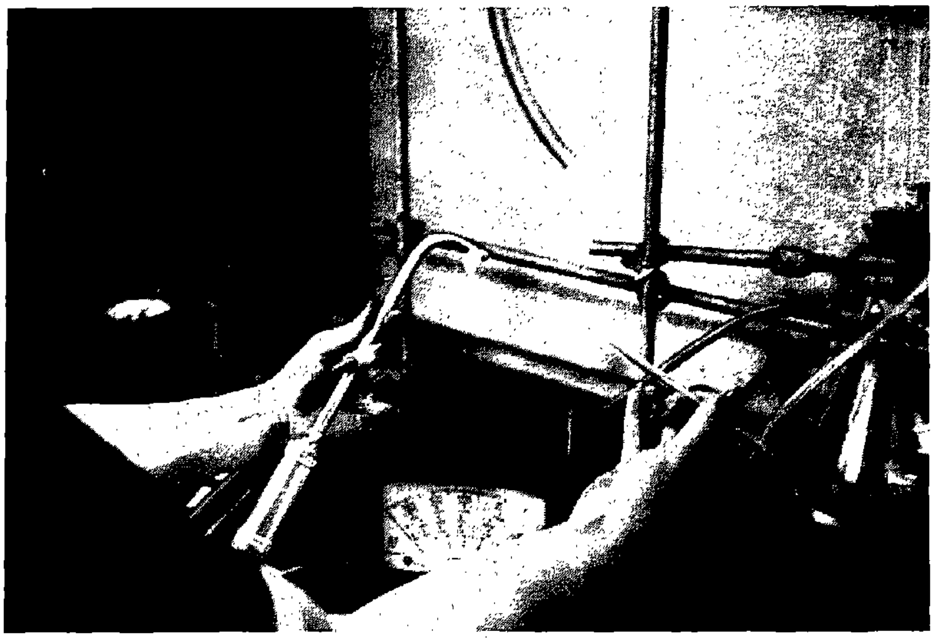
Fabric patches were dusted off using a back-and-forth movement of the nozzle repeated at distances from one to ten inches from the fabric patch. Twenty seconds of simulated airshower operation were used for each test board. One board was held vertically, the other was placed horizontally. The third board served as a control. Figure 3-7 illustrates the airshower simulation.

After dusting, all fabric patches were removed from the boards and reweighed. Fabric patches on board number three were handled in the same manner as those on boards number one and two, except that they were not dusted with the airspray. These patches served as controls. Filter backings and a filter blank were folded and placed in sample bottles for laboratory analysis.

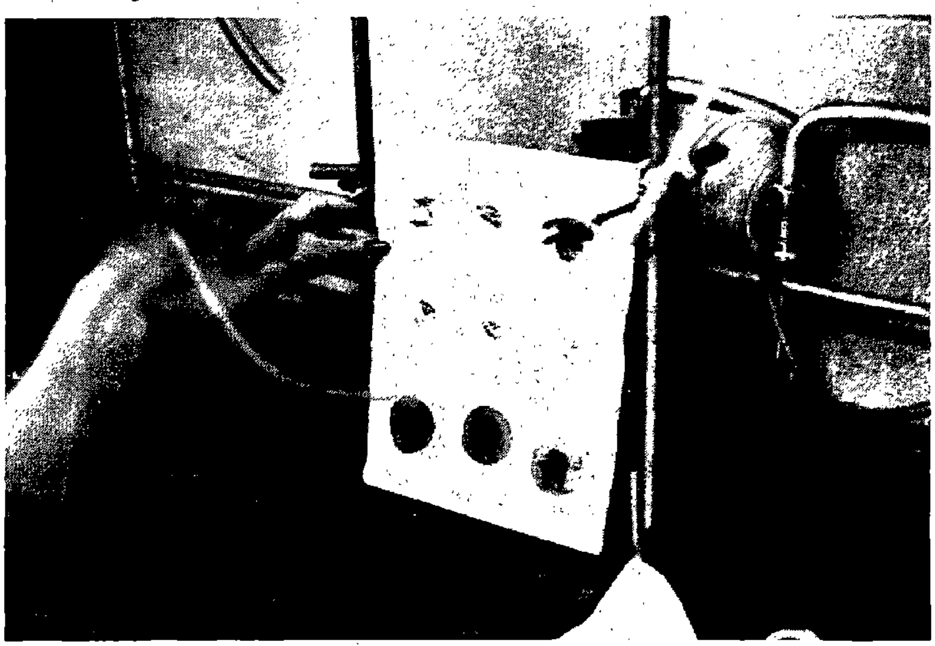
Results

Figure 3-8 shows a before and after comparison of the fabric patches.

Table 3-5 shows net loading and percent removal for fabric patches used in the airshower simulation. Table 3-6 shows lead breakthroughs (as measured on the back-up filter) for each of the fabric types. An analysis of the data shows the following:

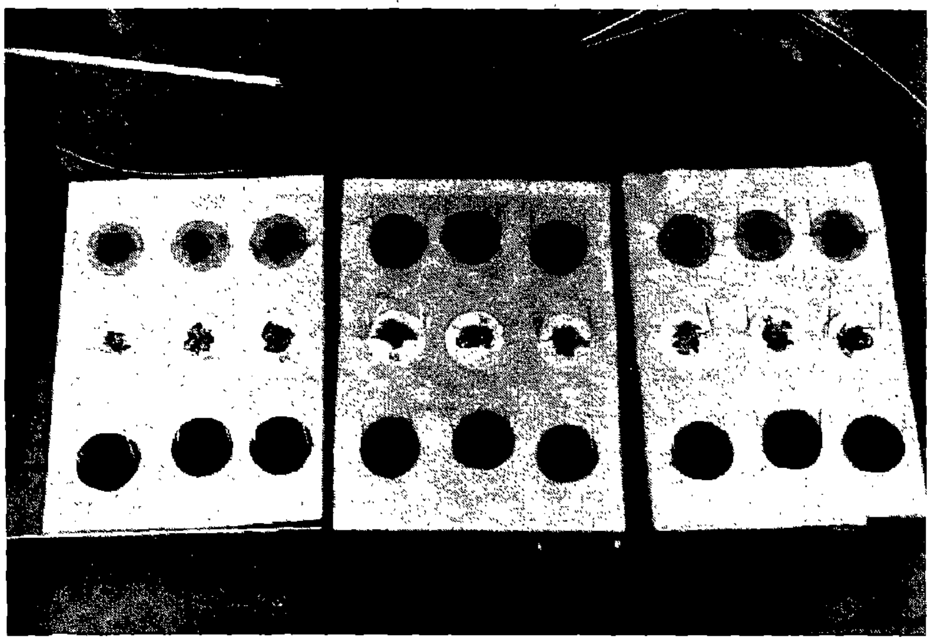


Industrial hygienist adjusts velocity of air jet to approximate that measured in airshower field testing.

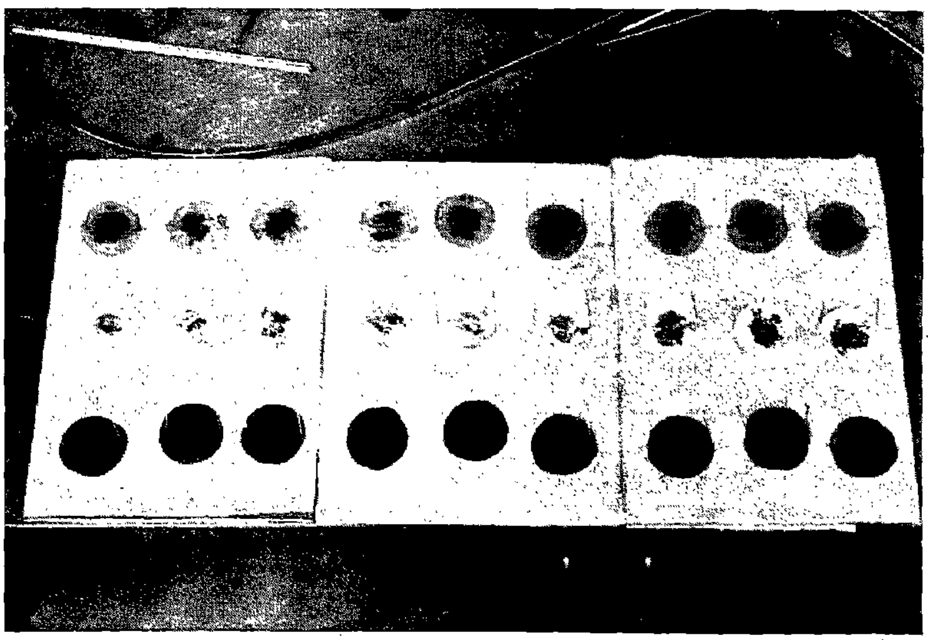


Use of airjet to dust off fabric patches on vertical board.

FIGURE 3-7. LABORATORY SIMULATION OF AIRSHOWER



Fabric patches loaded with lead oxide dust before dusting with airjet. Board on right used as control.



Fabric patches after dusting in airshower (left and center). Board on right used as control.

FIGURE 3-8. BEFORE AND AFTER COMPARISON OF FABRIC PATCHES USED IN AIRSHOWER SIMULATION TESTING

Table 3-5. DUST REMOVAL - AIRSHOWER SIMULATION

Fabric Type	Fabric Handling	Original Dust Loading (mg)	Percent Removal
• Plain-weave shirting.	• Dusted with airspray, vertical board.	22.8	40
		12.5	51
		18.9	52
	• Dusted with airspray, horizontal board.	17.0	49
		22.5	52
		26.5	43
	• Control (not dusted with airspray).	14.3	< 1
		17.5	< 1
		30.7	< 1
• Non-woven.	• Dusted with airspray, vertical board.	27.0	71
		38.5	74
		25.6	55
	• Dusted wtih airspray, horizontal board.	18.9	58
		20.8	72
		35.0	83
	• Control (not dusted with airspray).	31.1	< 1
		45.3	< 1
		18.5	< 1
• Twill-weave coverall fabric.	• Dusted with airspray, vertical board.	34.3	26
		23.9	18
		28.3	29
	• Dusted with airspray, horizontal board.	31.7	15
		49.2	27
		34.7	24
	• Control (not dusted with airspray).	48.7	< 1
		51.2	< 1
		30.6	< 1

Table 3-6. DUST BREAKTHROUGH - AIRSHOWER SIMULATION

Cover Fabric Type	Cover Fabric Handling	Breakthrough (mg) (1)
• Plain-weave shirting.	• Dusted with airspray, vertical board.	0.24
	• Dusted with airspray, horizontal board.	0.20
	• Control (not dusted with airspray).	0.003
• Non-woven disposable.	• Dusted with airspray, vertical board.	0.18
	• Dusted with airspray, horizontal board.	0.048
	• Control (not dusted with airspray).	0.004
• Twill-weave coverall fabric.	• Dusted with airspray, vertical board.	0.069
	• Dusted with airspray, horizontal board.	0.058
	• Control (not dusted with airspray).	<0.002

(1) Limit of detection = 0.002 mg
(Blank determination = <0.002 mg)

- Different fabrics have different "holding" properties for dust and affect the amount of dust that can be removed by dusting with an airspray. The average percent dust removals for the three fabric types tested were:

Fabric Type	Average Dust Removal
Non-woven disposable	69%
Plain-weave shirting	48%
Twill-weave coverall fabric	23%

- Different types of fabric are more or less succeptable to having dust blown through them. All fabrics tested showed some degree of breakthrough. It appears that the amount of breakthrough, although small, may present a significant source of skin contamination.

4.0 SHOECLEANING EQUIPMENT

Most commercially available shoecleaners use power brushes and a vacuum exhaust for cleaning. The majority of these vacuum/brush shoecleaners are designed to clean one shoe at a time. The user steps up to the shoecleaner, holds onto a handle for balance, starts the shoecleaner, and inserts one shoe at a time for cleaning. Rotating brushes inside the machine loosen dust and dirt on the user's shoes and this dust is collected and removed via the vacuum exhaust. Variations on this basic shoecleaner machine design include machines that clean both shoes at once and machines that use power brushes and water to scrub the shoes. Figure 4-1 is a photograph of a typical shoecleaning machine.

4.1 MANUFACTURERS OF SHOECLEANING EQUIPMENT

The following companies have been identified as manufacturers of shoecleaning equipment. Although an attempt was made to identify as many manufacturers as possible, some may have been overlooked and, consequently, are not included in this list.

- Advanced Purification Systems, Inc.
  40-9 Oser Avenue
  Hauppauge, NY 11787
  (516) 273-2680

- Bio-logical Controls
  375 South Street
  Eatonton, NJ 07724
  (201) 544-0505

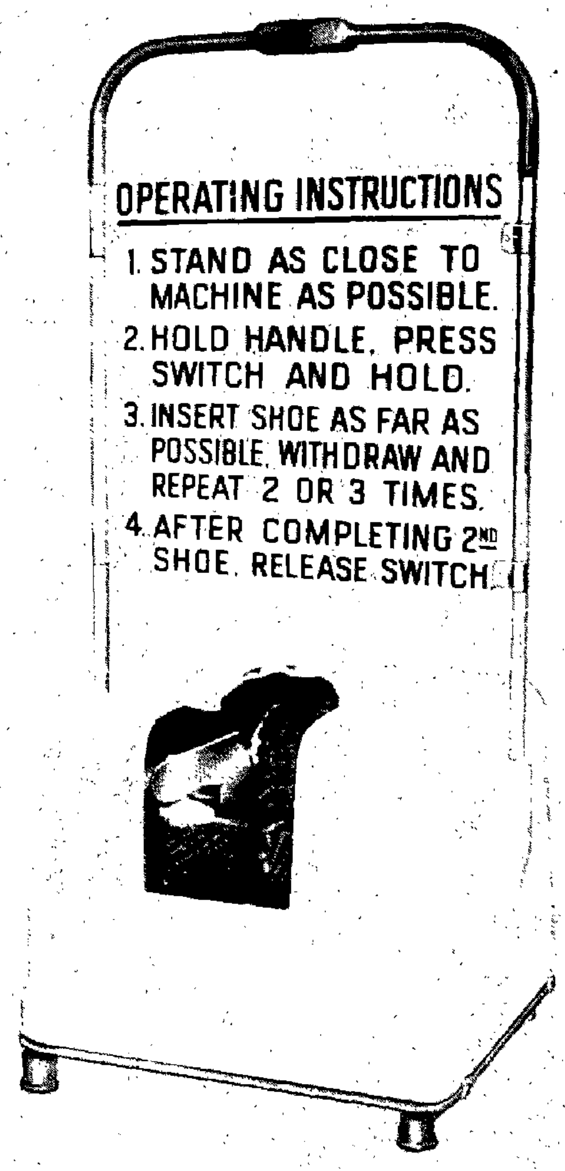


FIGURE 4-1. TYPICAL SHOECLEANING MACHINE

- Liberty Industries, Inc.
  133 Commerce Street
  East Berlin, CT 06023
  (203) 828-8361

- Space Walker Inc.
  Box 1116 Route 2
  Bonne Terre, MO 63628
  (314) 358-3872

All of the companies listed above manufacture vacuum/brush-type shoecleaners. One of the shoecleaning machines studied in this demonstration project uses a water/brush cleaning method. The firm manufacturing this line of equipment is no longer in business. Other manufacturers producing a similar product were not identified. However, a representative of Liberty Industries stated that Liberty is designing a wet shoecleaner and may market it in the near future.

4.2 COSTS OF SHOECLEANING EQUIPMENT

A vacuum/brush shoecleaning machine can cost from $950 to $3000 depending upon its ruggedness and intended service. At the lower end of the cost scale are shoecleaners designed primarily for cleanroom use in light industry. At the higher end of the cost scale are shoecleaners especially designed for use in heavy industry. Most shoecleaner applications for secondary lead smelters would typically require a heavy duty model. Shoecleaners may feature an internal vacuum producer, an external vacuum producer, or a solenoid valve for connection into an existing central vacuum system.

Routine maintenance for shoecleaning machines consists primarily of cleaning, filter replacement, and brush replacement.

Annual maintenance costs, as estimated by equipment manufacturers, typically range from $150 - $300.

5.0 SHOECLEANER EVALUATION

Shoecleaning equipment was observed during site visits made to East Penn Manufacturing, Lyon Station, Pennsylvania; General Battery Corporation, Reading, Pennsylvania; Tonnoli Corporation, Nesquehoning, Pennsylvania; and Schuylkill Metals, Baton Rouge, Louisiana.

5.1 SHOECLEANERS AT EAST PENN MANUFACTURING

Two water/brush shoecleaners were installed in 1982 outside the locker room used by smelter employees at East Penn Manufacturing Co. The shoecleaners were manufactured by Duin Enterprises, Calgary, Canada, a firm which has since gone out of business.

The shoecleaner uses water and power brushes to do the cleaning. The user steps up to the machine and places one shoe at a time in it. Pressure on the footplate activates an electric motor which causes the cleaning brush to rotate through a water reservoir while brushing the sides and sole of the shoe at the same time. Figure 5-1 shows an employee using the shoecleaner.

Employee use of the shoecleaners was observed as workers entered the locker room/washroom on their way to lunch. Most employees used the machines. Since employees arrived at the boot cleaning station individually or in groups of two or three, there was no line-up or waiting to use it. Shoes that had been cleaned in the shoecleaner were wet (but not soaked) and accumulations of mud and dirt were removed from the soles. Overall, the shoecleaners appeared effective and easy to use.

Worker uses vacuum/brush shoecleaner to clean work boots before entering breakroom at General Battery's Reading plant.

Worker uses bootwasher to clean workboots before entering locker room at East Penn Manufacturing Co.

FIGURE 5-1. USE OF VACUUM/BRUSH AND WASH/BRUSH SHOECLEANERS.

5.2 SHOECLEANERS AT GENERAL BATTERY CORPORATION

Two types of shoecleaners are used at General Battery Corporation in Reading, Pennsylvania. A water/brush shoecleaner (same type as those used at East Penn Manufacturing) is located at the entrance to the smelter lunchroom. A wet-type shoecleaner was selected because smelter workers are likely to walk through muddy areas and track mud into the lunchroom. A vacuum/brush shoecleaner is not well suited for mud removal.

Employee use of the shoecleaner was observed before lunch break. The shoecleaner was used by only 3 of the 24 workers who passed by the shoecleaning station on their way to the lunchroom.

A vacuum/brush shoecleaner manufactured by Liberty Industries, Berlin, Connecticut, is located at the entrance to the changeroom and lunchroom at GBC/Reading industrial battery plant. The unit is connected to the plant's central vacuum system.

To use the vacuum/brush shoecleaner, the user steps up to the unit and presses a button located on the top handle and starts the machine. The user then inserts one shoe at a time into the machine for cleaning. Rotating brushes are located inside the machine and remove dust from the sole, sides, and top of the shoe. The dust that is brushed loose is picked up by the vacuum portion of the cleaner. A sign located on the shoecleaner instructs the user to repeat shoecleaning two or three times for each shoe and then release the start switch. Figure 5-1 shows an employee using the vacuum/brush cleaner at GBC/Reading.

Employee use of the vacuum/brush shoecleaner was observed before a break period and again before lunch. All but two of the twenty-one workers who used the lunchroom used the shoecleaner.

Since many of the workers left for break or lunch at about the same time, a line formed at the shoecleaner.

The shoecleaner appeared to do a good job of removing surface dust accumulations. Figure 5-2 shows a comparison of shoes before and after cleaning. Many of the workers wore shoes with metatarsal guards. Lead oxide dust accumulated around and under the guard and could not be removed by the shoecleaner. The vacuum exhaust on the shoecleaner worked well. Figure 5-2 shows use of a smoke tube to check the draft. The shoecleaner demonstrated excellent capture. Use of a direct-reading respirable dust monitor showed no increase in respirable dust concentrations in the area surrounding the shoecleaner when it was in use.

5.3 SHOECLEANER AT TONOLLI CORPORATION

A vacuum/brush shoecleaner is currently used at Tonnoli Corporation (Nesquehoning, Pennsylvania) to clean employees' shoes before they enter the washroom and the smelter lunchroom. The shoecleaner is attached to a portable vacuum exhaust system. This particular installation does not provide sufficient draft for adequate control of dust emissions from the shoecleaner, as evidenced by visible dust emissions during shoecleaner operation. Management personnel at Tonnoli are not totally satisfied with the shoecleaner and are looking for a wet-type shoecleaner to supplement its operation.

5.4 SHOECLEANER AT SCHUYLKILL METALS

A vacuum/brush shoecleaner is installed just inside the entrance to the airshower at Schuylkill Metal's plant in Baton Rouge, Louisiana. The shoecleaner is used to remove heavy dust accumulations before employees use the airshower and then enter the washroom and lunchroom. The shoecleaner vacuum exhaust is

Industrial hygienist uses smoke tube to illustrate draft of vacuum/brush shoecleaner.

Left shoe has been cleaned with shoecleaner. Note contrast with dusty right shoe.

FIGURE 5-2. USE OF VACUUM/BRUSH SHOECLEANER integrated with the airshower to control dust emissions from the shoecleaner. Management personnel report that they are less satisfied with the shoecleaner than the airshower, primarily because the shoecleaner requires a great deal of maintenance.

6.0 RECOMMENDATIONS

Airshowers and shoecleaning machines can provide convenient means of removing surface dust accumulations from protective workclothing. A number of secondary lead smelters are currently using airshowers and shoecleaners and report varying degrees of success and satisfaction with the equipment they have purchased. This section contains a number of recommendations presented as points to consider when considering purchase and installation of airshowers and shoecleaners. These recommendations are taken from literature and comments supplied by equipment manufacturers, from experience reported by smelter operators and equipment users, and from field observation of the equipment in use.

6.1 AIRSHOWERS

Airshowers for use in secondary lead smelters should be selected to meet heavy duty service requirements. Since most commercially available airshowers were originally designed for use in light industry, their suitability for heavy industrial use needs to be determined. For example, the return air exhaust for many commercial airshowers connects to a plenum underneath the floor grating. In airshowers subject to heavy traffic, dirt and dust is likely to accumulate rapidly in the plenum beneath the floor grating as it falls off worker's shoes and boots. This extra dust load can plug airfilters rapidly and restrict airflow if it builds up sufficiently. An airshower with the return air exhaust at floor level, but in the wall is a better choice for a heavy traffic application.

The airshower should be selected according to its expected use. If many workers will be expected to use the airshower before entering a lunchroom or breakroom and it is likely that most will arrive at about the same time, a booth-style airshower is likely to create a bottleneck. A tunnel-style airshower is an advantage in this situation since it allows many people to pass through at the same time.

The placement of the airshower should be considered carefully. In light industrial manufacturing operations where a cleanroom is used for process control, an airshower is often located at the entrance to keep dust and dirt out of the cleanroom. Traffic in and out of the cleanroom is minimal because manufacturing processes and most job tasks are necessarily restricted to its interior. In contrast however, cleanrooms used in secondary lead smelters function as employee exposure controls. Consequently, manufacturing processes and many job tasks take place outside the cleanroom. This can result in heavy traffic in and out of the cleanroom and many trips through the airshower, if one is located there. In this application, the airshower can become a burden to the employees and interfere with their work routines, especially if it is a booth style with automatic locking doors and timed operating cycle. It may be more effective, in this situation, to locate the airshower centrally at the entrance to the lunchroom or breakroom and to wash the cleanroom several times each shift to control dust that may be carried into it.

Airshower use should be considered when selecting protective clothing. Both the field and laboratory tests conducted for this Demonstration Project have shown that different fabrics exhibit different holding and breakthrough properties. A tighter weave will permit less dust breakthrough; a smoother, slicker surface will facilitate dust removal.

6.2 SHOECLEANERS

Shoecleaners should be selected for durability and the type of cleaning service that will be required. For example, vacuum/brush shoecleaners should not be used where shoes and boots are likely to be wet and muddy.

Shoecleaner placement should encourage use. Shoecleaners should be placed near traffic paths so that they are obvious and readily accessible but so that employees do not obstruct the flow of traffic by using them. An adequate number of shoecleaners should be available so that employees need not line up and wait to use them.

In addition to shoecleaner machines, mats and carpets should be used to contain residual dust from shoes and keep it from being tracked into lunchrooms and cleanrooms. Figure 6-1 shows the effectiveness of mats and carpets in containing dust. Floor mats and carpets should be cleaned and changed frequently.

Vacuum/brush shoecleaners should be selected and installed so that there is adequate draft for dust control and so that dust from the vacuum exhaust is not discharged into the workplace. Otherwise the shoecleaner may become an exposure source. The shoecleaner exhaust may be connected via solenoid valve to a plant's central vacuum system, if one is available, or it may be connected to a portable vacuum producer equipped with high efficiency filters.

6.3 EMPLOYEE EDUCATION

Employee information and training programs are important in promoting diligent use of available airshower and shoecleaning equipment. The contribution of dust from shoes and workclothing to the employee's lead exposure should be pointed out and the role of shoecleaners and airshowers in controlling this source of exposure should be emphasized.

Dust containment by slotted rubber mat. Note dust accumulation on floor. Dust falls through slots in mat as workers walk across it.

Dust containment by carpet mat. Note dust tracks where employees have walked across the mat.

FIGURE 6-1. USE OF FLOOR MATS TO COLLECT DUST FROM WORK SHOES

7.0 ALTERNATIVES

Some smelter operators have selected alternative methods of controlling lead contamination from protective clothing. One approach, which was observed at Tonnoli Corporation and at General Battery Corporation, involves containment rather than removal of surface lead dust. A description of this approach is given in the paragraphs that follow.

7.1 CONTAINMENT OF SURFACE DUST

To prevent dust from their workclothes from contaminating the lunchroom, employees at Tonnoli Corporation in Nesquehoning, Pennsylvania wear white lab coats over their regular workclothes while eating lunch. The procedure is:

(1) Employees enter the washroom directly from smelter work areas. (A hand-held vacuum attachment and mechanical shoecleaner are available outside the washroom for employees to use if their protective clothing is heavily contaminated.)

(2) Employees then remove the jacket portion of their two-piece coverall ensemble and hang it on wall-mounted hangers.

(3) Employees wash at sinks to remove dust and dirt from hands, arms, and face.

(4) Employees put on clean, white lab coats over their regular workclothes.

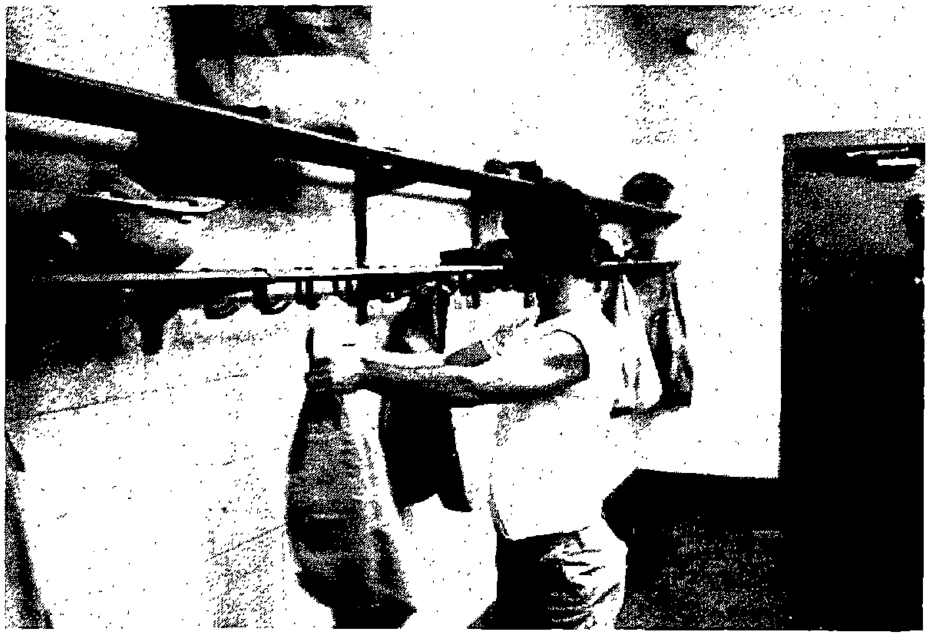
(5) Employees then enter the lunchroom wearing the lab coats.

(6) After eating lunch, employees remove the lab coats and place them in a central collection bin for cleaning.

(7) Employees put on the jacket portion of their coveralls and return to their work stations.

Figures 7-1 and 7-2 are photographs taken at Tonnoli Corporation to illustrate dust containment practices used there. The procedure is simple and appears to work well. No obvious contamination of lunch tabletops or lab coats (outside sleeves, elbows, and fronts) was observed.

A similar procedure is used at some lunchrooms at General Battery Corporation in Reading, Pennsylvania. In addition to smocks and lab coats, disposable shoe covers are used in some plant areas to contain dust contamination from shoes.



Smelter worker first removes top part of protective clothing work suit.

Employee then washes thoroughly before entering lunch room.

FIGURE 7-1. SURFACE DUST CONTAINMENT PRACTICES AT TONOLLI NORTH AMERICA'S NESQUEHONING, PENNSYLVANIA PLANT.

After washing, smelter workers don clean white lab coats to cover their workclothes.

Labcoats are removed after lunch and placed in central collection bin for cleaning.

FIGURE 7-2. SURFACE DUST CONTAINMENT PRACTICES AT TONOLLI NORTH AMERICA'S NESQUEHONING, PENNSYLVANIA PLANT.

Demonstration
No. 11

DCN 83-204-023-05

USE OF SUPPLIED AIR CONTROL ROOMS AND STAND-BY PULPITS TO CONTROL AIRBORNE LEAD EXPOSURE

Final Technical Report
Demonstration Project Number 11

Barbara B. Lee
Radian Corporation
Division of Occupational Safety and Health
Salt Lake City, Utah 84115

NIOSH Contract No. 210-81-7106

Centers for Disease Control
National Institute for Occupational Safety and Health
Division of Physical Sciences and Engineering
Cincinnati, Ohio 45226

May 1983

157<

DISCLAIMER

The contents of this report are herein as received from the contractor.

The opinions, findings, and conclusions expressed herein are not necessarily those of the National Institute for Occupational Safety and Health, nor does mention of company names or products constitute endorsement by the National Institute for Occupational Safety and Health.

NIOSH Project Officer: Robert T. Hughes

Project Technical Director: D. Jeff Burton
for Radian Corporation

FOREWORD

The National Institute for Occupational Safety and Health (NIOSH) is responsible for helping ensure that every person in the U.S. has safe and healthful working conditions. To accomplish this end, the Institute engages in research on occupational safety and health problems including evaluation of hazards and their control.

One of the hazards considered for evaluation and control is lead exposure in the secondary lead smelting industry. NIOSH therefore funded a study to demonstrate emission and exposure controls at secondary lead smelters.

This technical report presents the findings of one of the demonstration projects. It has been written primarily for the secondary lead smelter operator. We hope it will provide the basis for further exposure reductions in plants where the technology can be adopted.

EXECUTIVE SUMMARY

Use of supplied air control rooms or stand-by pulpits has been suggested as an effective means of lowering employee lead exposure in the secondary lead industry. To evaluate and document such enclosures' effectiveness, Radian Corporation, Salt Lake City, Utah, performed a field evaluation program for the National Institute for Occupational Safety and Health. On-site evaluations were made at General Battery Corporation's (GBC) plants in Reading and Hamburg, Pennsylvania, and Tonolli North America's plant at Nesquehoning, Pennsylvania.

Control rooms at both GBC plants are concrete and glass enclosures built to GBC specifications in 1981. Tonolli purchased stand-by pulpits from Lintern Corporation in 1981 and installed them in three Nesquehoning plant locations. Both GBC control rooms and one Tonolli pulpit contain process equipment controls which enable operators to perform most of their duties from within the control room.

Personal and area sampling were conducted to measure airborne lead concentrations inside and outside each enclosure and to determine time weighted average lead exposures for employees accessing the enclosures. A strategy was developed for personal sampling which allowed estimation of the enclosures' contributions to overall exposure reduction. Additionally, the ventilation system in each enclosure was thoroughly characterized.

From the results of this demonstration study, we have concluded that supplied air control rooms and stand-by pulpits can be effective control devices in reducing exposure to airborne lead. Exposure reductions ranged from 23 to 77 percent. The degree of effectiveness will vary with control room design, maintenance, extent of employee use, and employee work practices. The results of this study support control room or pulpit use as a major contributor to a comprehensive exposure control program.

Capital costs for enclosures vary with size and design. Costs ranged from $20,000 - $120,000. Maintenance costs are reportedly minimal at GBC, while Tonolli carries a maintenance agreement with the Lintern Corporation at a cost of $800 per month.

TABLE OF CONTENTS

Section		Page
	DISCLAIMER	ii
	FOREWORD	iii
	EXECUTIVE SUMMARY	iv
	ACKNOWLEDGEMENTS	ix
1.0	INTRODUCTION	1
2.0	DISCUSSION AND CONCLUSIONS	2
3.0	SUPPLIED AIR CONTROL ROOMS AT GENERAL BATTERY CORPORATION	7
	3.1 DESIGN PARAMETERS	7
	3.1.1 Structural Design	7
	3.1.2 Ventilation System Design	11
	3.2 CONTROL FACILITY COSTS	14
	3.3 EMPLOYEE USE OF CONTROL ROOMS	14
	3.4 CONTROL ROOM MAINTENANCE	16
4.0	STAND-BY PULPITS AT TONOLLI NORTH AMERICA	17
	4.1 DESIGN PARAMETERS	17
	4.1.1 Structural Design	17
	4.1.2 Ventilation System Design	20
	4.2 PULPIT COSTS	24
	4.3 EMPLOYEE USE OF PULPITS	25
	4.4 PULPIT MAINTENANCE	26
5.0	EXPOSURE REDUCTION EVALUATION	27
	5.1 METHODOLOGY FOR ESTIMATING EXPOSURE REDUCTION	27
	5.2 SAMPLING STRATEGY	29
	5.3 EXPOSURE REDUCTION AT GENERAL BATTERY CORPORATION	31
	5.3.1 Reading Sampling Results and Exposure Evaluation	31
	5.3.2 Hamburg Sampling Results and Exposure Evaluation	33

TABLE OF CONTENTS (Continued)

Section		Page
5.4	EXPOSURE REDUCTION AT TONOLLI NORTH AMERICA	38
5.4.1	Smelter Pulpit Sampling Results and Exposure Evaluation	39
5.4.2	Crusher Pulpit Sampling Results and Exposure Evaluation	42
6.0	RECOMMENDATIONS	46

LIST OF TABLES

Table		Page
3-1	COST DATA FOR GBC-TYPE CONTROL ROOMS	15
4-1	SPECIFICATIONS FOR LINTERN FILTERED AIR SUPPLY SYSTEMS	20
4-2	COST DATA FOR TONOLLI STAND-BY PULPITS	25
5-1	EXPOSURE REDUCTION AS A FUNCTION OF CONTROL ROOM TIME	28
5-2	SUMMARY OF OPERATOR ACTIVITIES GBC/READING LEAD OXIDE PLANT	32
5-3	GBC/READING SAMPLING RESULTS	34
5-4	SUMMARY OF OPERATOR ACTIVITIES GBC/HAMBURG LEAD OXIDE PLANT	36
5-5	SAMPLING RESULTS FOR GBC/HAMBURG	38
5-6	SUMMARY OF FURNACE LEADMAN ACTIVITIES AT TONOLLI NA	40
5-7	SAMPLING RESULTS FOR TONOLLI SMELTER AREA	41
5-8	ACTIVITY SUMMARY FOR CRUSHER OPERATOR, TONOLLI NA	43
5-9	SAMPLING RESULTS FOR TONOLLI CRUSHER AREA	44
6-1	DAILY CHECKLIST FOR ENCLOSURE EVALUATION	48

LIST OF FIGURES

Figure		Page
3-1	SCHEMATIC OF OXIDE PLANT AND CONTROL ROOM AT GBC/READING	8
3-2	SCHEMATIC OF OXIDE PLANT AND CONTROL ROOM AT GBC/HAMBURG	9
3-3	GLASS WALL OF READING CONTROL ROOM	10
3-4	VIDEO MONITORS INSIDE READING CONTROL ROOM	10
3-5	GBC CONTROL ROOM LABORATORY	12
3-6	ENTRANCE TO READING CONTROL ROOM AIR SHOWER	13
3-7	INTERIOR OF READING CONTROL ROOM AIR SHOWER	13
4-1	REFINERY PULPIT AT TONOLLI	18
4-2	TONOLLI CRUSHER PULPIT EXTERIOR	19
4-3	INTERIOR OF TONOLLI CRUSHER PULPIT, SHOWING CONTROL BOARD	19
4-4	AIR SUPPLY SYSTEM FOR TONOLLI SMELTER PULPIT	21
4-5A	BLOWER AND MOTOR FOR TONOLLI CRUSHER PULPIT	22
4-5B	FILTER TRAIN ENCLOSURE FOR TONOLLI CRUSHER PULPIT	22
4-6	SCHEMATIC OF LINTERN AIR SUPPLY SYSTEM	23
5-1	DUAL PUMP PERSONAL SAMPLING TRAIN	30
5-2	MANUAL OPERATION OF HAMBURG PIG SHEAR	37

ACKNOWLEDGEMENTS

Radian Corporation greatly appreciates the cooperation of the General Battery Corporation and Tonolli North America in conducting this study. Special thanks go to John Bitler, Neal Lebo, and Roy Rakiewicz at General Battery, and to Sergio Legati, Cosimo De Angelis, and Jim Robertson at Tonolli.

1.0 INTRODUCTION

This report describes the results of a study to evaluate the effectiveness of supplied air control rooms and stand-by pulpits as employee exposure controls for airborne lead. Control rooms are supplied air enclosures which house process equipment controls and monitors. Pulpits are insulated supplied air enclosures in which employees may stand or sit when no "hands-on" tasks must be performed in the workplace. Pulpits may or may not contain process control equipment.

The purpose of this project was to collect data documenting control effectiveness and present them, along with useful design, cost and operating information, in a way useful to secondary lead processors and others interested in installing control rooms or pulpits.

To evaluate control room effectiveness, Radian made site visits to General Battery Corporation's lead oxide plants in Reading and Hamburg, Pennsylvania, and Tonolli North America's secondary metals processing plant in Nesquehoning, Pennsylvania. Additional technical and cost data were supplied by General Battery and Tonolli, and by equipment manufacturers and suppliers.

Radian performed this study for the Division of Physical Sciences and Engineering, National Institute for Occupational Safety and Health. We hope that use of information contained in this report will result in reduced airborne lead exposure to secondary lead industry employees, and more cost-effective implementation of occupational exposure controls.

2.0 DISCUSSION AND CONCLUSIONS

The effectiveness of supplied air control rooms and pulpits as controls to reduce employee exposure to airborne lead depends on several factors. Three that most influence the degree to which supplied air control rooms reduce employee exposure are (1) control room ambient lead concentration; (2) employee time spent in control room; and (3) employee work practices.

Ideally, control room lead levels should remain constant near 0 ug/m^3. To achieve and maintain this low concentration, the control room must be kept clean and must be equipped with a ventilation system that filters out even the smallest particulate matter and is capable of maintaining the room under slight positive pressure.

One should not attempt to directly compare the supplied are control rooms at General Battery to the stand-by pulpits at Tonolli. The enclosures used by the two companies are very different in design and construction. Additionally, they service highly dissimilar process areas with varying lead exposure potential: The General Battery control rooms are located in lead oxide plants, while the Tonolli pulpits are located in the Nesquehoning plant's smelter, refinery, and battery crushing and separation area. The lead oxide manufacturing process lends itself to automation more than smelting or refining process.

The control rooms at General Battery's Reading and Hamburg oxide plants are excellent examples of properly cleaned and maintained facilities. Radian measured lead levels inside each at less than 5 ug/m^3, the limit of detection of the instrument used to analyze the samples. A stringent housekeeping program at both GBC plants ensures that control room surfaces are both vacuumed and scrubbed with soap and water once per shift to remove any tracked-in lead dust.

We found ventilation systems in GBC control rooms in good working order. Both rooms were under positive pressure. Clean, filtered air entered the room above the breathing zone and was exhausted at floor level. Minimal turbulence was observed.

Because the Tonolli smelter and refinery pulpits are identical in design and operating mode, only the smelter pulpit (which receives more continuous use) and the crusher pulpit (which is designed and operated somewhat differently) were characterized. Lead concentrations in the Tonolli pulpits, although orders of magnitude less than workplace ambient levels, were measured by Radian to be somewhat higher than those recorded in the GBC control rooms. This can be attributed partially to design differences in control rooms and pulpits. However, the housekeeping program at Tonolli is not as stringent as that at GBC. The Tonolli smelter pulpit is vacuumed once per day and is not wet-scrubbed. The crusher pulpit is washed once daily.

The ventilation system in the Tonolli smelter pulpit was out of adjustment on the day of Radian's field survey, so that the pulpit was under slight negative rather than positive pressure. The problem was remedied by adjusting the system's makeup air flow and positioning the vanes on inlet and exhaust air diffusers to minimize turbulence and cross currents. The ventilation system in the crusher pulpit was functioning adequately and no adjustments were required.

Equally as important as low control room lead concentration is the amount of time employees spend in the control room's clean environment. Control effectiveness increases as employee time in the workplace decreases and control room time is maximized.

Because they are built around process equipment controls, the control rooms at GBC and the crusher pulpit at Tonolli are designed so that operators may spend a maximum amount of their shifts in a clean environment. All three enclosures allow operators to perform most of their job responsibilities under normal plant operating conditions from within the control room. Operators must enter the workplace for extended time periods only if a process upset or mechanical problem occurs.

The Tonolli smelter pulpit is designed simply as a filtered air enclosure and contains no process equipment controls. Although employees cannot perform the majority of their duties from within the pulpit, they are encouraged by Tonolli management to spend as much time there as possible. Employees may remove their respirators while accessing all of the Tonolli pulpits.

The employee activity summaries discussed in Section 5 illustrate the variability of employee time spent in the GBC and Tonolli control rooms and pulpits. Two employees (the GBC/Reading operator and the Tonolli crusher operator) spent close to 50 percent of their shifts in the control room. The GBC/Hamburg operator and the Tonolli smelter furnaceman, however, spent less than 10 and 5 percent respectively, of their shifts in the control room or pulpit. As one would expect, the greatest exposure reductions were observed for employees spending the most time in a control room.

A third factor influencing control room effectiveness is not related directly to the design, maintenance, or employee use of supplied air control rooms. Good work practices, because they can potentially impact employees' overall time weighted average exposures, are extremely important. An employee with poor work habits may increase his actual lead exposure through sloppy or careless work habits or inadequate personal hygiene. The effectiveness of a supplied air control room or pulpit may increase in these situations, because the time spent in a clean environment can somewhat offset periods of high short-term exposure.

The GBC/Reading operator probably increased his overall lead exposure through his habitual hammering of the plant's screw conveyor cyclones. Had the operator demonstrated better work habits, his time weighted average exposure may have decreased to near that of his counterpart at Hamburg. The Hamburg operator exhibited very good work habits, and his time-weighted average exposure was close to the OSHA Permissible Exposure Level (PEL) of 50 ug/m^3.

From the results of this demonstration project, we have concluded that supplied air control rooms and stand-by pulpits can be effective control devices in reducing exposure to airborne lead. The degree of effectiveness will vary with control room design, maintenance, extent of employee use, and employee work practices.

In areas where workplace lead concentrations are relatively low, and where it is possible for employees to spend most of their time in a clean control room, use of supplied air control rooms alone may reduce employee time weighted average exposures to 50

ug/m^3 or less. In high concentration areas, or in situations where employees must spend extended periods outside the control room, use of control rooms must be combined with other engineered or administrative controls to meet the PEL mandated by the OSHA lead standard (29 CFR 1910.1025).

3.0 SUPPLIED AIR CONTROL ROOMS AT GENERAL BATTERY CORPORATION

General Battery Corporation (GBC) has installed supplied air control rooms in its lead oxide plants at Reading and Hamburg, Pennsylvania. These enclosures, completed in 1980-1981, were designed to enable oxide plant operators to monitor oxide production equipment in a clean environment and thus minimize time spent in the oxide plant. Design specifications for control rooms in both locations are similar, as described in the following paragraphs.

3.1 DESIGN PARAMETERS

3.1.1 Structural Design

Schematic drawings of control rooms at GBC's Reading and Hamburg oxide plants are shown in Figures 3-1 and 3-2. The Reading control room (including its air shower, laboratory and hallway) occupies an area of approximately 13 feet by 22 feet by 10 feet high. The Hamburg control room is slightly larger, measuring 16 feet by 20 feet by 9 feet high. The primary construction material is concrete block. At least one wall of each control room is glass, enabling operators inside the room to see activities occurring on the oxide plant floor (Figure 3-3).

The control board inside each GBC enclosure allows operators to monitor and adjust process parameters such as ball mill temperature or steam pressure. Video monitors installed above the mill feed chutes provide a view of lead ingot ("pig") loading to the oxide mills, as shown in Figure 3-4. In the Hamburg control room, an illuminated process schematic board indicates the operating status of the plant's oxide mills and auxilliary equipment.

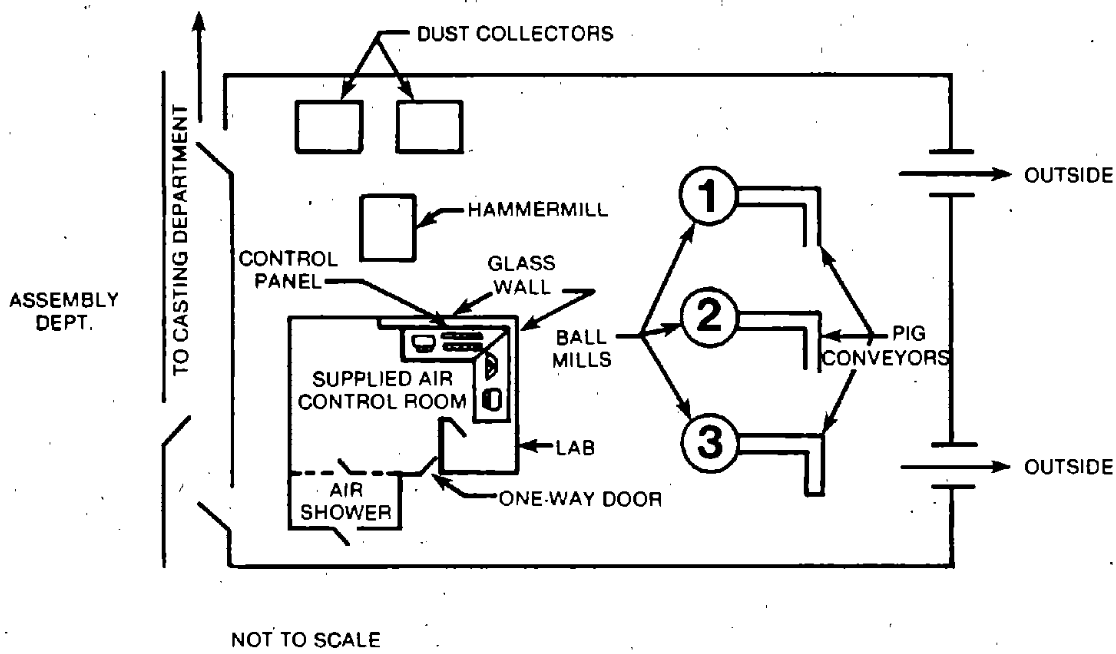


FIGURE 3-1. SCHEMATIC OF OXIDE PLANT AND CONTROL ROOM AT GBC/READING

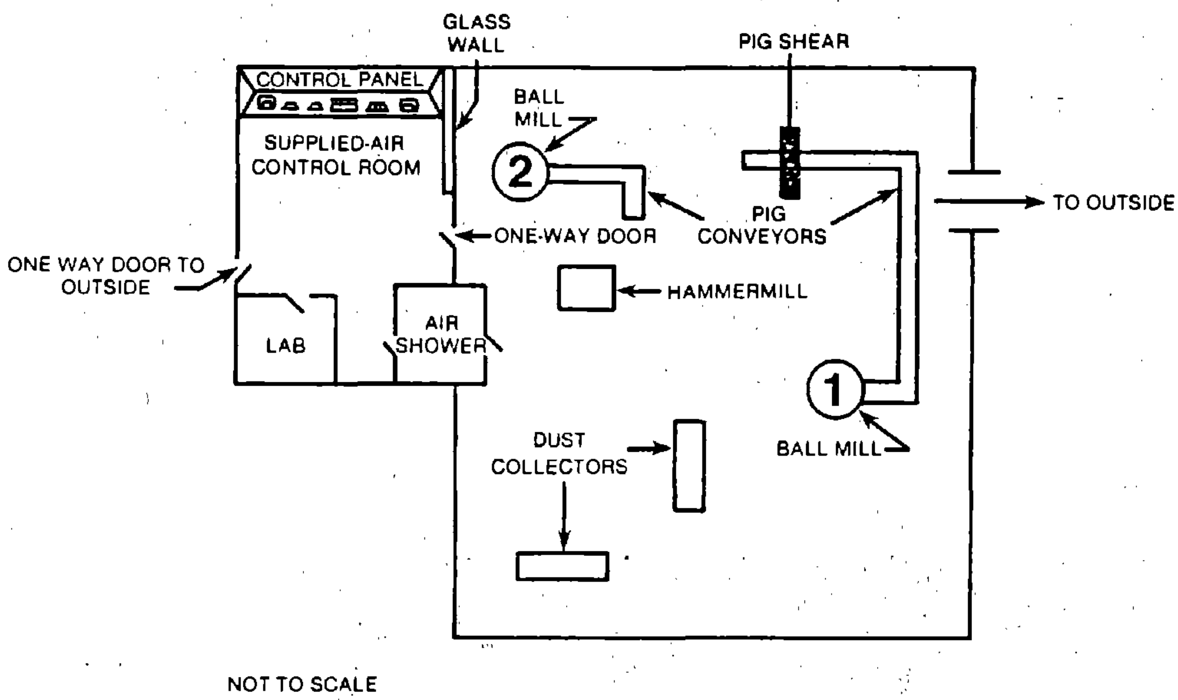


FIGURE 3-2. SCHEMATIC OF OXIDE PLANT AND CONTROL ROOM AT GBC/HAMBURG

174<

FIGURE 3-3. GLASS WALL OF READING CONTROL ROOM

FIGURE 3-4. VIDEO MONITORS INSIDE READING CONTROL ROOM

Each control room houses a small, separate laboratory (shown in Figure 3-5) equipped with a laboratory bench, sink, and exhaust hood. Operators use the laboratory to perform quality control analyses on lead oxide samples collected periodically during each shift.

GBC control rooms may be entered only through a door preceded by an air shower, as shown in Figures 3-6 and 3-7. The air shower at Reading was designed by GBC and built to GBC specifications by Saxon Air Systems. Hamburg's air shower was purchased directly from Liberty Industries, Inc.

The control rooms are exited through a one-way door leading to the oxide plant floor. The control room at Hamburg has a second one-way door to the outside.

3.1.2 Ventilation System Design

Each GBC control room is continuously supplied with filtered, tempered air. The HVAC unit in each is designed to maintain a positive pressure of 1/8 inch w.g. in the room. Air enters the control room through a single circular diffuser located in the ceiling, and is exhausted through multiple rectangular vents at floor level.

The filter train installed in the HVAC unit consists of three filters: a prefilter, an intermediate filter, and a HEPA filter. The unit is designed to remove 99.97 percent of lead dust greater than 0.3 micron in diameter from air entering the control room. Approximately 95 percent of particles greater than 0.1 micron in diameter are removed.

Remote readout gauges to indicate air flow restriction across each filter are provided in the Hamburg control room. A flashing alarm light on the control panel indicates a 50 percent

176<

FIGURE 3-5. GBC CONTROL ROOM LABORATORY

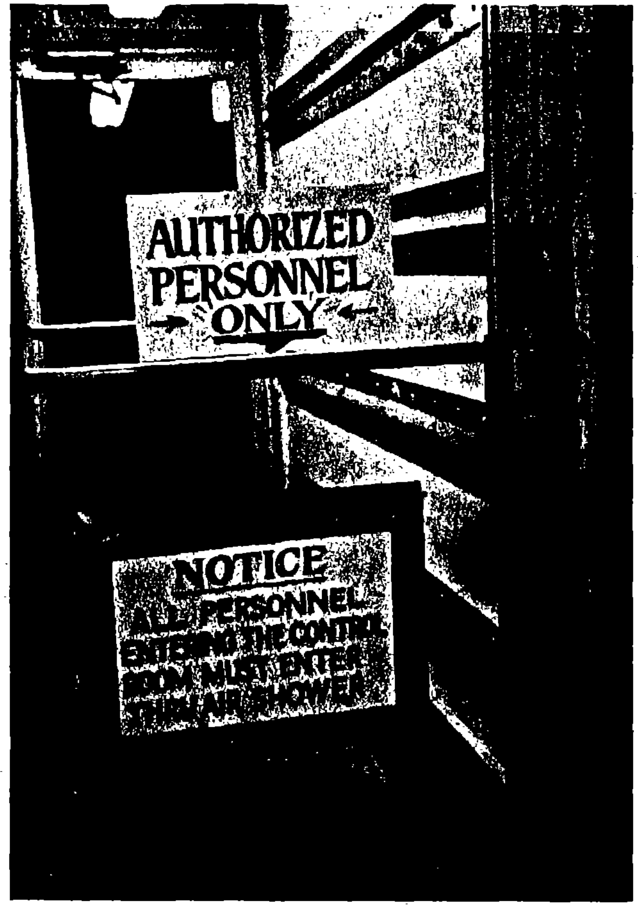


FIGURE 3-6. ENTRANCE TO READING CONTROL ROOM AIR SHOWER

FIGURE 3-7. INTERIOR OF READING CONTROL ROOM AIR SHOWER

restriction in air flow; a warning buzzer sounds when a 75 percent restriction has been reached.

3.2 CONTROL FACILITY COSTS

The GBC control rooms were built to GBC specifications using off-the-shelf components where possible. Costs for constructing and equipping similar control rooms will depend on such factors as process configuration, availability of space, and degree of instrumental sophistication required. GBC has provided the cost data in Table 3-1 as a guide to estimating the cost of constructing and equipping a control room similar to GBC's.

3.3 EMPLOYEE USE OF CONTROL ROOMS

The number of operators assigned to GBC control rooms varies with each plant and with each shift. At the time of the Radian field survey, Reading and Hamburg lead oxide plants were operating 24 hours per day, 7 days per week. Work is conducted on three eight-hour shifts (7:00 AM - 3:00 PM, 3:00 - 11:00 PM, and 11:00 PM - 7:00 AM).

Each control room has a drinking fountain and sink. No eating, smoking, or drinking (other than from the fountain) is allowed in the control rooms.

At the Reading plant, one operator per shift is assigned to the control room. The operator is relieved by an employee from the Milling and Casting Department for two 20-minute breaks during the shift. At Hamburg, two employees (an operator and an assistant) are stationed in the control room during the 7:00 AM to 3:00 PM shift. On the two remaining shifts, only one operator is assigned to the control room. Operators at Hamburg receive break periods similar to those given to Reading plant operators.

TABLE 3-1 COST DATA FOR GBC-TYPE CONTROL ROOMS*

Basic Costs	
Control room construction (includes cost of ventilation system):	$41,000
Air shower:	11,700
Total Basic Costs:	$52,700
Cost of Optional Equipment	
Video monitoring system:	16,100
Electronic instruments and control panel:	31,000
Remote control vibrators for lead oxide conveyance system:	19,000
Total Optional and Basic Costs:	$118,000

*1981$

Operator time spent in the control room varies with process conditions. Each control room has been designed so that operators can perform many of their duties without leaving the room. However, some jobs, such as loading flats of lead pigs onto conveyors feeding the oxide mills, must be performed outside the control room.

At both GBC plants, lead pigs are loaded on conveyors about once per hour. Additionally, operators typically collect lead oxide samples from a screw conveyor four times per shift. These samples are analyzed in the control room laboratory.

If process upsets or mechanical problems occur, operators must spend additional time outside the control room. Although operators are encouraged by GBC to remain in the control room as much as possible, operator work habits vary and thus so does control room time.

3.4 CONTROL ROOM MAINTENANCE

Virtually no maintenance problems have been reported by GBC personnel for either the Reading or Hamburg control rooms. At the time field work for this demonstration study was conducted, the primary problem had been malfunction of the automatic release on the Hamburg air shower door. The control rooms' ventilation systems, display panels, and electronic instrumentation have functioned satisfactorily.

A stringent housekeeping policy governs daily maintenance and cleaning of the GBC control rooms. An inlet to the oxide plant's central vacuum cleaning system is installed in each control room. All surfaces in both the Reading and Hamburg control rooms are vacuumed once per shift. Additionally, surfaces are scrubbed with soap and water once per shift.

4.0 STAND-BY PULPITS AT TONOLLI NORTH AMERICA

Tonolli installed three stand-by pulpits in its Nesquehoning, Pennsylvania secondary lead processing plant in 1981. Located in the plant's smelter, refinery, and battery crushing/separation areas, the pulpits were purchased directly from Lintern Corporation in Mentor, Ohio.

The smelter and refinery pulpits are simple insulated enclosures equipped with filtered air supply units. The pulpit in the battery crushing building, although similar to the other pulpits, houses the controls for the crushing and separation equipment.

4.1 DESIGN PARAMETERS

4.1.1 Structural Design

Each Tonolli pulpit is constructed similarly to the one shown in Figure 4-1. Lintern designed and constructed the metal and glass modular enclosures to meet Tonolli's specifications.

Pulpits in the smelter and refinery areas measure approximately eight feet by six feet by eight feet high. Each has four insulated glass windows to facilitate operators' observations of the plant area. A bench is installed along each pulpit's back wall for operator comfort. Pulpit heating and cooling is controlled by a self-contained heating/air conditioning unit installed inside each pulpit. A single door leading directly to the workplace is used to access the pulpits.

The crusher building pulpit, shown in Figure 4-2, has the same features as those described above. Additionally, it is somewhat larger than the other Tonolli pulpits, occupying space measuring approximately 24 feet by 8 feet by 11 feet high. The control panel for the plant's battery crushing and separation equipment is located along the back wall of the pulpit (Figure 4-3).

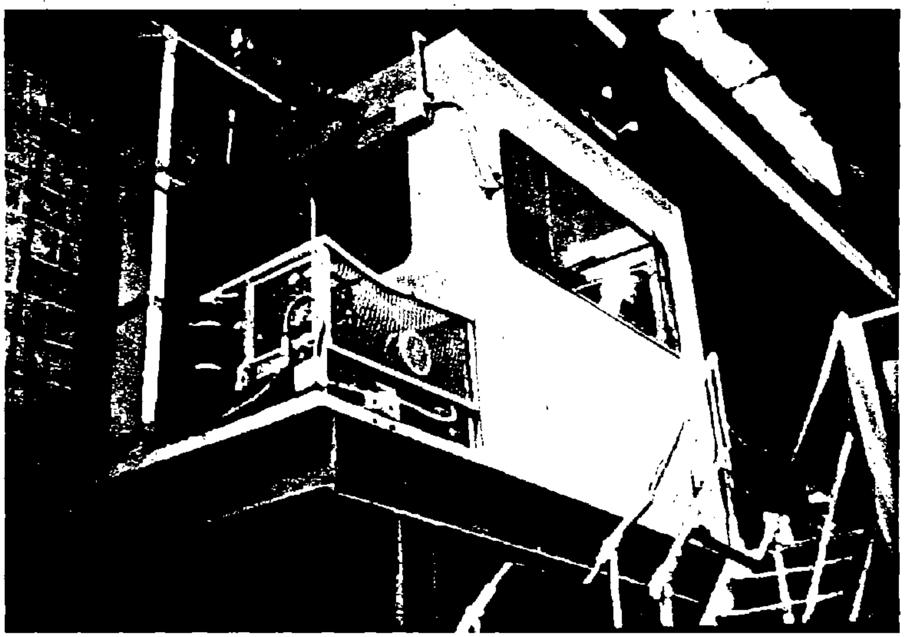


FIGURE 4-1. REFINERY PULPIT AT TONOLLI

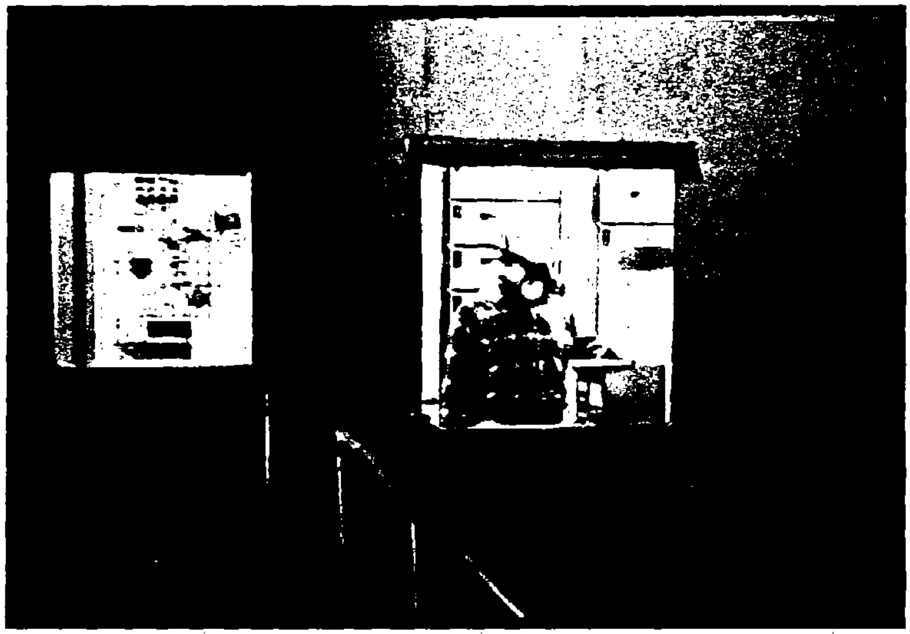


FIGURE 4-2. TONOLLI CRUSHER PULPIT EXTERIOR

FIGURE 4-3. INTERIOR OF TONOLLI CRUSHER PULPIT, SHOWING CONTROL BOARD

4.1.2 Ventilation System Design

Clean, filtered air is supplied to the pulpits via a Lintern-designed air cleaning unit. Air supply units are side-mounted on smelter and refinery pulpits (Figure 4-4) and roof-mounted on the crusher pulpit (Figures 4-5A and 4-5B). Design specifications for the air supply units are given in Table 4-1.

A filter train composed of four filters gives each air supply unit a design particle removal efficiency of 99.97 percent for particles greater than or equal to 0.3 micron in diameter. A typical filter arrangement is shown schematically in Figure 4-6. The first filter is a washable electrostatic prefilter. The second is a disposable filter of fine, non-woven fiber in a deformed pleat configuration. Filter number three consists of a bed of disposable activated alumina pellets impregnated with potassium permanganate. The fourth is an absolute filter which uses a disposable glass medium. Filter loading is monitored monthly by Lintern personnel.

TABLE 4-1 SPECIFICATIONS FOR LINTERN FILTERED AIR SUPPLY SYSTEMS

Cabinet dimensions: 62-1/2" high x 26-1/8" wide x 25" deep
Weight: 420 pounds
Auxilliary Equipment: 4" - 6" diameter flexible hose
Total Air Volume: 200 - 400 cfm
Filter Efficiency: 99.97% removal of particles $\geq$ 0.3 micron
Blower: Squirrel cage fan with continuous duty motor

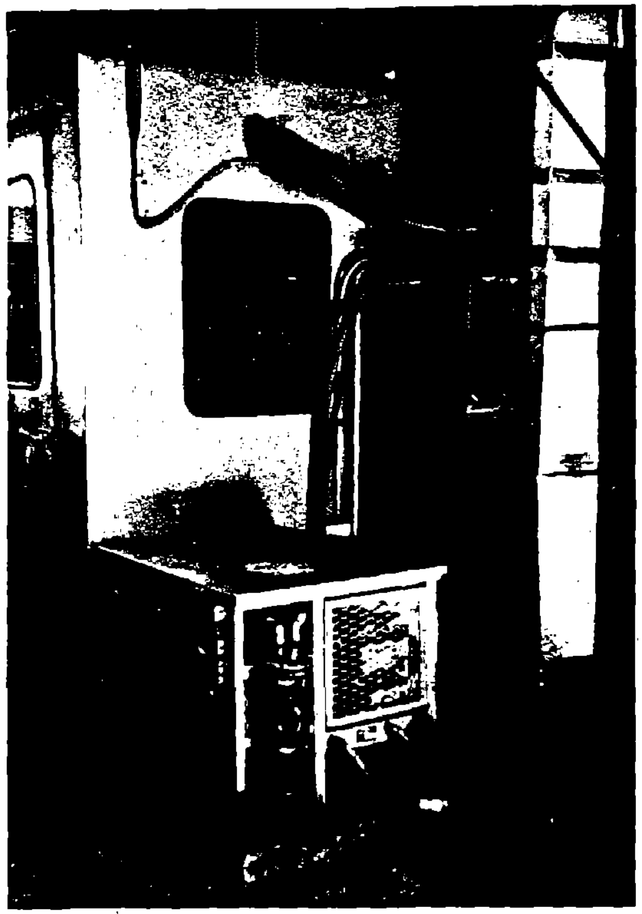


FIGURE 4-4. AIR SUPPLY SYSTEM FOR TONOLLI SMELTER PULPIT

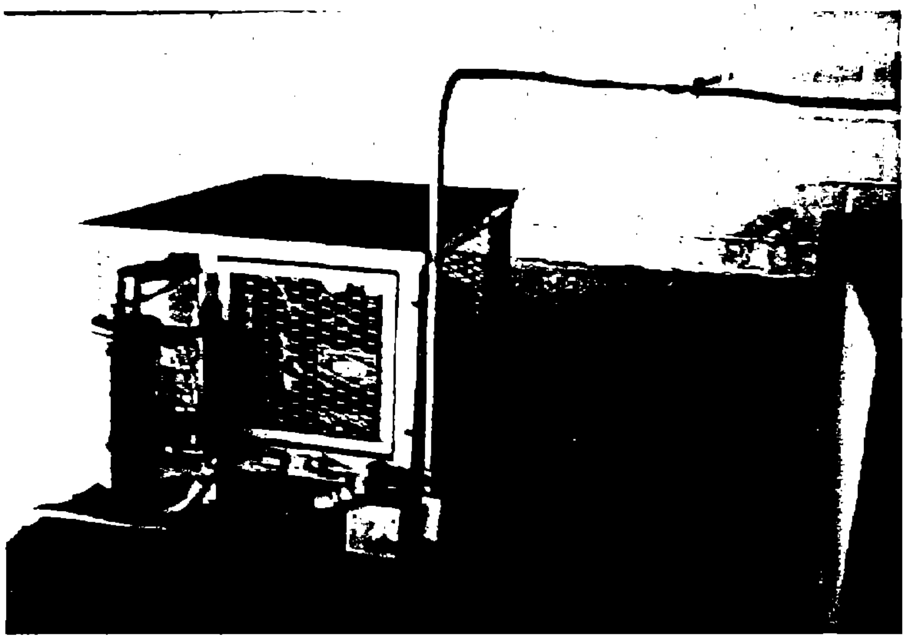


FIGURE 4-5A. BLOWER AND MOTOR FOR TONOLLI CRUSHER PULPIT

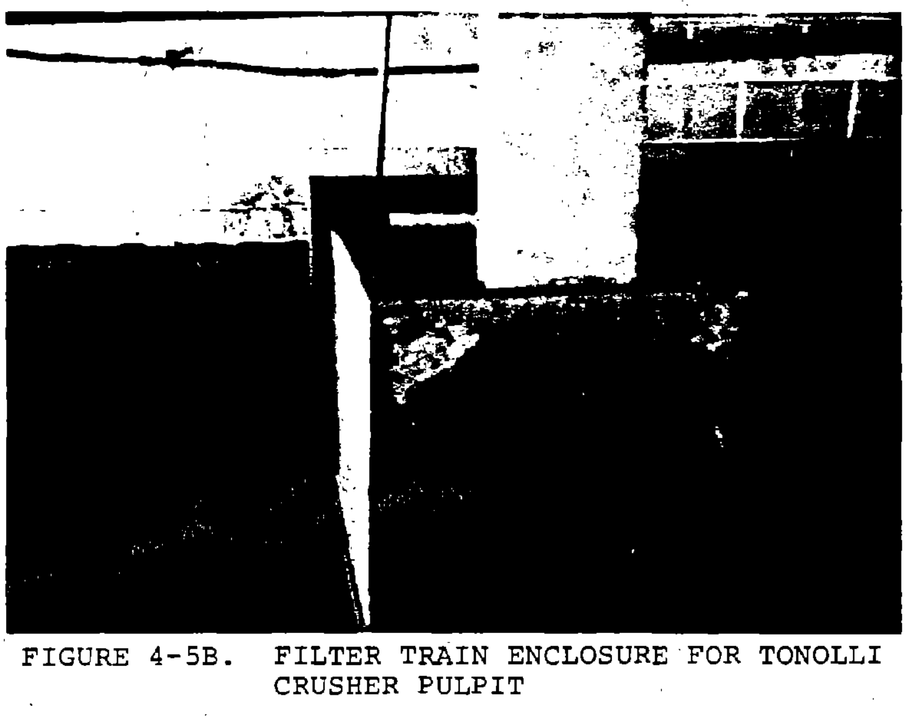


FIGURE 4-5B. FILTER TRAIN ENCLOSURE FOR TONOLLI CRUSHER PULPIT

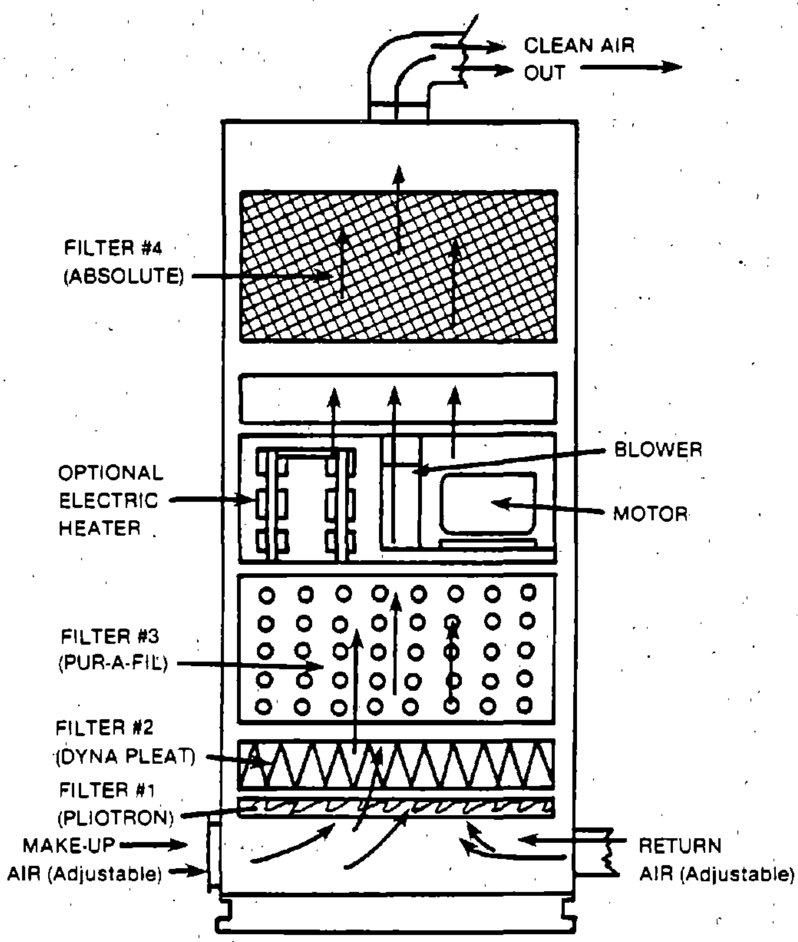


FIGURE 4-6. SCHEMATIC OF LINTERN AIR SUPPLY SYSTEM

Air enters smelter and refinery pulpits through a four-inch diameter round duct and a four-inch wide rectangular diffuser. The inlet air diffuser is located in the pulpit wall approximately seven feet above the floor. Air is exhausted through a floor-level, nine-by four-inch diffuser. At the crusher pulpit, inlet air and exhaust ducts are located in the ceiling. Adjustable diffuser vanes can be used to direct air flow.

The air supply system in each pulpit is designed to maintain a positive pressure of 0.1 inch w.g. in the pulpit. Smelter and refinery pulpits receive a design air volume of 200 cubic feet per minute. The larger crusher pulpit air supply system is designed to deliver 400 cubic feet per minute.

4.2 PULPIT COSTS

Lintern constructs pulpits like those at Tonolli to meet clients' specifications using modular construction materials. Lintern will supply, as it did for Tonolli, a complete design, engineering and construction package ready for turnkey installation by the client. Site preparation and installation costs are additional.

As was true for the GBC control rooms, costs for construction and installation of stand-by pulpits will vary with such factors as pulpit size and plant configuration. As a guide, Tonolli has provided the cost data in Table 4-2 for use in estimating various pulpit costs.

TABLE 4-2 COST DATA FOR TONOLLI STAND-BY PULPITS

Item	Smelter	Refinery	Crusher
		$/Location (1981 $)	
Main equipment (pulpit and ventilation system, from Lintern)	18,730	18,739	37,680
Additional materials	330	6,470	1,145
Preparatory work	1,040	3,825	10,040
Installation and start-up	910	810	2,360
TOTALS	$21,010	$19,835	$51,225

4.3 EMPLOYEE USE OF PULPITS

Employee use of the Tonolli smelter and refinery pulpits varies with process status and employee responsibilities. At the time of this project's field survey, three of the plant's four rotary furnaces were in operation 24 hours per day, 7 days per week. Crusher equipment was operating 24 hours per day, 5 days per week (Monday - Friday). Drossing and other refining operations were conducted intermittently on all three shifts, seven days per week. Employees rotated among three eight-hour shifts, extending from 7:00 AM - 3:00 PM; 3:00 - 11:00 PM; and 11:00 PM - 7:00 AM.

As many as seven employees per shift may access the smelter pulpit: furnacemen, furnace helpers, and fork lift operators. Five to seven employees, including kettlemen, kettlemen's helpers, and crane operators may use the refinery pulpit when refining operations are in progress. Two operators per shift are assigned to the crusher pulpit.

Employees are encouraged by Tonolli management to maximize time spent in the pulpits, occupying them whenever "hands-on" tasks are not being performed. Because equipment controls are located in the crusher pulpit, operators may spend most of their time in the pulpits unless process upsets or mechanical failures occur.

4.4 PULPIT MAINTENANCE

Tonolli personnel reported that no maintenance problems occurred during the pulpits' first twelve months of service. During start-up of the crusher pulpit, it was discovered that the supplied air system originally designed for the pulpit was not adequate because it could not maintain a positive pressure of 0.1 inch w.g. in the pulpit. A larger system was subsequently installed which has proved capable of supplying a sufficient volume of air.

Each of the three pulpits is cleaned once per day by the plant's cleaning crew. Smelter and refinery pulpits are vacuumed using the plant's central vacuum system. The crusher pulpit is cleaned with soap and water. Dust is removed from all surfaces and pulpit windows are cleaned.

Tonolli has a maintenance contract with Lintern through which a Lintern representative inspects the three Tonolli pulpits once per month. Spent filters in the pulpits' ventilation systems are replaced during the inspection. The cost of this service is approximately $800 per month.

5.0 EXPOSURE REDUCTION EVALUATION

One of the objectives of this demonstration project was to evaluate the effectiveness of supplied air control rooms and pulpits in reducing employee exposure to airborne lead. This section describes the methodology used to estimate exposure reduction, the sampling strategy developed to collect exposure data, and the results of sampling conducted at General Battery and Tonolli facilities.

5.1 METHODOLOGY FOR ESTIMATING EXPOSURE REDUCTION

We anticipated that two factors would most influence the amount of reduction contributed by employee use of supplied air control rooms or pulpits: ambient lead concentration inside and outside the control room, and the amount of time spent by employees in the control room. Ideally, the ambient lead concentration inside supplied air control rooms should be near 0 ug/m^3. By maximizing time spent in the clean environment, an employee can minimize the eight hour time-weighted average lead, which may be estimated as shown below:

$$TWA = \left(\frac{\text{Control Room Time}}{480}\right)\left(\begin{array}{c}\text{Control Room}\\ \text{Concentration}\end{array}\right) + \left(\frac{\text{Workplace Time}}{480}\right)\left(\begin{array}{c}\text{Workplace}\\ \text{Concentration}\end{array}\right) \qquad (1)$$

Assuming that the control room concentration remains constant at zero, the time-weighted average concentration is dependent on workplace exposure and workplace time. As time in the control room increases, time in the uncontrolled workplace atmosphere decreases, thus reducing the time-weighted average concentration. Table 5-1 shows the influence of increased control room time on time-weighted average concentrations and percent exposure reduction. As the table indicates, even relatively small control room times can effectively reduce employee exposure.

TABLE 5-1 EXPOSURE REDUCTION AS A FUNCTION OF CONTROL ROOM TIME

TIME IN CONTROL ROOM (MINUTES)	AVERAGE WORKPLACE LEAD CONCENTRATION ($\mu g/m^3$)			TIME-WEIGHTED AVERAGE CONCENTRATION** ($\mu g/m^3$)			PERCENT EXPOSURE REDUCTION***
60	100	225	500	88	197	438	12%
180	100	225	500	63	141	312	38%
220	100	225	500	54	122	271	46%
260	100	225	500	46	103	229	54%
300	100	225	500	38	84	188	62%
360	100	225	500	25	56	125	75%
400	100	225	500	17	38	83	83%
440	100	225	500	8	19	42	92%

* Assumes control room exposure to be 0 ug/m^3.

** $\left(\frac{\text{Control Room Time}}{400}\right)\left(0\ \text{ug/m}^3\right) + \left(\frac{\text{Workplace Time}}{480}\right)\left(\text{Workplace Concentration}\right)$ Time-Weighted Average Concentration

*** $\left(\frac{\text{Average Workplace Concentration} - \text{Time-Weighted Average Concentration}}{\text{Average Workplace Concentration}}\right)(100)$

Percent reduction may be calculated:

$$\% \text{ Reduction} = \left(\frac{\text{Average Workplace Concentration} - \text{Time-Weighted Average Concentration}}{\text{Average Workplace Concentration}}\right)(100) \quad (2)$$

5.2 SAMPLING STRATEGY

Timing of the demonstration project did not allow Radian to conduct full shift personal sampling of GBC or Tonolli employees prior to installation of supplied air control rooms or pulpits. Thus, no "before and after" exposure data were available from which to measure exposure reduction. To collect data from which exposure reduction could be estimated, dual samples were collected simultaneously on employees accessing the control rooms, as described below.

Employees selected for personal monitoring wore two sampling trains, as shown in Figure 5-1. Each train consisted of a high-flow pump (MSA Model G) and a 0.8 μ, 37 mm cellulose ester membrane filter encased in a plastic cassette. An air sample was drawn continuously at a rate of two liters per minute through one sampling train for an employee's full work shift. From this sample Radian calculated the employee's time-weighted average lead exposure, which was used in Equation 2 (Section 5.1) to estimate exposure reduction.

Air was drawn through the second sampling train (at the same flow rate as above) only when the employee left the clean environments of the control room or break room and entered the uncontrolled workplace atmosphere. This sample was used to calculate a value representative of the workplace lead concentration encountered by the employee throughout his work shift. The calculated workplace concentration was used in Equation 2 to estimate exposure reduction.

FIGURE 5-1. DUAL PUMP PERSONAL SAMPLING TRAIN

In addition to the personal samples described above, area samples were collected inside the control rooms, at point sources throughout the workplace and in employee break rooms. Samples were collected and analyzed according to NIOSH method S-341.

At each plant, Radian catalogued employee work habits in detail. The monitored employee's time in the control room, break room, and workplace was carefully recorded throughout the work shift. Employees were interviewed to collect further information about activities conducted during a typical shift and to identify any atypical problems or events occurring during the sampling period. Specific sampling and exposure data for each facility evaluated are provided in the following sections.

5.3 EXPOSURE REDUCTION AT GENERAL BATTERY CORPORATION

Results of field evaluations conducted during the 3:00 - 11:00 PM shift at GBC's Reading lead oxide plant, and for the 7:00 AM - 3:00 PM shift at GBC's Hamburg lead oxide plant are given below.

5.3.1 Reading Sampling Results and Exposure Evaluation

A summary of operator activities at the GBC/Reading plant is shown in Table 5-2. The operator indicated that his activities were those of a typical work shift, except for a problem with the hammer mill, which required that he spend additional time away from the control room. During his shift, the operator spent:

228 minutes (48% of his time) in the control room.
199 minutes (41%) in the workplace.
28 minutes (6%) in the employee breakroom.
25 minutes (5%) in the shower.

TABLE 5-2 SUMMARY OF OPERATOR ACTIVITIES GBC/READING LEAD OXIDE PLANT

TIME	ACTIVITY
3:00 P	Draws samples from screw conveyor carrying lead oxide.
3:13 P	Returns to control room.
3:19 P	Goes upstairs to check screw conveyor cyclone (pounds vibrators with hammer).
3:22 P	Returns to control room.
3:49 P	Oils gears on #2 ball mill. Goes to cyclone and pounds vibrators.
4:04 P	Returns to control room.
4:22 P	Loads pigs on conveyor at each ball mill. Pounds cyclone vibrators and collects oxide samples.
4:35 P	Returns to control room. Runs oxide laboratory analysis.
4:45 P	Loads pigs, pounds cyclone vibrators.
4:59 P	Goes to employee lunchroom.
5:27 P	Returns to ball mill area, loads pigs, collects oxide sample, hammers vibrators.
5:39 P	Returns to control room.
5:59 P	Collects oxide sample, hammers vibrators.
6:15 P	Returns to control rooms.
6:31 P	Collects oxide samples.
6:46 P	Returns to control room. Runs oxide laboratory analysis.
7:18 P	Problem with hammer mill. Works to solve problem. Loads pigs on conveyor.
7:42 P	Returns to control room.
7:51 P	Checks hammer mill operation.
7:57 P	Returns to control room.
8:03 P	Checks hammer mill operation.
8:05 P	Returns to control room.
8:10 P	Loads pigs on conveyor. Hammers vibrators.
8:22 P	Returns to control room.
8:40 P	Collects oxide samples. Hammers vibrators.
8:56 P	Returns to control room. Runs oxide laboratory analysis.
9:34 P	Loads pigs on conveyor and hammers vibrators. Vacuums ball mill area.
10:02 P	Returns to control room.
10:25 P	Makes "final rounds" before shift change.
10:35 P	Goes to shower.

Sampling results for the GBC/Reading plant are shown in Table 5-3. From the operator TWA and workplace concentration data, and using Equation 2 from Section 5.1, exposure reduction due to operator use of the supplied air control room could be estimated:

$$\% \text{ Reduction} = \left(\frac{206 \text{ ug/m3} - 92 \text{ ug/m3}}{206 \text{ ug/m}^3}\right)(100)$$

$$= 55\%$$

The Reading operator's primary source of exposure appeared to be his periodic hammering of the screw conveyor cyclone vibrators. An area sample taken near the vibrators was inadvertently destroyed by the operator's vigorous hammering. However, measurements taken with a Sibata P5 real time aerosol counter indicated high levels of dust in the area. Had the operator limited his hammering activity (as he has been encouraged to do by GBC management) his exposure would likely have been further reduced.

5.3.2 Hamburg Sampling Results and Exposure Evaluation

Two employees were assigned to the Hamburg control room on the day of Radian's field evaluation. The mill operator had responsibilities similar to those of the Reading operator. The assistant operator's duties included control room and workplace housekeeping and maintenance and miscellaneous tasks to support plant operation. The mill operator was chosen for personal monitoring because his activities were considered more representative of typical plant operating tasks.

TABLE 5-3 GBC/READING SAMPLING RESULTS

Location	Concentration ($\mu g/m^3$)	Type
Operator (full shift sample)	92*	BZ
Workplace (from operator intermittent sample)	206	BZ
Control room	<5	Area
Oxide plant near pig conveyors	16	Area
Employee breakroom	<5	Area

*8-hour, time-weighted average concentration.

An activity summary for the Hamburg operator is given in Table 5-4. The summary shows that the Hamburg operator, although performing essentially the same tasks as the Reading operator, spent much less time in the control room. The difference is due in part to a mechanical problem with the pig shear, which required manual operation (Figure 5-2).

The operator indicated that he spent somewhat less time in the control room because of the problem, but that he typically spent less than 50 percent of his time in the control room. During his shift, the Hamburg operator spent:

348 minutes (72% of his time) in the workplace.
59 minutes (12%) in the breakroom.
32 minutes (7%) in the control room.
41 minutes (9%) in the hygiene facility.

Sampling results for the GBC/Hamburg plant are shown in Table 5-5. From these data, operator exposure reduction potentially attributable to the control room and other "clean areas" could be estimated:

$$\text{\% Reduction} = \left(\frac{100\ \text{ug/m3} - 56\ \text{ug/m3}}{100\ \text{ug/m}^3}\right)(100)$$

$$= 44\%$$

The relationship betwen control room ambient lead concentration and time, and employee exposure reduction is not as clearly delineated for the GBC/Hamburg operator as for the GBC/Reading operator. Although he spent much less time in "clean areas," the Hamburg operator's overall exposure to airborne lead (almost half that of the Reading operator), was very close to the OSHA Permissible Exposure Limit (PEL) of 50 ug/m^3. Use of the control

TABLE 5-4 SUMMARY OF OPERATOR ACTIVITIES GBC/HAMBURG LEAD OXIDE PLANT

Time	Activity
7:10 A	Goes to mill area from control room. Loads pigs on conveyors. Monitors pig shear operation.
8:38 A	Returns to control room.
8:47 A	Goes to mill area - activities same as listed above for 7:10 A.
8:58 A	Returns to control room, goes immediately to break room.
9:34 A	Goes to mill area. Loads pigs; collects oxide samples.
10:32 A	Returns to control room. Runs oxide laboratory analysis.
10:48 A	Feeds pigs to shear. Collects oxide samples.
12:04 A	Goes to break room for lunch.
12:27 P	Returns to mill area. Loads pigs; feeds pigs to shear. Collects oxide samples.
1:31 P	Returns to control room. Starts oxide laboratory analysis.
1:32 P	Goes to mill area.
2:29 P	Returns to control room; goes immediately to shower.

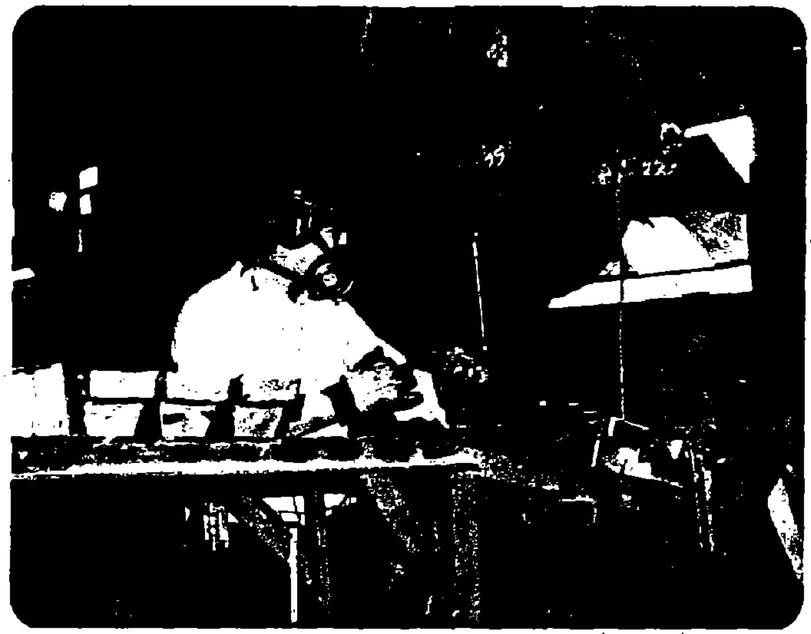


FIGURE 5-2. MANUAL OPERATION OF HAMBURG PIG SHEAR

room and other "clean areas" undoubtedly influenced exposure reduction, however. An additional contributing factor could be the Hamburg operator's work habits, which were considerably more careful than those of the Reading operator.

TABLE 5-5 SAMPLING RESULTS FOR GBC/HAMBURG

Location	Concentration ($\mu g/m^3$)	Type
Operator	56*	BZ
Workplace (from operator intermittent sample)	100	BZ
Control room	<5	Area
Oxide plant near pig conveyors	21	Area
Employee breakroom	27	Area

*8-hour, time-weighted average concentration.

5.4 EXPOSURE REDUCTION AT TONOLLI NORTH AMERICA

Field evaluations were conducted by Radian for two of Tonolli's three pulpits. Because smelter and refinery pulpits are identical in construction and operating mode, only the smelter pulpit, which receives more continuous use, was characterized. Additionally, the crusher pulpit was evaluated. Both were observed during the 7:00 AM - 3:00 PM shift.

5.4.1 Smelter Pulpit Sampling Results and Exposure Evaluation

A summary of activities for one Tonolli employee accessing the smelter pulpit is shown in Table 5-6. The employee chosen for personal monitoring was a furnace operator, with responsibility for tending the smelter's rotary furnaces.

Activities recorded for the furnaceman are somewhat atypical. The employee was away from the smelter area more than usual; he went to the employee lunchroom to have a blood sample drawn at the beginning of his shift and left the work area early to attend a safety meeting in the plant administrative office building. The furnaceman indicated that he spent less time in the smelter pulpit than usual because he was needed in the furnace area during most of his shift. Throughout his shift the furnaceman spent:

- 319 minutes (67% of his time) in the smelter area.
- 52 minutes (11%) in the employee lunchroom.
- 16 minutes (3%) in the smelter pulpit.
- 93 minutes (19%) in hygiene facilities and plant administrative area.

Sampling results for the furnaceman, smelter pulpit, surrounding workplace are shown in Table 5-7. From these data, employee exposure reduction potentially attributable to time spent in clean areas (pulpit, lunchroom, administrative offices) could be estimated:

$$\% \text{ Reduction} = \left(\frac{297 \text{ ug/m3} - 230 \text{ ug/m3}}{297 \text{ ug/m}^3}\right)\left(100\right)$$

$$= 23\%$$

TABLE 5-6 SUMMARY OF FURNACE LEADMAN ACTIVITIES AT TONOLLI NA

Time	Activity
7:43 A	Employee to furnace area. Activities include operating a jackhammer prior to tapping, monitoring furnace conditions, recording data.
8:05 A	Employee to lunchroom for blood test.
8:32 A	Employee to furnace area. Activities same as for 7:43 A.
10:02 A	Returns to pulpit for break.
10:18 A	Returns to furnace area.
12.05 P	Goes to lunchroom.
12:30 P	Returns to furnace area
2:10 P	Leaves smelter for day. Goes to shower and to office building for safety meeting.

TABLE 5-7 SAMPLING RESULTS FOR TONOLLI SMELTER AREA

Location	Concentration (ug/m^3)	Type
Operator (full shift sample)	230*	BZ
Workplace (from operator intermittent sample)	297	BZ
Pulpit	23	Area
Smelter floor near operator's stand	333	Area
Employee lunchroom	30	Area

*8-hour, time-weighted average exposure.

Because the monitored employee spent so little time in the smelter pulpit, we can reasonably assume that pulpit use alone cannot account for the furnaceman's overall exposure reduction. However, because the furnaceman spent a total of 33 percent of his time in "clean" areas away from the workplace, some reduction was observed despite his low pulpit use.

One might have expected the furnaceman's overall exposure reduction to have been greater than 23 percent, as one-third of his shift was spent away from the workplace. Reduction was probably not as great because lead concentrations in the "clean areas" were not near 0 ug/m^3, but ranged from 20 to 30 ug/m^3.

5.4.2 Crusher Pulpit Sampling Results and Exposure Evaluation

The crusher pulpit at Tonolli's Nesquehoning plant is much-needed, because airborne lead levels in the crusher building are among the highest at the plant. By enclosing the crushing and separation equipment controls within the pulpit, Tonolli has enabled crusher operators to remain in a clean environment for extended periods under normal operating conditions.

Unfortunately, Radian did not evaluate the crusher pulpit under normal conditions. On the day of the field survey, mechanical problems forced the shutdown of the crushing and separation equipment. The operator assigned to the crusher pulpit spent much more time than usual outside the pulpit in his attempts to repair the problem and restart the equipment. However, a substantial reduction in exposure was achieved, as is discussed below.

An activity summary for the crusher operator is given in Table 5-8. The summary shows that the operator entered and exited the pulpit many times as he attempted to solve equipment problems, and that he stayed in the pulpit only for short periods of time for most of the shift. During his shift the operator spent:

198 minutes (41% of his time) in the pulpit.
140 minutes (29%) in the crusher area.
86 minutes (18%) in the shower/offices.
56 minutes (12%) in the employee breakroom.

TABLE 5-8 ACTIVITY SUMMARY FOR CRUSHER OPERATOR, TONOLLI NA

TIME	ACTIVITY
7:46 A	Goes to crusher area.
7:50 A	Returns to pulpit.
7:51 A	Goes to crusher area to check charging elevator.
8:00 A	Returns to pulpit.
8:23 A	Goes to crusher.
8:24 A	Returns to pulpit.
8:26 A	Goes to crusher.
8:28 A	Returns to crusher.
8:37 A	Goes to crusher.
8:40 A	Returns to pulpit.
8:46 A	Goes to crusher.
8:58 A	Returns to crusher.
9:04 A	Goes to crusher.
9:06 A	Returns to crusher.
9:10 A	Goes to crusher.
9:20 A	Returns to pulpit.
9:27 A	Goes to crusher.
9:28 A	Returns to crusher.
9:37 A	Goes to crusher.
9:40 A	Returns to pulpit.
9:42 A	Goes to crusher.
9:43 A	Returns to pulpit.
9:45 A	Goes to crusher.
9:46 A	Returns to pulpit.
9:51 A	Goes to crusher.
9:53 A	Returns to pulpit.
10:24 A	Goes to crusher; attempts to restart crusher.
10:26 A	Returns to pulpit.
10:28 A	Goes to crusher.

TIME	ACTIVITY
10:34 A	Returns to pulpit.
10:41 A	Goes to crusher.
10:45 A	Returns to pulpit.
10:49 A	Goes to crusher.
10:53 A	Returns to pulpit.
11:21 A	Goes to crusher.
11:32 A	Returns to pulpit.
11:35 A	Goes to crusher.
11:37 A	Returns to pulpit.
11:50 A	Goes to crusher.
11:55 A	Goes to lunchroom.
12:20 P	Returns to crusher.
12:25 P	Returns to pulpit.
1:06 P	Goes to crusher.
1:42 P	Returns to pulpit.
1:44 P	Goes to crusher.
1:56 P	Returns to pulpit.
2:04 P	Goes to crusher.
2:06 P	Returns to pulpit.
2:20 P	Goes to shower.

Sampling results for the crusher operator and crusher building and pulpit are shown in Table 5-9. From these data, operator exposure reduction could be estimated:

$$\% \text{ Reduction} = \left(\frac{1570 \text{ ug/m3} - 364 \text{ ug/m}^3}{1570 \text{ ug/m}^3}\right)\left(100\right)$$

$$= 77\%$$

TABLE 5-9 SAMPLING RESULTS FOR TONOLLI CRUSHER AREA

Location	Concentration (ug/m^3)	Type
Operator (full shift sample)	364*	BZ
Workplace (from operator intermittent sample)	1570	BZ
Pulpit	53	Area
Crusher area near plastic conveyor	568	Area
Employee lunchroom	23	Area

*8-hour, time-weighted average concentration.

The crusher operator's estimated exposure reduction, due primarily to his use of the crusher pulpit, dramatically illustrates the effectiveness of pulpit enclosures as control devices. Although ambient lead concentrations in the pulpit were higher than observed in other pulpits and control rooms, and though the operator's time-weighted average exposure was still far above the OSHA PEL of 50 ug/m^3, the relative exposure reduction of over 1 mg/m^3 represents a substantial improvement in employee exposure.

The higher ambient lead concentration in the crusher pulpit is probably due to the high airborne lead concentration in the surrounding workplace and to the high degree of traffic the pulpit experienced during the sampling period. The pulpit's ventilation system appeared to be operating properly; the pulpit was under positive pressure and the filter train seemed to be in good working order. Better housekeeping in the pulpit (as discussed in Section 6 of this report) could minimize entrainment of tracked-in dust within the pulpit and thus lower its ambient concentration.

6.0 RECOMMENDATIONS

Supplied air control rooms and stand-by pulpits must be properly cleaned and maintained if they are to continuously maintain low ambient lead concentrations. Enclosures should be vacuumed and scrubbed with soap and water so that no lead dust is allowed to collect on flat surfaces. The structural integrity of the enclosures must remain intact; no holes or cracks through which lead may enter should be tolerated.

Preventive maintenance should be performed on a regularly scheduled basis. Maintenance of enclosures' ventilation systems is particularly important. The systems' filter trains should not become clogged or damaged. Intake and exhaust air flow must be carefully monitored to ensure that the rooms are under positive pressure at all times.

If auxilliary equipment such as air showers or shoe cleaners is a part of the control room or pulpit, this equipment should be kept in good working order. Malfunctioning equipment will not serve its intended purpose of reducing employee lead exposure. Additionally, employees may be discouraged from accessing enclosures if they must deal with malfunctioning or broken equipment.

Area monitoring should be conducted inside enclosures as a part of a plant's comprehensive monitoring program. Periodic measurements should be made to ensure that airborne lead levels within enclosures remain close to 0 $\mu g/m^3$.

To assist secondary lead industry management in maintaining high performance of control rooms and pulpits, Radian has developed a checklist for supplied-air enclosure evaluation. The checklist, shown in Table 6-1, may be used daily by plant management to ensure that enclosures are operating up to specification.

A preventive maintenance checklist should be developed for individual plants based on their enclosures' specific designs and operating modes. The checklist should include such items as:

- Schedule for ventilation system filter replacement.
- Schedule for replacing ventilation system hoses, clamps, and blower internal parts.
- Schedule for replacing window and door moldings.
- Schedule for checking and replacing air shower ventilation system internal parts, including automatic doors, blower, nozzles and lighting.

TABLE 6-1: DAILY CHECKLIST FOR ENCLOSURE EVALUATION

Ventilation System:

1) Is the ventilation system turned on?

2) Is the pulpit under positive pressure?

3) Are the inlet and exhaust diffusers open and adjusted properly?

4) Are the door and windows sealing properly? (No cracks or holes.)

5) Is heating/air conditioning system functioning properly?

Housekeeping

1) Are all surfaces (floor, windowsills, etc.) dust-free?

2) Is a daily housekeeping program (vacuuming plus wet-scrubbing) being followed?

Auxilliary Equipment

1) Are air showers, shoe cleaners, etc. functioning properly?

2) Are employees using the equipment properly?

Demonstration
No. 13

CONSTRUCTION AND EVALUATION OF
EMISSION CONTROLS ON BLAST FURNACE TUYERES

Demonstration Project Number 13

Preliminary

Draft Final Report

B. B. Lee, D. J. Burton and C. C. Mecham
Radian Corporation
Division of Occupational Safety and Health
Salt Lake City, Utah 84115

NIOSH Contract No. 210-81-7106

Centers for Disease Control
National Institute for Occupational Safety and Health
Division of Physical Sciences and Engineering
Cincinnati, Ohio 45226

May 1983

215<

DISCLAIMER

The contents of this report are herein as received from the contractor.

The opinions, findings, and conclusions expressed herein are not necessarily those of the National Institute for Occupational Safety and Health, nor does mention of company names or products constitute endorsement by the National Institute for Occupational Safety and Health.

NIOSH Project Officer:	Robert T. Hughes
Project Technical Director:	D. Jeff Burton for Radian Corporation
Demonstration #13 Task Leader:	Barbara Lee Radian Corporation

FOREWORD

The National Institute for Occupational Safety and Health (NIOSH) is responsible for helping ensure that every person in the U.S. has safe and healthful working conditions. To accomplish this end, the Institute engages in research on occupational safety and health problems including evaluation of hazards and their control.

One of the hazards considered for evaluation and control is lead exposure in the secondary lead smelting industry. NIOSH therefore funded a study to demonstrate emission and exposure controls at secondary lead smelters.

This technical report presents the findings of one of the demonstration projects. It has been written primarily for the secondary lead smelter operator. We hope it will provide the basis for further exposure reductions in plants where the technology can be adopted.

EXECUTIVE SUMMARY

Lead emissions generated from clearing blast furnace tuyere nozzles have been suspected as major contributors to furnaceman lead exposures in secondary lead smelters. The primary objectives of this study were to characterize furnaceman exposure during tuyere "punching" and to construct and evaluate engineering and work practice controls applied to tuyere punching.

Radian performed this study under the sponsorship of the National Institute for Occupational Safety and Health. On-site control evaluations were made at East Penn Manufacturing Company's secondary lead smelter in Lyon Station, Pennsylvania.

Personal sampling data collected during the study indicate that tuyere punching may account for as much as half of a furnaceman's lead exposure. Three major emission sources contribute to tuyere punching exposure: fume from the metal punch rod; clouds of dust from gloves entrained in escaping blast air; and fume and particulate material from the blast furnace.

East Penn has developed and tested numerous engineering and work practice controls for use on blast furnace tuyeres. The most effective of these is a hydraulically-powered tuyere punching device which seals the tuyere outlet during punching. This device eliminates employee exposures from furnace or punch rod emissions and dust entrained in blast air escaping the tuyere.

East Penn considers its hydraulic tuyere punch as a state-of-the-art control for blast furnace tuyeres. The Company plans to install hydraulic devices on its eight blast furnace tuyeres by August 1983. Estimated cost is $12,000, which includes materials, fabrication and installation. An appropriate hydraulic system adds about $2000 to overall control costs.

Other controls tested by East Penn include work practice controls such as a glove cleaning station with local exhaust ventilation and a variety of engineered controls applied directly to the tuyere. None of these controls were as effective as the hydraulic punch. Additionally, many proved to be either technically or economically infeasible, and several demonstrated serious maintenance problems.

CONTENTS

Disclaimer ii
Foreword iii
Executive Summary iv
Acknowledgements viii

1.0 Introduction 1
2.0 Discussion and Conclusions 3
3.0 Overview of Smelting and Refining Operations 6
3.1 Raw Materials Handling 6
3.2 Furnace Operation 8
3.2.1 Tuyere Punching 8
3.2.2 Slag Tapping 9
3.2.3 Crude Metal Tapping 9
3.3 Crude Metal Refining 12
3.4 Ingot Casting 12
3.5 Process Emission Controls 12
4.0 Exposure Evaluation 15
4.1 Employee Work Practices 16
4.2 Employee Exposure Measurements 21
4.3 Determination of Emission Sources 26
5.0 Control Evaluation 28
5.1 Hydraulic Tuyere Punch 28
5.1.1 Control Description 28
5.1.2 Design Modifications 29
5.1.3 Exposure Reduction 32
5.1.4 Control Costs 32
5.2 Feasible Exposure Controls 33
5.2.1 Glove Cleaning Station 33
5.2.2 Elevated Platform 35
5.2.3 Pressurized Air Injection with Fiberglass-Silicon Flange 35
5.3 Unsuccessful Exposure Controls 39
5.3.1 Tuyere Vacuum System 39
5.3.2 Hand-held Flange 41
5.3.3 Spring-loaded Tuyere Valve 41
5.3.4 Sliding Gate Tuyere Valve 44
5.3.5 Tuyere Ball Valve 44
6.0 Sampling and Analytical Methods and Results 47
6.1 Area Sampling 47
6.1.1 Methodology 47
6.1.2 Sampling Results 50
6.2 Personal Sampling 51
6.2.1 Methodology 51
6.2.2 Sampling Results 51

LIST OF TABLES

Title		Page
Table 4-1	Furnaceman 8-Hour Time-Weighted Average Exposure Data	15
Table 4-2	Comparison of Furnaceman Breathing Zone Lead Concentrations	25
Table 6-1	East Penn Area Sampling Results	50
Table 6-2	Furnaceman Personal Sampling Results	53

LIST OF FIGURES

Title		Page
Figure 3-1	East Penn Smelter Layout	7
Figure 3-2	Furnaceman Manually Punching Tuyere	10
Figure 3-3	Opening Slag Tap Hole	11
Figure 3-4	Crude Metal Tapping	11
Figure 3-5	Refining Kettle	13
Figure 3-6	Molten Lead Pumped into Casting Machine	13
Figure 4-1	Furnaceman Monitoring Slag Tapping	17
Figure 4-2	Removing Slag Pot from the Smelter	17
Figure 4-3	Removing Crude Metal Blocks from Crucibles	18
Figure 4-4	Schematic Drawing of Blast Furnace Tuyere	19
Figure 4-5	Furnaceman Closing By-Pass Valve	20
Figure 4-6	Furnaceman with Hand over Tuyere Outlet	22
Figure 4-7	Furnaceman Manually Punching Tuyere	22
Figure 4-8	Checking Tuyere Nozzle Clearance through Eyepiece	23
Figure 4-9	Using Sledge Hammer to Insert Tuyere Punching Rod	24
Figure 5-1	Conventional Tuyere	30
Figure 5-2	Hydraulically-Punched Tuyere	30
Figure 5-3	Control Switch for Hydraulic Punch	31
Figure 5-4	Glove Cleaning Station, Showing Brushes Inside	34
Figure 5-5	Glove Cleaning Station Side View, Showing Exhaust Duct	34
Figure 5-6	Elevated Platform Directly Under Blast Furnace Tuyeres	36
Figure 5-7	Furnaceman Punching Tuyeres on Elevated Platform	36
Figure 5-8	Schematic of Tuyere with Pressurized Air Injection	37
Figure 5-9	Conventional Tuyere with Air Hose	38
Figure 5-10	Schematic of Tuyere with Vacuum System	40
Figure 5-11	Schematic of Hand-Held Flange Used During Manual Tuyere Punching	42
Figure 5-12	Schematic of Spring-Loaded Tuyere Valve	43
Figure 5-13	Schematic of Sliding Gate Tuyere Valve	45
Figure 5-14	Schematic of Tuyere Ball Valve	46
Figure 6-1	Location of Area Sampling Points Around Blast Furnace	48
Figure 6-2	Sampling Pump and Filter Cassette	49
Figure 6-3	Dual Pump Personal Sampling Train	52

ACKNOWLEDGEMENTS

Radian Corporation greatly appreciates the cooperation of East Penn Manufacturing Company in conducting this study. Special thanks go to Kenneth Pike, Vice President, Metals Division; Rick Leiby, Smelter Manager; Steve Bergert, Industrial Hygienist; and Steve Puskas, Design Engineer.

1.0 INTRODUCTION

This report describes the results of a study to construct and evaluate the effectiveness of controls for lead emissions from blast furnace tuyeres. A tuyere is a mechanical device through which air or oxygen-enriched air is supplied to the blast furnace to support combustion.

The objectives of the study were to:

- Investigate and characterize the equipment and operation of a tuyere nozzle system.
- Investigate lead emissions associated with tuyere operations, particularly during tuyere punching.
- Design and build tuyere punching emission controls.
- Develop and implement work practice controls which reduce or eliminate tuyere emissions and exposures.
- Evaluate the effectiveness of controls in reducing emissions and exposure.
- Develop technical, cost, and operating information which will be useful to smelter operators interested in reducing or eliminating tuyere punching emissions and exposures.

To conduct this study, Radian made site visits to East Penn Manufacturing Company's secondary lead smelter in Lyon Station, Pennsylvania. Additional technical and cost data were supplied by East Penn personnel.

East Penn considers detailed design specifications for the hydraulic tuyere punching device described in this report as proprietary. However, the Company has agreed to make available technical information and technical assistance on a fee-for-service basis. Persons wishing additional information should contact:

Kenneth Pike
Vice President, Metals Division
East Penn Manufacturing Company
Lyon Station, Pennsylvania 19536
215-682-6361

Radian performed this study for the Division of Physical Sciences and Engineering, National Institute for Occupational Safety and Health. We hope that use of information contained in this report will result in reduced airborne lead exposure to secondary lead industry employees, and more cost-effective implementation of occupational exposure controls.

2.0 DISCUSSION AND CONCLUSIONS

Time-weighted average lead exposures of blast furnace operators in secondary lead smelters are typically high: in some instances they may be greater than ten times the OSHA Permissible Exposure Level (PEL) of 50 $\mu g/m^3$ (29 CFR 1910.1025). Although many emission sources contribute to furnaceman lead exposure, tuyere "punching" (removal of slag accretions from tuyere nozzles) has been considered a major source of exposure by smelter operators and occupational health professionals.

In this demonstration study, Radian characterized tuyere punching as an emission source. Sampling results obtained and observations made during two visits to East Penn Manufacturing's secondary lead smelter documented tuyere punching's contribution to furnaceman exposure.

Personal sampling data collected during this study indicate that tuyere punching may account for as much as 50 percent of a furnaceman's lead exposure. Process conditions and individual employee work habits may influence the extent to which tuyere punching activities affect exposure. However, the nature of these activities is such that high exposure levels may be unavoidable if no controls are employed.

Three emission sources appear to contribute to overall exposure potential presented by tuyere punching. Readings taken with a real-time aerosol counter indicated that fume from the metal punch rod as it is withdrawn from the tuyere may contribute the most to exposure. A second source is clouds of dust entrained by blast air escaping from open tuyeres. Radian observed numerous dust clouds blowing from furnacemen's gloves and from surfaces around the blast furnace. Additionally, smoke sometimes poured from open tuyere outlets, indicating that fume and particulate material from the blast furnace were entering the workplace in streams of escaping blast air.

The most effective control for blast furnace tuyere emissions is one that minimizes or eliminates the flow of blast air from the tuyere outlets during punching. At East Penn, process considerations prohibit diversion of blast air to the baghouse when tuyeres are punched as it is during slag tapping. Such a diversion of air from the furnace could consume as much as 10 minutes per hour, causing a considerable decrease in crude metal production from the furnace.

East Penn has tested a number of control devices which have been applied directly to its blast furnace tuyeres. The most effective of these controls is a hydraulically-powered punching device which remains in the tuyere at all times. In contrast to manual tuyere punching, which requires close employee contact wth blast air from the tuyeres, employee use of the hydraulic punch is limited to activation of the control switch which turns the device on and off.

Because it seals the tuyere outlet during punching, the hydraulic punch effectively eliminates lead exposures from furnace or punch rod emissions or exposure from entrained dust from gloves or surfaces in the furnace area. Use of the hydraulic punch does not adversely impact furnace operating conditions. Additionally, the hydraulic punch is enthusiastically accepted by furnace operators, many of whom say that manual tuyere punching is "a nasty job." East Penn plans to install hydraulic punches on its eight blast furnace tuyeres by August 1983.

Other tuyere controls implemented by East Penn have been much less successful than the hydraulic punch. None controlled tuyere emissions as effectively, and several exhibited severe maintenance and operating problems.

Because East Penn had in place only one hydraulic punch during the course of this demonstration project, Radian could not quantify employee exposure reduction effected by a hydraulic tuyere punching system. Our personal sampling results showed no significant difference in furnaceman lead exposure due to the installation of one hydraulic device.

However, we have concluded from observing the operation of the prototype hydraulic punch that a system of hydraulic devices, applied to all blast furnace tuyeres, should eliminate tuyere punching as a lead emission source. Hydraulically-punched tuyeres are not opened prior to punching; thus no blast air escapes from the tuyeres. Punch rods remain inside the tuyeres and therefore are not sources of high concentrations of lead fume.

Sampling data from this project suggest that eliminating tuyere punching as an emission source should substantially reduce blast furnace operators' exposure to airborne lead. Since many other sources potentially contribute to furnacemen's exposures, implementation of a hydraulic tuyere punching system probably will not be sufficient to reduce exposures below the OSHA PEL. When used in conjunction with other engineering and work practice controls, however, a hydraulic system like the one at East Penn should form an integral part of a comprehensive exposure control program.

3.0 OVERVIEW OF SMELTING AND REFINING OPERATIONS

This section briefly describes process activities associated with secondary lead smelting and refining at East Penn Manufacturing Company. It has been included to familiarize readers with process parameters and thus facilitate understanding of the controls described in Section 5 of this report.

Figure 3-1 shows the layout of the East Penn smelting and refining area. The smelter processes automotive and industrial lead acid batteries and small amounts of lead scrap materials. Produced are hard lead pigs which are used captively by the Company's adjacent battery and cable manufacturing divisions. The smelter operates 24 hours/day, 7 days/week, 46 weeks/year under normal conditions and employs 40 employees who rotate through three eight-hour shifts.

Major process equipment at the smelter includes a 42-inch diameter blast furnace and two refining kettles. Support equipment includes a flue dust agglomeration furnace, battery breaking and separation equipment, baghouses, scrubbers, materials handling equipment and casting machines.

3.1 RAW MATERIALS HANDLING

East Penn uses 90-95 percent SLI (start, light, ignite) batteries and 5-10 percent industrial batteries as blast furnace feed materials. Both are delivered to the plant by truck.

At the time of this demonstration project's initial site visit, scrap SLI batteries were broken by a slow-speed saw in a small building adjacent to the smelter. On our return visit, the SLI battery breaking facility was shut down in preparation for major process and equipment changes scheduled for completion in August 1983. Until then, the smelter is having batteries dismantled by outside breakers.

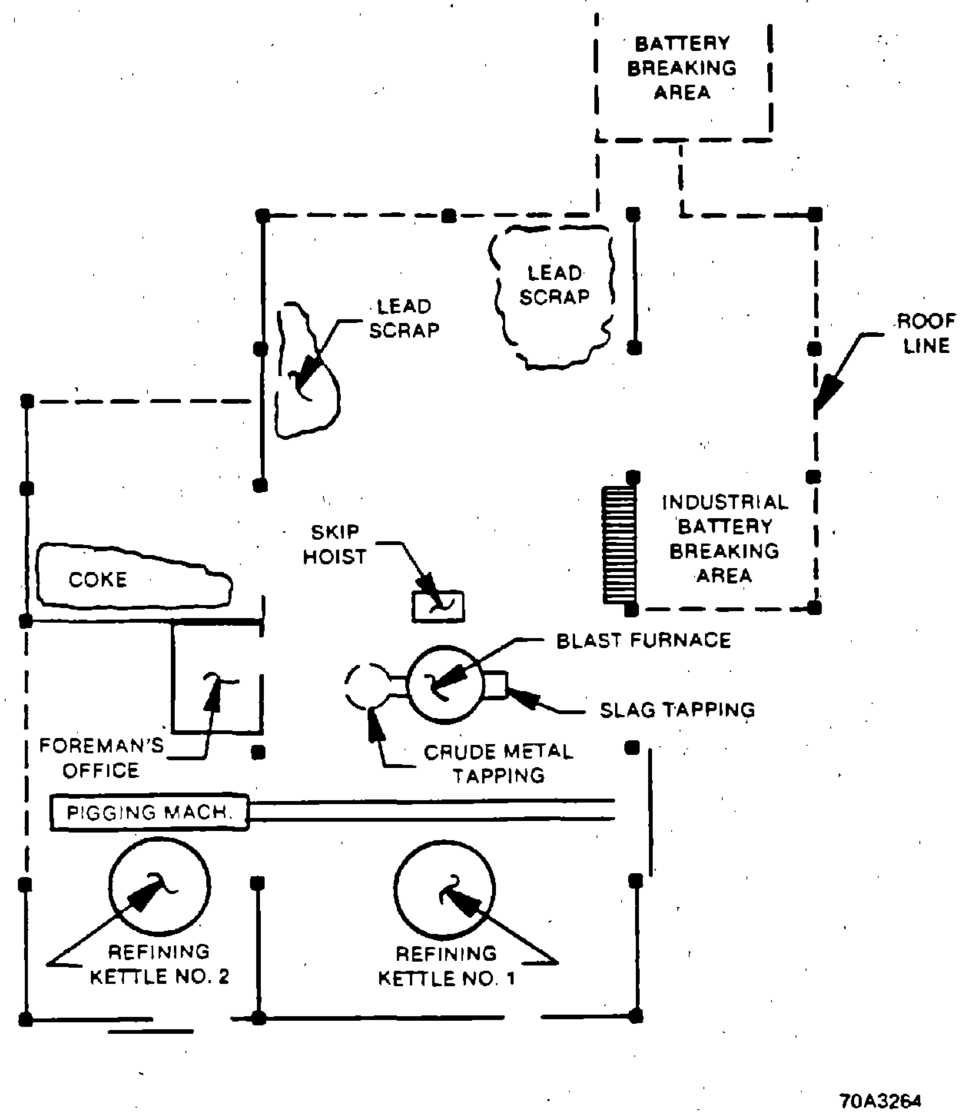


FIGURE 3-1. EAST PENN SMELTER LAYOUT

Industrial batteries are manually broken in an open air work area near the smelter building. Battery groups from both SLI and industrial batteries are stored in an outside storage pile.

3.2 FURNACE OPERATION

The East Penn blast furnace measures 42 inches in diameter and is constructed of steel, water-jacketed and lined with refractory at the top. Charge materials are introduced through access doors in the top of the furnace via a skip hoist. Blast air (design volume 800-950 cubic feet per minute), mixed with an additional two percent oxygen, is introduced through tuyeres located near the furnace crucible.

Charge materials include:

- Scrap batteries
- Battery mud
- Manufacturing scrap
- Dross
- Agglomerated flue dust
- Rerun slag
- Coke
- Limestone
- Iron
- Silica

3.2.1 Tuyere Punching

As smelting progresses, molten lead sinks to a lead well at the bottom of the furnace and is covered by a layer of molten slag. Because blast air is considerably colder than the furnace interior, slag tends to solidify in the tuyere nozzles, thus clogging the tuyeres, restricting the flow of blast air, and inhibiting the smelting process. Slag accretions must be removed by "punching" each tuyere once or twice per hour to restore the flow of blast air and maintain optimium furnace operating conditions.

Blast air is not bypassed during tuyere punching. In manual punching, shown in Figure 3-2, the furnaceman opens the tuyere cap, inserts a steel rod into the tuyere to remove slag accretions, removes the rod, inspects the tuyere nozzle through an eyepiece located in the tuyere, and recaps the tuyere. The process is repeated for each of the furnace's eight tuyeres.

3.2.2 Slag Tapping

Depending on furnace operating conditions, slag is tapped every 45 to 60 minutes. A fire clay plug is removed from the slag tap hole with a steel bar attached to a pneumatic hammer (Figure 3-3). Initially, slag is allowed to flow while blast air is at normal pressure, but as it empties into the slag crucible, tuyere blast air is bypassed and exhausted to the ventilation baghouse. When slag tapping is completed, blast air is restored to the furnace.

3.2.3 Crude Metal Tapping

Crude metal is continuously tapped from the blast furnace into one-ton crucibles located on a revolving carousel (Figure 3-4). Steel lifting handles are inserted into each crucible before the metal solidifies. Solifified blocks of crude lead are lifted from the crucibles with an overhead monorail hoist and stockpiled near the blast furnace until they are sent to the refining kettles.

The East Penn blast furnace had the capacity to produce 65 tons of crude lead per 24-hour day at the time this demonstration project was conducted.

FIGURE 3-2. FURNACEMAN MANUALLY PUNCHING TUYERE

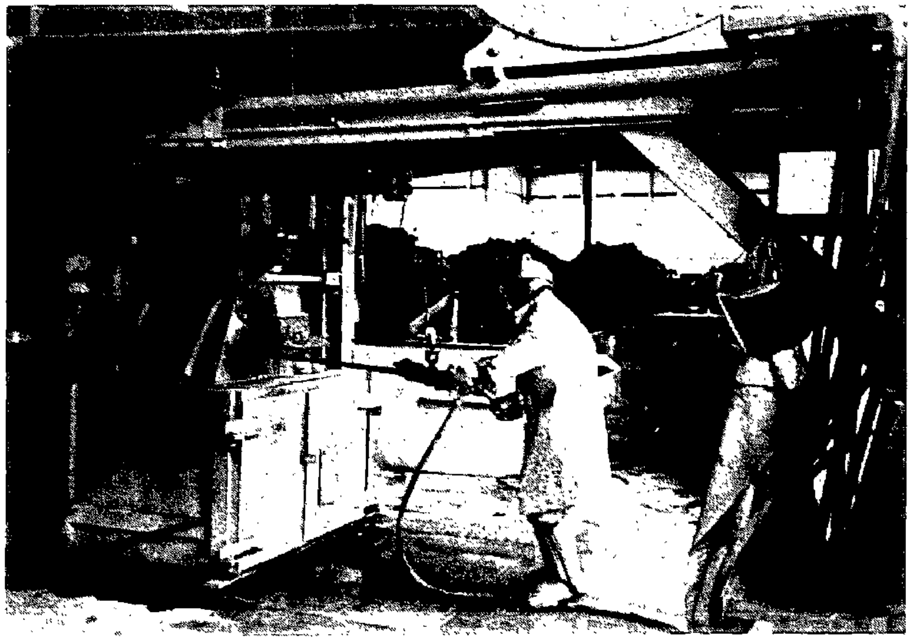


FIGURE 3-3. OPENING SLAG TAP HOLE

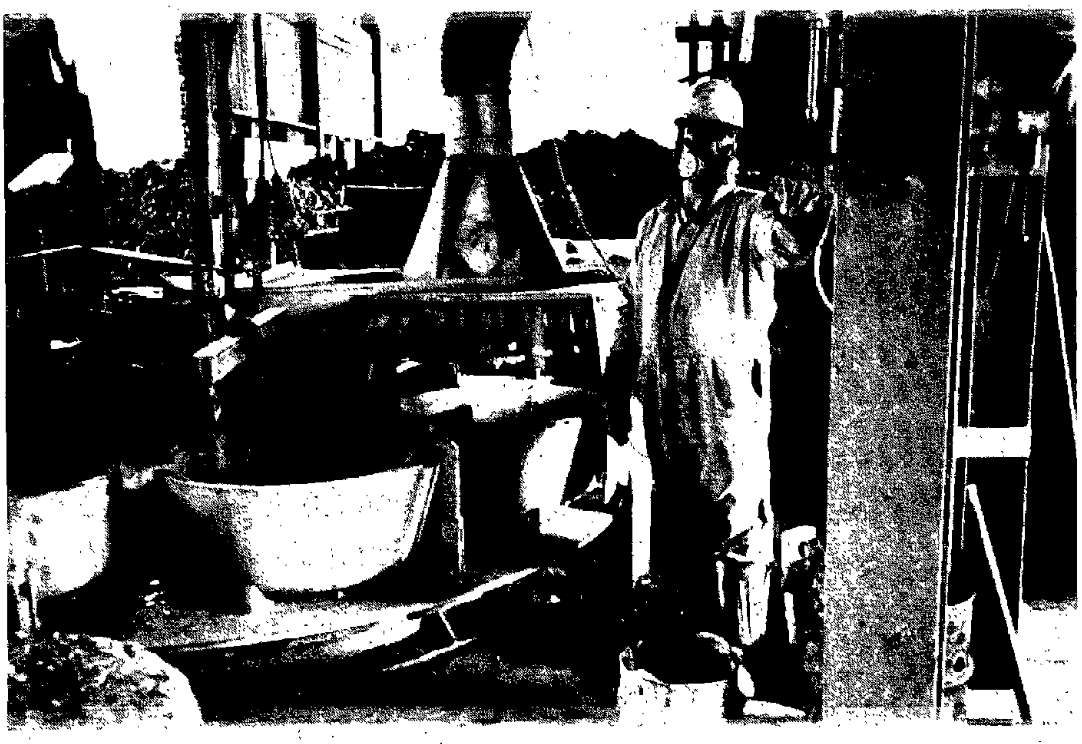


FIGURE 3-4. CRUDE METAL TAPPING

3.3 CRUDE METAL REFINING

The smelter has two 30-ton refining kettles (Figure 3-5) which operate on a staggered schedule to produce 23 to 25 tons each of finished lead. Crude lead blocks are placed in the kettles, melted, and stirred with a mechanical stirring device lowered into the molten metal. Refining agents are manually added and stirred into the melt.

Dross is manually skimmed from the top of the melt and deposited in "pies" on steel pallets. After skimming is complete and desired alloying agents are added, the melt is allowed to cool until pumped to the casting machine.

3.4 INGOT CASTING

Ingots or pigs are cast in a mobile machine which moves between the two refining kettles on metal tracks. Molten lead is pumped from the refining kettles through a preheated pipe to the preheated casting machine reservoir, as shown in Figure 3-6. From the reservoir, it is poured into water-cooled molds which are mechanically advanced along the length of the casting machine. Cooled pigs are ejected from the molds and manually stacked in piles. Pig stacks are removed from the smelter by forklift.

3.5 PROCESS EMISSION CONTROLS

Extensive process emission control systems have been installed at East Penn since 1979. Exhaust ventilation hoods are provided at the bottom and the top of the skip hoist, over the blast furnace charging doors and over the furnace access doors. Slag tapping emissions are controlled by a local exhaust enclosure. Local exhaust ventilation also is provided for the crude metal tapping area, over each of the refining kettles, and over the casting line.

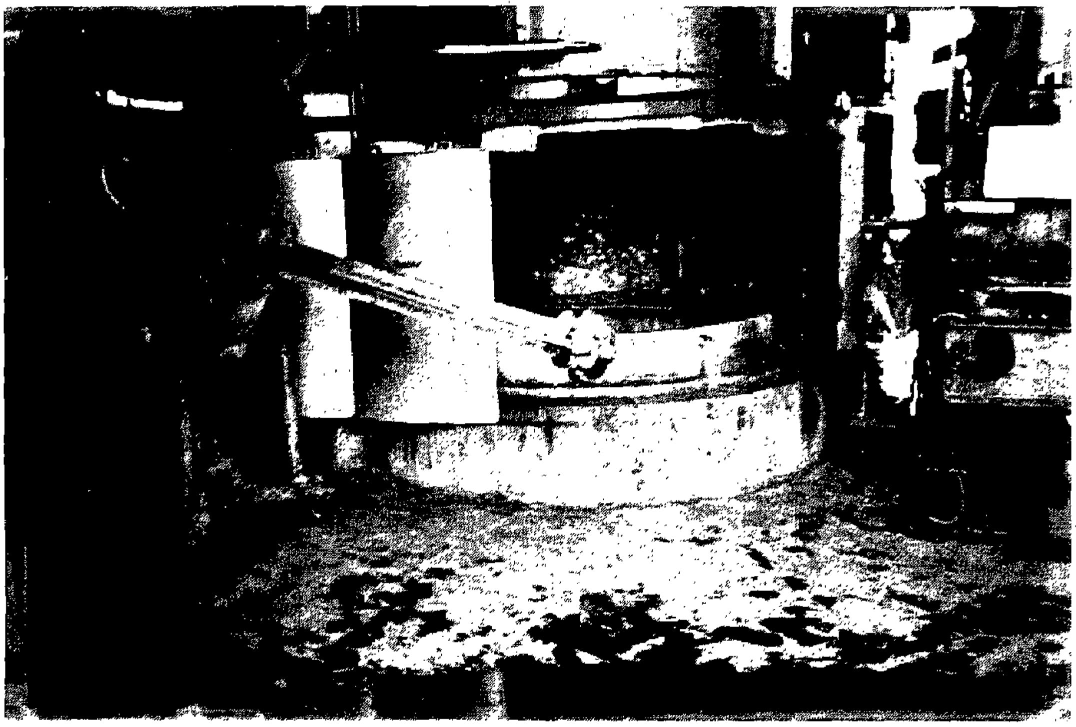


FIGURE 3-5. REFINING KETTLE

FIGURE 3-6. MOLTEN LEAD PUMPED INTO CASTING MACHINE

235<

The emissions captured in the above exhaust systems are treated for particulate removal in two baghouse systems. The slag tapping baghouse controls emissions from the slag tapping hood. The sanitary baghouse serves the skip hoist hoods, the blast furnace charging door and access door, crude metal tapping, refining kettle, and pigging machine hoods. Hot blast furnace off-gas is treated in a third air cleaning system for process gas.

4.0 EXPOSURE EVALUATION

One of the major objectives of this demonstration project was to investigate and characterize lead emissions associated with manual tuyere punching activities. Data collected by East Penn and Radian indicated that furnacemen's eight-hour time-weighted average (TWA) lead exposures (shown in Table 4-1) were high.

TABLE 4-1. FURNACEMAN 8-HOUR TIME-WEIGHTED AVERAGE EXPOSURE DATA

Date	Data Source	8-Hr. TWA (μg/m3)
2/16/82	East Penn	488
3/19/82	East Penn	342
3/19/82	East Penn	1391
3/28/82	East Penn	1423
3/28/82	East Penn	837
4/28/82	East Penn	665
7/26/82	East Penn	314
7/26/82	East Penn	379
9/28/82	Radian	435
3/01/83	Radian	699

However, little information was available about the extent to which manual tuyere punching activities contributed to employees' overall time-weighted average lead exposures.

Smelter operators contacted by Radian indicated that they perceived tuyere punching as accompanied by high lead exposures, but none had data to support this assumption. Additionally, the sources of lead emissions (e.g. fume from the furnace mixing with tuyere air) were not known.

This section presents the results of Radian's attempts to document employee work practices and characterize emissions from tuyere punching activities at East Penn Manufacturing. Sampling and analytical methods used to generate these results are described in detail in Section 6.

4.1 EMPLOYEE WORK PRACTICES

Three employees per shift are responsible for blast furnace operation at East Penn. These employees rotate through three jobs (furnaceman, hoistman, and payloader operator), performing each job every fourth working day. The furnaceman monitors slag levels, initiates slag tapping operations (Figure 4-1), removes solidified slag from the smelter (Figure 4-2), and punches tuyeres. The hoistman monitors crude metal tapping operations, is responsible for loading and unloading crucibles from the metal tapping carousel (Figure 4-3), and if necessary, assists the furnaceman in punching tuyeres. The payloader operator, responsible for furnace charging activities, is not involved in tuyere punching activities.

A schematic diagram of a blast furnace tuyere is shown in Figure 4-4. Tuyeres at East Penn are punched at least as often as slag is tapped (every 45 to 60 minutes). If furnace conditions result in rapid buildup of slag accretions in the tuyere nozzles, the tuyeres are punched more frequently.

At East Penn, the tuyere air bypass valve remains closed during tuyere punching, as shown in Figure 4-5. Thus, a stream of blast air escapes through the tuyere outlet each time it is opened. East Penn management indicated that production losses would occur if blast air is bypassed each time tuyere punching occurs.

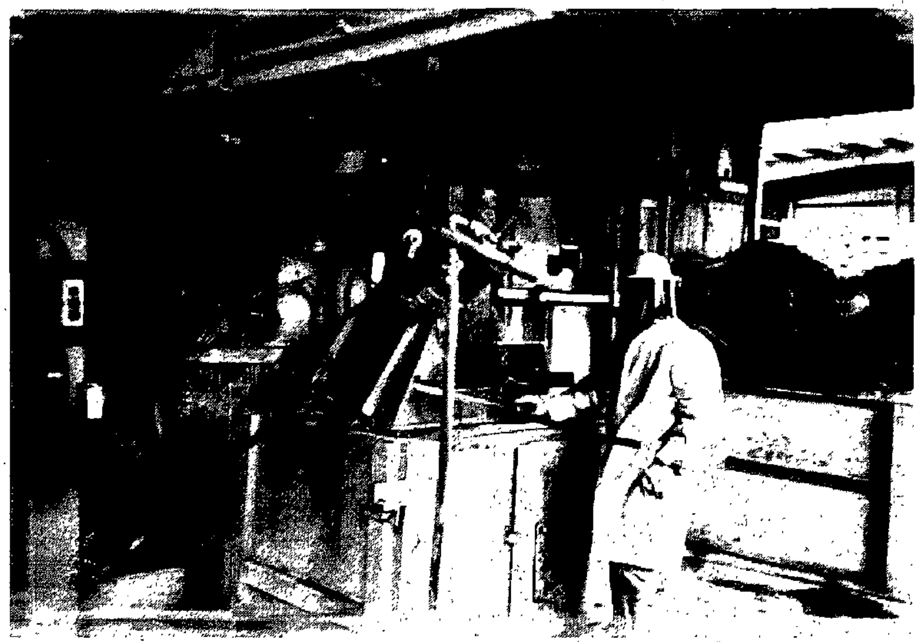


FIGURE 4-1. FURNACEMAN MONITORING SLAG TAPPING

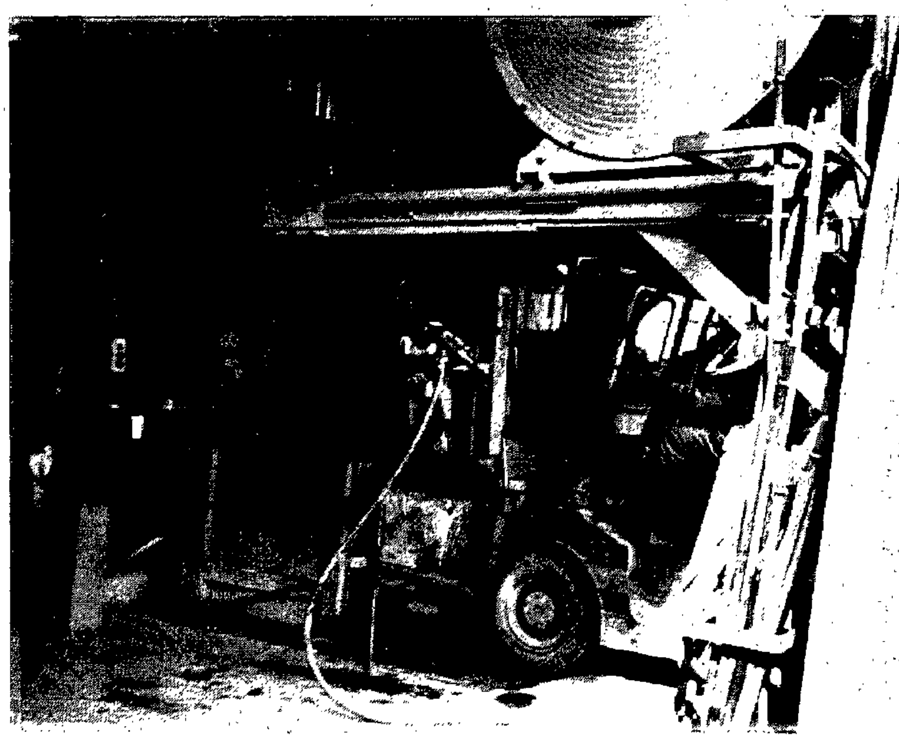


FIGURE 4-2. REMOVING SLAG POT FROM THE SMELTER

FIGURE 4-3. REMOVING CRUDE METAL BLOCKS FROM CRUCIBLES