

# **DEMONSTRATIONS OF CONTROL TECHNOLOGY FOR SECONDARY LEAD REPROCESSING**

**Final Report  
Volume One  
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**



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FINAL REPORT

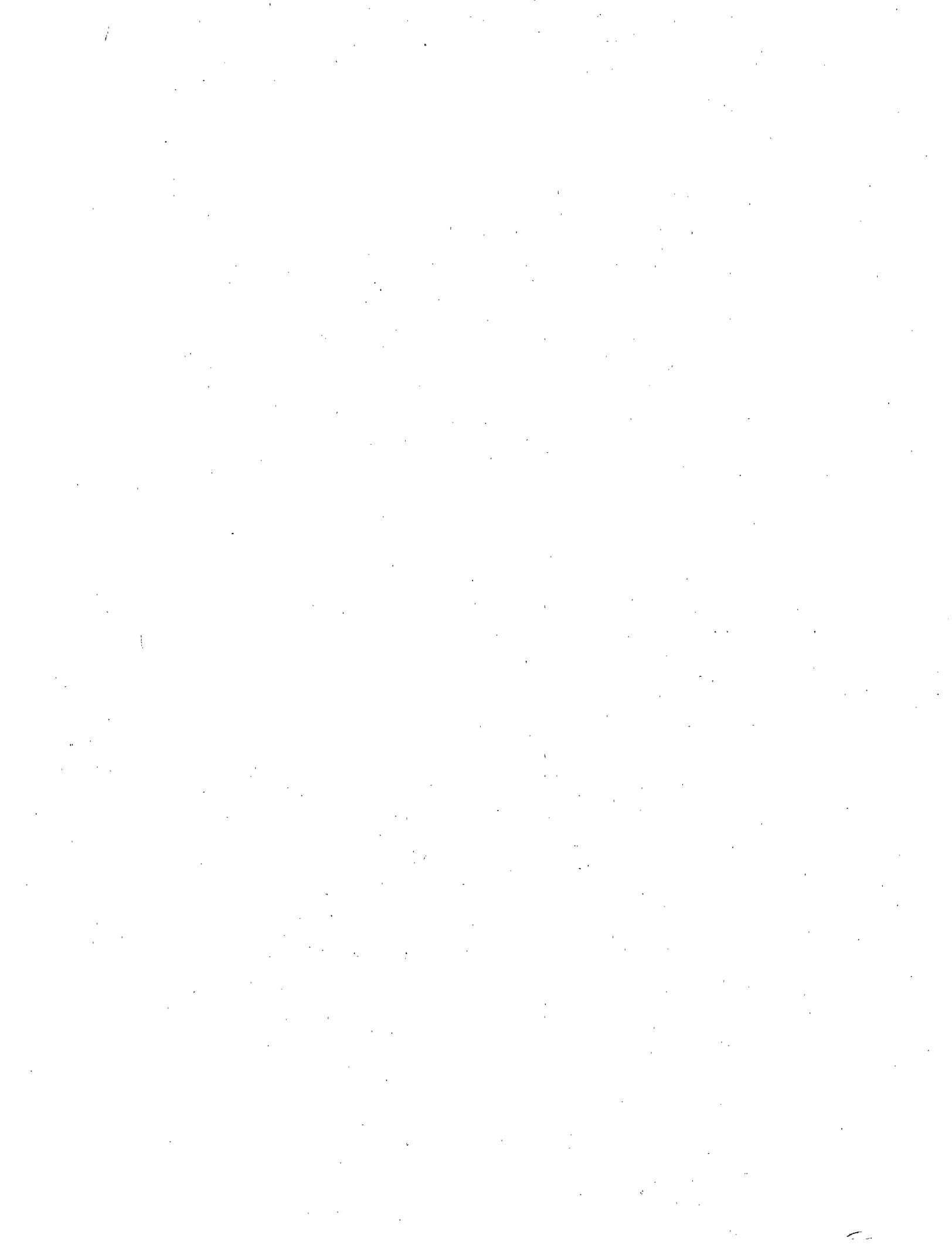
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LEAD REPROCESSING

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VOLUME ONE

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## FOREWORD

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

One of the hazards considered for evaluation and control is lead exposure in the secondary lead smelting industry. NIOSH therefore contracted with Radian Corporation to perform a project to demonstrate emission and exposure controls at secondary lead smelters.

This Final Report presents findings of the various demonstration projects.

## ACKNOWLEDGEMENTS

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## GLOSSARY OF TERMS

Agglomerating Furnace- A furnace which forms a coherent bonded mass from metallic compounds without melting them.

Air Quality- The composition of air with respect to quantities of pollutants; used most frequently in connection with "standards" of maximum acceptable pollutant concentrations.

Ambient Air- The air of the surrounding environment; outdoor air.

Blast Furnace- A tall, refractory-lined shaft furnace using the counter-current flow principle. Raw materials are charged at the top. The air blast introduced at the bottom burns coke to reduce and melt the charge as it descends. Molten metal and slag are tapped at the bottom.

Casting- Pouring molten metal into a previously prepared mold where it solidifies into the shape of the mold.

Charging- The process of placing materials in furnaces and ovens for heating or melting.

Cupola- A refractory-lined vertical cylinder open at the top and equipped with air ports (known as tuyeres) at the bottom. A coke bed at the bottom is covered with alternating layers of metal, coke, and flux. Molten metal is drawn off the bottom. The tube is air charged at the side.

Dilution Ventilation- Also, General Ventilation- Dilution ventilation occurs when industrial contaminants which are released into the worker's environment are mixed with air flowing through the space. Dilution ventilation refers to both natural and mechanically-induced air movement.

Dross- Metal oxides in or on molten metal.

Emission- The discharge or release of pollutants into the air.

Emission Factor- The discharge into the open air of a specific weight of material per unit weight of total raw material processed or per unit weight of product.

Emissions Inventory- A list of air pollutant sources and the amounts of pollutant emitted.

Engineering Control- An engineering method used to reduce or eliminate emissions of a toxic chemical substance or harmful physical agent into the workplace. Examples include:

- (1) Process enclosure

- (2) Isolation of a process or worker
- (3) Shielding
- (4) Local exhaust ventilation
- (5) Process modification

Flue- An enclosed passageway for gases.

Flue Dust- An accumulation of small particles of furnace materials, such as lead oxide and dust, which escape with off-gases and collect along the flue. The term may be applied to any collection of dust in flues or separators, e.g. cyclones, baghouses, etc.

Fumes- Particulate matter consisting of the solid particles generated by condensation from the gaseous state, generally after volatilization from melted substances, and often accompanied by a chemical reaction, such as oxidation.

Fugitive Emission- Nonconfined or non-ducted emissions of a material into the open air.

Hydrometallurgy- Treatment of metals and metal-containing materials by wet processes.

Hygiene Facilities- Facilities provided to employees for the purpose of minimizing personal hygiene-related exposures. These may include lockers, locker rooms, showers, wash basins, hand and face cleaners, disposable towels, separate change rooms and storage for street and work clothing.

Industrial Hygiene- The science associated with the recognition, evaluation and control of chemical and physical hazards in the workplace.

Ingot- A large rectangular shaped piece of metal produced by pouring molten metal into an ingot mold and allowing it to freeze or solidify. Ingots upon solidification form special kinds of castings for subsequent rolling, extrusion, or melting.

Ladle- A large vessel for receiving and handling molten metal and slag.

Local Exhaust Ventilation- Local exhaust ventilation systems capture or contain industrial contaminants at the source before they reach the occupational or ambient environment. A local exhaust ventilation system typically includes a capture hood, ductwork, a contaminant separator, and an air mover.

Make-up Ventilation- Air introduced to the plant environment to replace air removed for control purposes. Also, Replacement Air.

Matte- An impure metallic sulfide mixture resulting from smelting copper, nickel, or lead.

Particulates- Any solid or liquid particles suspended in or falling throughout the atmosphere.

Pig- A crude casting of lead.

Pig Casting Machine- A machine containing a series of molds of convenient size arranged to form an endless chain. Into these molds the molten lead is poured, solidified, and discast as pig blocks.

Plume- The volume of air space containing any of the substances emitted from a point source.

Point Source- Confined or ducted emissions of a material into the open air.

Potentially Exposed- Employees who have the potential of being exposed to a chemical or physical hazard.

Primary Lead- Primary lead refers to lead which is produced from ores and concentrates.

Pyrometallurgical- Pertaining to high-temperature process metallurgy.

Re-entrainment- The resuspension of materials previously emitted and settled.

Refining- The operation of purifying crude metals.

Replacement Air- See Make-up Ventilation.

Respirable- Particles with an equivalent aerodynamic diameter of 1-10 microns; particles which have the capability of reaching the alveolar regions of the lung.

Retrofitted- The process of applying additional equipment or controls to existing equipment.

Reverberatory furnace- A shallow, generally horizontal and rectangular furnace with a low, arched, refractory-lined roof. Fuel combustion occurs directly over the bath; the walls and roof receive radiant heat from hot combustion products and radiate this heat to bath surfaces.

Rotary furnace- A revolving tube constructed and operated essentially like a reverberatory furnace.

Secondary Lead- Lead which is obtained as a result of recycled lead materials, such as through scrap dealers.

Sintering- Forming a coherent bonded mass by heating metal powders without melting.

Slag- The waste material formed during smelting operations.

Smelting- Process by which molten metal is produced by reduction of concentrates or scrap materials.

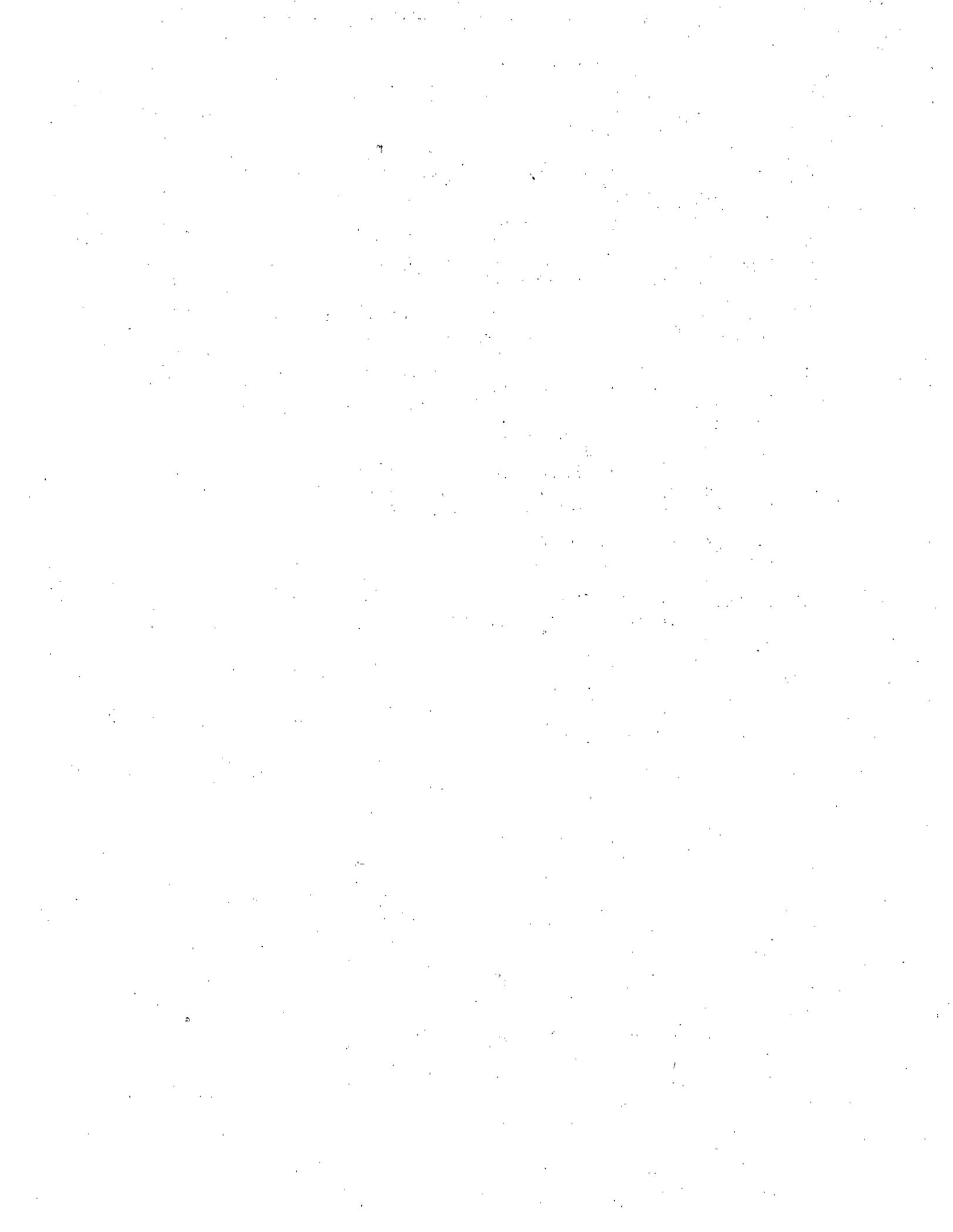
Speiss- A pyrometallurgical product containing arsenides, antimonides and copper.

Sweating Furnace- A relatively low temperature, carefully controlled, reverberatory furnace, rotary furnace or sweating tube. Temperatures are controlled just above the melting point of lead.

Tapping- The act of drawing off molten metal or slag from a furnace. It consists primarily of mechanically digging or burning the plugged tap hole open and allowing the molten metal or slag to flow freely into a receiving container.

Tuyere- An opening in the shell and refractory lining of a furnace through which air is forced.

Tuyere Punching- Cleaning the tuyere, usually a hand operation using a steel punching rod.



## 1.0 INTRODUCTION

In 1980, the U.S. Department of the Interior reported that about half of all the lead consumed in the United States was recovered from secondary sources. While playing an important role in the Country's supply of lead, the secondary lead smelting industry has the problem of exposure of employees to inorganic lead.

Two recent government regulations, OSHA's Inorganic Lead Standard and EPA's Ambient Lead Standard, have generated considerable interest in the technology required to further reduce emissions and exposures.

At the time OSHA proposed lowering its Permissible Exposure Limit (PEL) for lead to  $50 \text{ ug/m}^3$ , few if any secondary lead smelters were in compliance with the existing  $200 \text{ ug/m}^3$  standard. Because of this, OSHA granted the secondary lead smelting industry five years to come into compliance with the new PEL through use of engineering, work practice and administrative controls. Secondary smelting involves three major process phases: scrap handling/treatment, furnace smelting, and refining/casting. Each of these phases has numerous emissions sources which contribute to employee exposure. It was generally recognized that if compliance with the new PEL was to be achieved, each emission source would have to be evaluated and control methods developed. The National Institute for Occupational Safety and Health (NIOSH) determined it would be appropriate to assist with the research necessary to evaluate emissions and exposures, and demonstrate new control methods. In 1981, NIOSH awarded a contract to Radian to conduct ten projects which would demonstrate new control technology or evaluate the feasibility of emerging control methods.

Volume I of this report provides a summary of the findings of the various projects and technical reports for four demonstration projects. Volume II provides technical reports for six completed demonstration projects.

### 1.1 Objective

The objective of this project was to demonstrate potentially transferable control technology which would reduce employee exposure to lead. Demonstration projects were chosen which met one or more of the standard approaches to exposure reduction: emission control, isolation, enclosure, path interruption, work practices, or administrative controls. About half of the projects evaluated new controls already in place, e.g., vacuum cleaners and battery shredding. Many of the projects were designed and built for this study, e.g. supplied-air islands and tuyere punching controls.

As would be expected, demonstration projects report both positive and negative results. However, all of the reported information should be useful to smelter operators. Radian has concentrated its efforts in describing the operation, the control equipment, and other matters which relate directly to the question each smelter operator will ask: "Can I adapt this control to my own operation?"

In most of the projects, substantial reductions in emissions and exposures have been reported. However, in most cases, strict compliance (i.e., eight-hour, time-weighted average exposures below  $50 \mu\text{g}/\text{m}^3$ ) has not been achieved. This is due to the following factors: (1) multiple emission sources contribute to exposure, and (2) demonstration projects typically concentrated on the evaluation and control of individual emission sources, not on the evaluation and control of all emission sources contributing to a single person's exposure.

## 1.2 Overview of the Secondary Smelting Industry

In July, 1983, there were about 50 secondary lead smelters in the United States. Figure 1 shows their geographical distribution. Table 1 presents a list of smelter operators. Figure 2 shows operations found in a typical smelter. While similar basic pyrometallurgical operations are used in the industry, many differences exist between plants. For example, all smelters dismantle batteries, but some break batteries with hammermills, some with saws, and some with shredders.

## 1.3 New Technology Prospects

Although the number of secondary smelters has been reduced during the past five years, new smelters have been built in Missouri, Oregon, and California. Most surviving smelters have undergone major remodeling. Furthermore, several new smelters are in the design stage and most existing smelters anticipate further rebuilding.

From conversations with members of SLSA, Radian has concluded that radical new process technology is not expected to be developed in the near future. Existing and new smelters will continue to employ blast/reverb furnace combinations, although rotary/kiln furnaces may also be employed. The industry can expect to see new developments in individual support operations and emission/exposure control equipment. This project for example, describes several major advances in control technology.

## 1.4 Overview of the OSHA Lead Standard

Secondary smelters must conform to OSHA requirements found in 29 CFR 1910.1025 (Inorganic Lead). Exposure control is not limited to simply reducing emission, but must include other

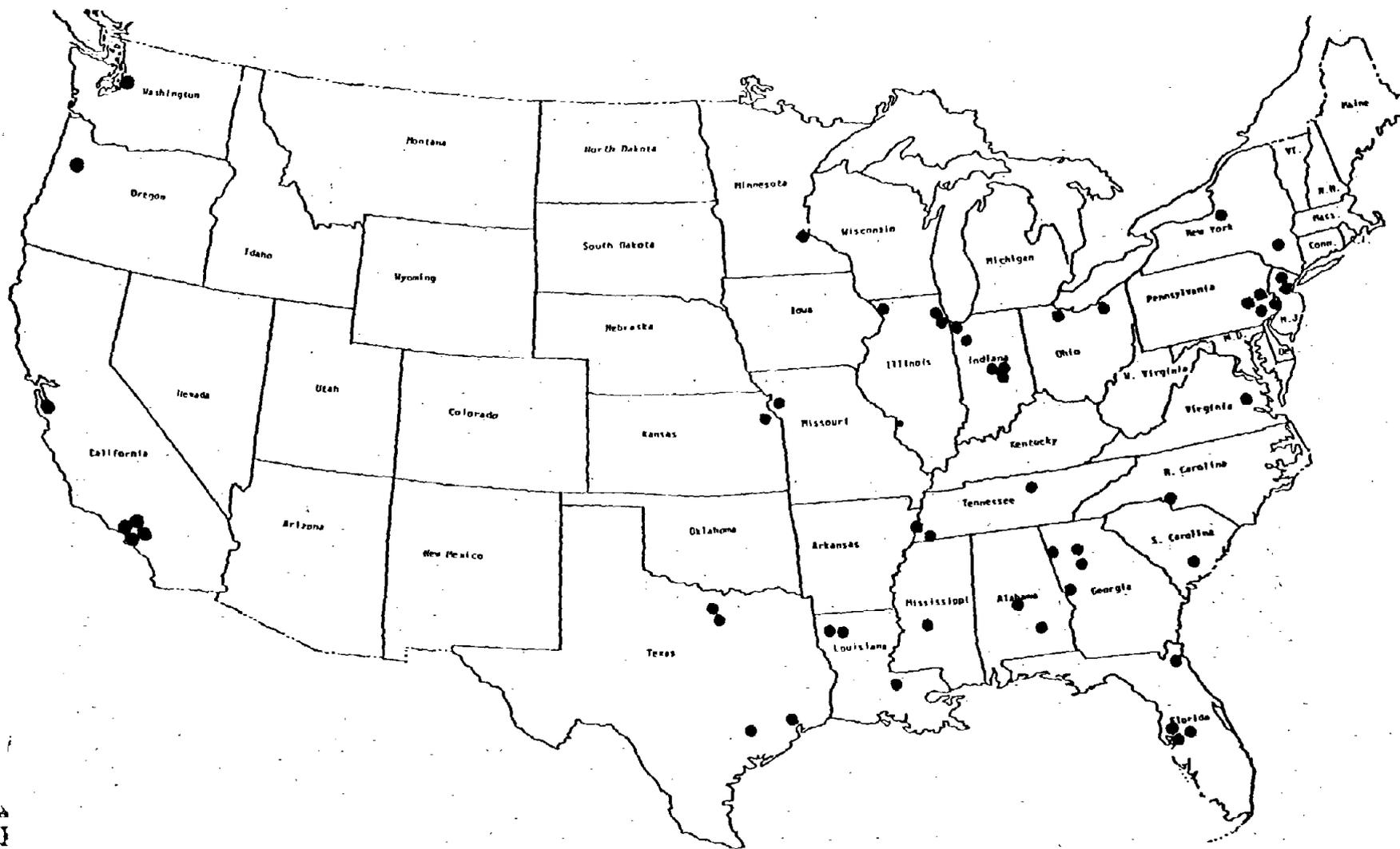


FIGURE 1. SECONDARY LEAD SMELTERS IN THE U.S.A.

Source: Radian Telephone Survey

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| Company                     | No. of Smelters | City/State   | Company                | No. of Smelters | City/State   |
|-----------------------------|-----------------|--|------------------------|-----------------|--|
| GNB Battery Inc.            | 2               | Frisco, Texas<br>Vernon, California                                  | ALCO Pacific           | 1               | Gardena, California  |
| ASARCO, Inc.                | 2               | Salt Lake City, Utah   | Hammond Lead           | 1               | Hammond, Indiana   |
| RSR, Inc.                   | 3               | Seattle, Washington<br>Dallas, Texas<br>City of Industry, California | Globe-Union            | 1               | Tampa, Florida   |
| ESB, Inc.                   | 1               | Memphis, Tennessee   | General Smelting       | 1               | College Grove, Tennessee   |
| Interstate Lead             | 2               | Jeeds, Alabama<br>Cedartown, Georgia                                 | Inland Metals          | 1               | Chicago, Illinois  |
| Chloride Metals             | 1               | Tampa, Florida   | Houston Lead           | 1               | Houston, Texas   |
| Tara Corporation            | 2               | McCook, Illinois   | Standard Industries    | 1               | San Antonio, Texas   |
| Master Metals               | 1               | Cleveland, Ohio  | Lancaster Battery      | 1               | Lancaster, Pennsylvania  |
| UN National Smelting        | 2               | Pedricktown, New Jersey<br>Atlanta, Georgia                          | ALPHA Metals           | 1               | Jersey City, New Jersey  |
| Schuylkill Metals           | 2               | Baton Rouge, Louisiana<br>Forest City, Missouri                      | DELCO Remy             | 3               | New Brunswick, New Jersey<br>Andersen, Indiana<br>Olathe, Kansas |
| East Penn Manufacturing Co. | 1               | Lyon Station, Pennsylvania   | Roth Brothers Smelting | 1               | E. Syracuse, New York  |
| Hyman Veiner & Sons         | 1               | Richmond, Virginia   | Imperial Metals        | 1               | Philadelphia, Pennsylvania                                       |
| Seitzinger, Inc.            | 1               | Atlanta, Georgia   | Bergsöe-Bollidén       | 1               | Muncie, Indiana  |
| Gulf Coast Lead Company     | 1               | Tampa, Florida   | USS Lead               | 1               | E. Chicago, Indiana  |
| Willard Lead Products       | 1               | Charlotte, North Carolina  | Sanders Lead           | 1               | Troy, Alabama  |
| Ross Metals                 | 1               | Rossville, Tennessee   | Prestolite Battery     | 1               | Vincennes, Indiana   |
| Gopher Lead                 | 1               | Eagan, Minnesota   | General Battery Corp.  | 2               | Reading, Pennsylvania<br>Dallas, Texas                           |
| Bergsöe Metals              | 1               | St. Helene, Oregon   | Tonolli Corporation    | 1               | Nesquehoning, Pennsylvania                                       |
|                             |                 |  | Cal-West Metals        | 1               | Long Beach, California   |

See Appendix for complete mailing list.

TABLE 1. SECONDARY SMELTER OPERATORS (JULY, 1983)

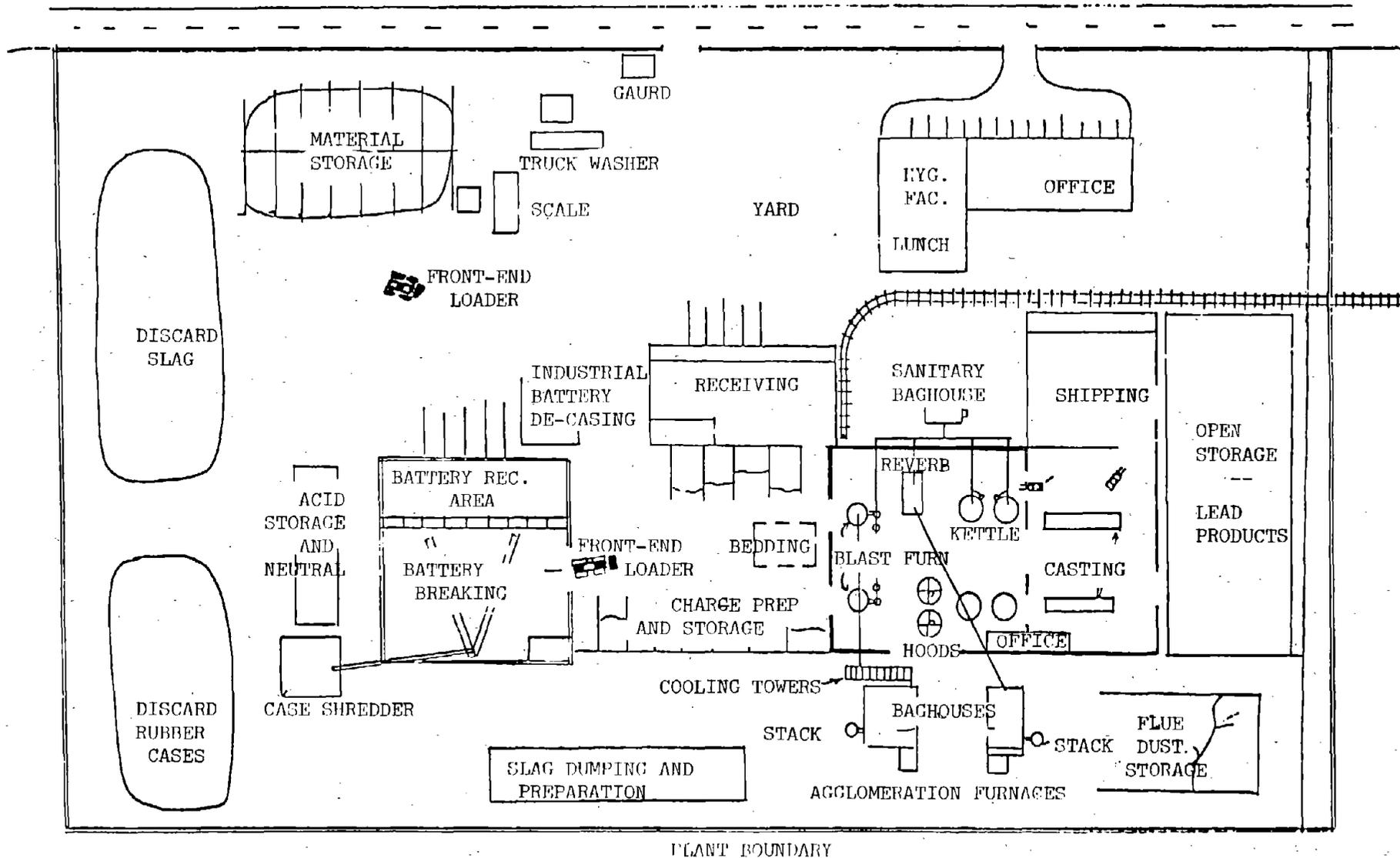


FIGURE 2. TYPICAL SECONDARY LEAD SMELTER

efforts such as preventing employee ingestion of lead, improving housekeeping, providing adequate maintenance, and reducing re-entrainment of settled lead dusts.

In June, 1983, OSHA announced that most major provisions of the standard would remain essentially unchanged, but that compliance activities would be negotiated at a local level reflecting process needs and technological/financial feasibility considerations. Because of the continuing uncertainty, designers should check on the issues surrounding the current status of the standard at the time controls are designed.

As presently written, the lead standard establishes the following requirements related to exposure control in the secondary lead smelter:

- Permissible Exposure Limit (PEL) - The employer must assure that no employee is exposed to airborne lead levels in excess of 50 ug/m<sup>3</sup>, expressed as an 8-hour time-weighted average.
- Exposure Monitoring - Routine monitoring is required for almost all areas of the lead smelter. Monitoring is required with any change in production, process, or control.
- Methods of Compliance - The employer is required to attempt compliance through engineering and work practice controls and must provide respiratory protection where these controls do not reduce exposures to below the PEL.
- Protective Clothing and Equipment - The employer must provide protective gear for all employees exposed above the PEL and is responsible for collecting and cleaning all such gear.

- Housekeeping - All surfaces must be maintained free of lead accumulation. Preferred methods are vacuum cleaning and water washdown. Dry sweeping and shoveling are discouraged.
- Hygiene Facilities and Practices - No food, beverage, or tobacco products may be present or consumed in the workplace. This implies separate facilities for such activities. The employer must provide dual change rooms and lunchrooms. These facilities should have clean, positive-pressure air supplies.
- Medical Removal - The employer must provide for the temporary removal of employees from lead exposure as a result of elevated blood leads or medical findings. This implies providing clean, non-contaminated facilities to which persons may be relocated.
- Employee Information and Training - The employer must advise employees of potential exposure to lead at any level.

#### 1.5 Feasibility of Compliance at Existing Facilities

Table 2 summarizes data representative of employee exposures at the time the OSHA standard was promulgated. Since that time, substantial reductions in exposure have occurred, but a sustained control development effort will be required if compliance with the 50 ug/m<sup>3</sup> standard is to be achieved. Radian's experience with regards to the feasibility of reaching this goal is summarized in the following paragraphs.

- Technological and financial feasibility issues are closely related.
- Any exposure limit is theoretically feasible if no time and money constraints exist.
- As of 1983, all secondary smelters had some operations in compliance; similarly, all had operations out of compliance.
- Lead exposure levels can be lowered at most operations in every plant.
- Exposure levels at similar operations vary from plant to plant; controls required to reduce exposures will likewise vary.
- Current research is expanding the knowledge and availability of emission/exposure controls.
- Regardless of air-exposures, employees will be required to use some type of "respirator" for protection against ingestion and unexpected upsets or emission excursions. (See Reference (m), "Administrative Controls and Management Practices Used to Minimize Lead Inhalation and Ingestion in Japan.")

TABLE 2. EXPOSURE LEVELS\* IN SECONDARY  
LEAD SMELTERS

| Smelter<br>Operation   | Lead-in-Air Measurements ( $\mu\text{g}/\text{m}^3$ ) |         |
|------------------------|---|---------|
|                        | Mean  | Maximum |
| Furnace Room           | 1760  | 6500    |
| Kettle Area            | 850   | 2900    |
| Castings               | 90  | 140     |
| Wire                   | 100   | 600     |
| Magnesium              | 30  | 30      |
| Brass Department       | 170   | 760     |
| White Metals           | 120   | 250     |
| Shops                  | 20  | 50      |
| Yard                   | 130   | 150     |
| Dross Area             | 1130  | 2840    |
| Maintenance            | --  | 5300    |
| Equipment              | --  | 8000    |
| Lab                    | --  | 190     |
| Shipping and Receiving | --  | 500     |
| Scrap                  | --  | 800     |

\* Represents Data from Five Plants in the Late 1970's.

Source: Submission No. 26 to OSHA Docket #H004.

## 2.0 MAJOR CLASSES OF CONTROL

This section discusses basic approaches to emission/exposure control which may find applicability in all lead smelting facilities.

### 2.1 Source Characterization

Exposure occurs when there is a source of lead. Sources may include process emissions, fugitive emissions, secondary emissions from vibrating surfaces, wind re-entrainment, clothing or skin contamination, and so forth.

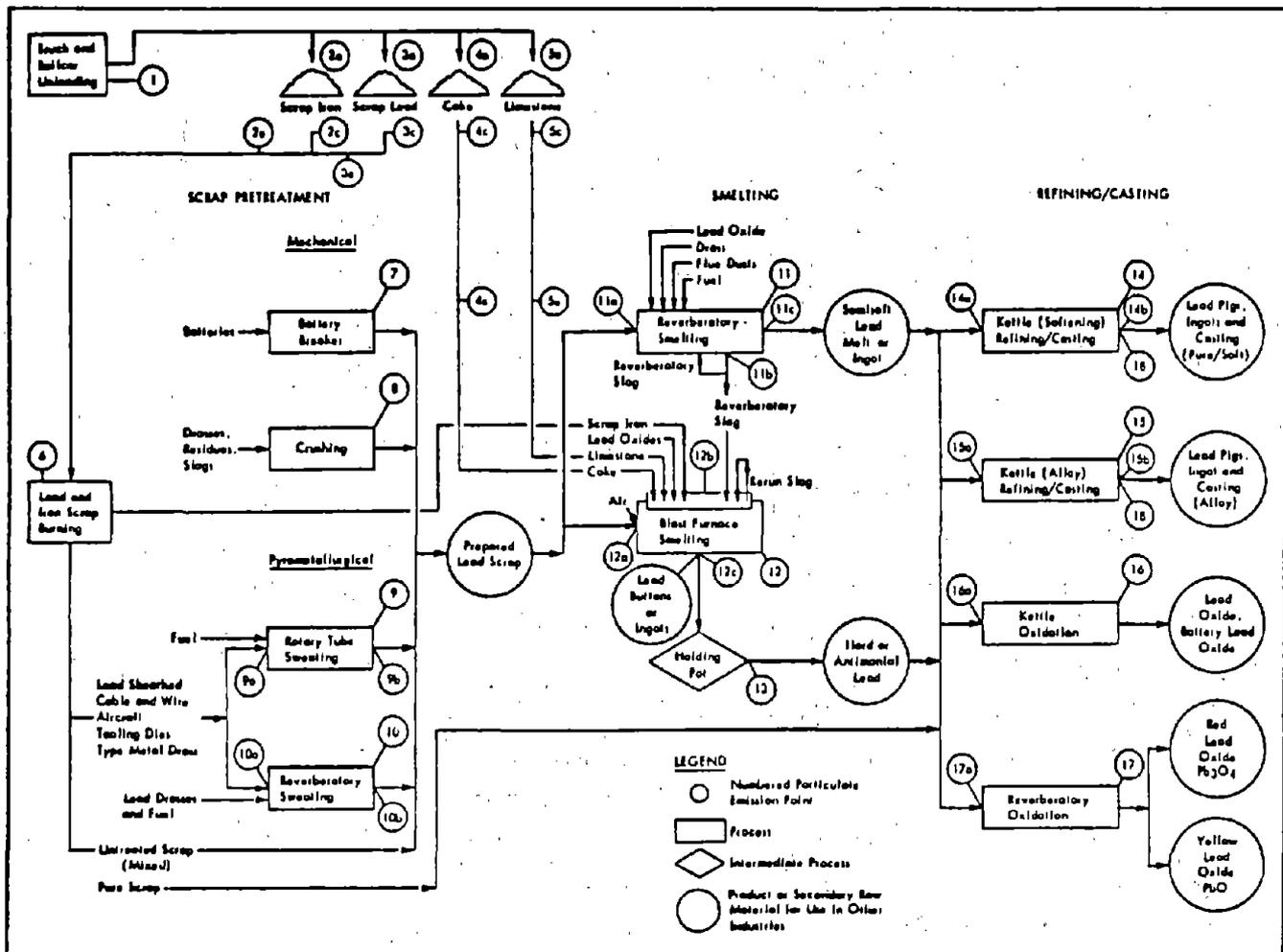
Exposure control should begin with source identification and characterization. It is generally accepted that all emission sources of lead must be identified and controlled to some extent if compliance with a 50 ug/m<sup>3</sup> standard is to be achieved. A typical emission characterization worksheet used to evaluate emission sources is included in the Appendix.

Figure 3 and Table 3 present information related to fugitive emission sources and emission factors. Emission factor estimates are general in nature. They should only be used to prioritize initial characterization efforts.

### 2.2 Control Approaches

The following general approaches are appropriate for new plants or major renovation of existing facilities:

- Isolate and enclose operations. Segregating various operations isolates major emission sources, makes emission characterization easier, enables the use of employee-specific controls, and



Description of Emission Source

- |   |  |   |
|---|--|---|
| <p>1. Truck and railcar unloading</p> <ul style="list-style-type: none"> <li>a. Coke</li> <li>b. Limestone</li> <li>c. Lead scrap</li> <li>d. Iron scrap</li> </ul> <p>2. Scrap iron</p> <ul style="list-style-type: none"> <li>a. Loading onto pile</li> <li>b. Vehicular traffic</li> <li>c. Load-out operations</li> <li>d. Wind erosion off pile(s)</li> <li>e. Handling and transfer</li> </ul> <p>3. Lead scrap</p> <ul style="list-style-type: none"> <li>a. Loading onto pile</li> <li>b. Vehicular traffic</li> <li>c. Load-out operations</li> <li>d. Wind erosion off pile(s)</li> <li>e. Handling and transfer</li> </ul> <p>4. Coke</p> <ul style="list-style-type: none"> <li>a. Loading onto piles</li> <li>b. Vehicular traffic</li> <li>c. Load-out operations</li> <li>d. Wind erosion off pile(s)</li> <li>e. Handling and transfer</li> </ul> | <p>5. Limestone</p> <ul style="list-style-type: none"> <li>a. Loading onto pile</li> <li>b. Vehicular traffic</li> <li>c. Load-out operations</li> <li>d. Wind erosion off pile(s)</li> <li>e. Handling and transfer</li> </ul> <p>6. Lead and iron scrap burning</p> <p>7. Battery breaker</p> <p>8. Crusher</p> <p>9. Rotary tube sweating furnace</p> <ul style="list-style-type: none"> <li>a. Charging</li> <li>b. Tapping</li> </ul> <p>10. Reverberatory sweating furnace</p> <ul style="list-style-type: none"> <li>a. Charging</li> <li>b. Tapping</li> </ul> <p>11. Reverberatory smelting furnace</p> <ul style="list-style-type: none"> <li>a. Charging</li> <li>b. Slag tapping</li> <li>c. Lead tapping/casting</li> </ul> | <p>12. Blast (cupola) furnace</p> <ul style="list-style-type: none"> <li>a. Charging</li> <li>b. Slag tapping</li> <li>c. Lead tapping/casting</li> </ul> <p>13. Holding pot tapping</p> <p>14. Kettle (softening) refining/casting furnace</p> <ul style="list-style-type: none"> <li>a. Charging</li> <li>b. Pigging</li> </ul> <p>15. Kettle (alloying) refining/casting furnace</p> <ul style="list-style-type: none"> <li>a. Charging</li> <li>b. Pigging</li> </ul> <p>16. Kettle oxidation furnace</p> <ul style="list-style-type: none"> <li>a. Charging</li> </ul> <p>17. Reverberatory oxidation furnace</p> <ul style="list-style-type: none"> <li>a. Charging</li> </ul> <p>18. Casting (pigging) soft and alloy</p> <p>19. Roadways</p> <ul style="list-style-type: none"> <li>a. Paved roads</li> <li>b. Unpaved roads</li> </ul> |
|---|--|---|

FIGURE 3. PARTICULATE EMISSION POINTS IN SECONDARY LEAD SMELTERS

Source: (r)

TABLE 3. FUGITIVE SECONDARY LEAD SMELTING EMISSION FACTORS

| Process   | Emission Factors<br>(Total Particulate)                     | Data<br>Source * | Comments  |
|---|---|------------------|---|
| Reverberatory Sweating<br>Furnace                 |   |                  |   |
| Charging  | 1.28 kg/Mg scrap<br>charged                                 | b                | Includes tapping as well as charging  |
| Total   | 0.8-1.75 kg/Mg charged                                      | c                | Based on 137,670 metric tons/year.  |
| Reverberatory Smelting<br>Furnace                 |   |                  |   |
| Charging  | 4.62 kg/Mg charged  | b                | Includes tapping slag and lead as well<br>as charging   |
| Total   | 1.4-7.85 kg/Mg charged                                      | c                | Based on 135,000 metric tons/year.  |
| Blast (Cupola)<br>Furnace                         |   |                  |   |
| Charging  | 6.00 kg/Mg charged  | b                | Includes charging, lead tapping to<br>holding pot, slag tapping, and<br>tapping of holding pot. |
| Scrap Burning                                     | 0.80 kg/Mg scrap<br>burned<br>0.5-1.0 kg/Mg scrap<br>burned | b<br><br>c       | Based on 151,437 metric tons scrap<br>burned/year.  |
| Rotary Tube Sweating<br>Furnace                   |   |                  |   |
| Charging  | 1.28 kg/Mg of metal<br>processed                            | b                | Includes both charging and tapping  |
| Kettle (Softening)<br>Refining/Casting<br>Furnace |   |                  |   |
| Charging  | 0.02 kg/Mg of metal<br>charged                              | b                | Includes pigging as well as charging  |
| Kettle (Alloying)<br>Refining/Casting<br>Furnace  |   |                  |   |
| Charging  | 0.02 kg/Mg of metal<br>charged                              | b                | Includes pigging as well as charging  |
| Kettle Oxidation<br>Furnace                       |   |                  |   |
| Charging  | 0.02 kg/Mg of metal<br>charged                              | b                |   |
| Reverberatory Oxidation<br>Furnace                | No Data   |                  |   |
| Casting (Soft & Alloy)                            | 0.44 kg/Mg lead cast  | b                |   |

\*Data Source refers to letter citation in Bibliography (See Appendix)

reduces contamination. Indeed, several plants are designating "clean" and "contaminated" areas within the smelter. Clean areas are intended to be controlled through emission controls and good housekeeping to provide low ambient lead levels. Employees in contaminated areas are protected by supplied-air cabs, islands, stand-by pulpits and control rooms, supplemented by respiratory protection.

- Automate, and minimize personnel needs. Where practical, automated process equipment reduces exposure by removing the employee.
- Provide sufficient space for process and control equipment. Allow sufficient space for hoods, ductwork, control rooms, maintenance activities, cleaning, and equipment storage.
- Avoid wheeled-vehicle transport. Wheeled vehicles are significant sources of secondary lead emissions.
- Minimize transport distances. Transport of loose lead materials by any means results in fugitive emissions. Designers should attempt to reduce transport distances. One approach is to surround primary operations with support operations, eliminating transport over long distances. For example, charge preparation, charging, tapping, and casting operations can be positioned like spokes on a wheel, with the blast furnace being the hub.

- Isolate power equipment to reduce pulsating vibrations. An often unrecognized source of airborne dust, vibration can create significant secondary emissions. Isolating power equipment will reduce such emissions.
- Avoid flat structural surfaces. Flat structural surfaces collect settled dust which may be reentrained as a secondary emission source through wind erosion or surface vibration. High flat surfaces are also difficult to reach for cleaning.
- Provide emission control of all emission sources which contribute to exposure. All recognized emission sources should be controlled to the degree possible, considering technical and financial feasibility.
- Utilize secondary hooding to control fugitive emissions. Few primary hoods collect 100% of the emission. Secondary hoods should be installed as required. Examples include secondary hoods over slag tap operations, charging ports, and metal tap cooling points.
- Provide replacement air ventilation systems. All exhaust or dilution ventilation systems require replacement air (known also as "make-up" air systems.) If the replacement air system is well designed and integrated into natural and comfort ventilation systems, more effective control of exposures can be expected. For example, replacement air outlets should be placed so that air flows from the outlet past the employee, to the emission source, and to the exhaust. This

places the employee between the incoming air and the emission source, as shown on Figure 4.

- Pave all ground surfaces. All plant surfaces should be paved, covered, or planted to minimize wind-entrainment of settled lead dust and to enhance the opportunity for surface cleaning.
- Select equipment which is compatible with and encourages good housekeeping. At lower levels of lead-in-air, i.e., less than  $100 \text{ ug/m}^3$ , secondary sources of lead from contaminated surfaces may become major contributors to exposure. Housekeeping thus becomes more important to compliance as time passes. Building and process equipment should be selected to facilitate housekeeping, e.g., avoid flat surfaces; use smooth, cleanable surfaces on floors, walls and equipments; and specify water-resistant electrical service.
- Isolate employees. Employee isolation is often less costly than emission controls. Successful stand-by pulpits and environmentally-controlled cabs and control rooms have average lead levels of  $10\text{-}30 \text{ ug/m}^3$ .

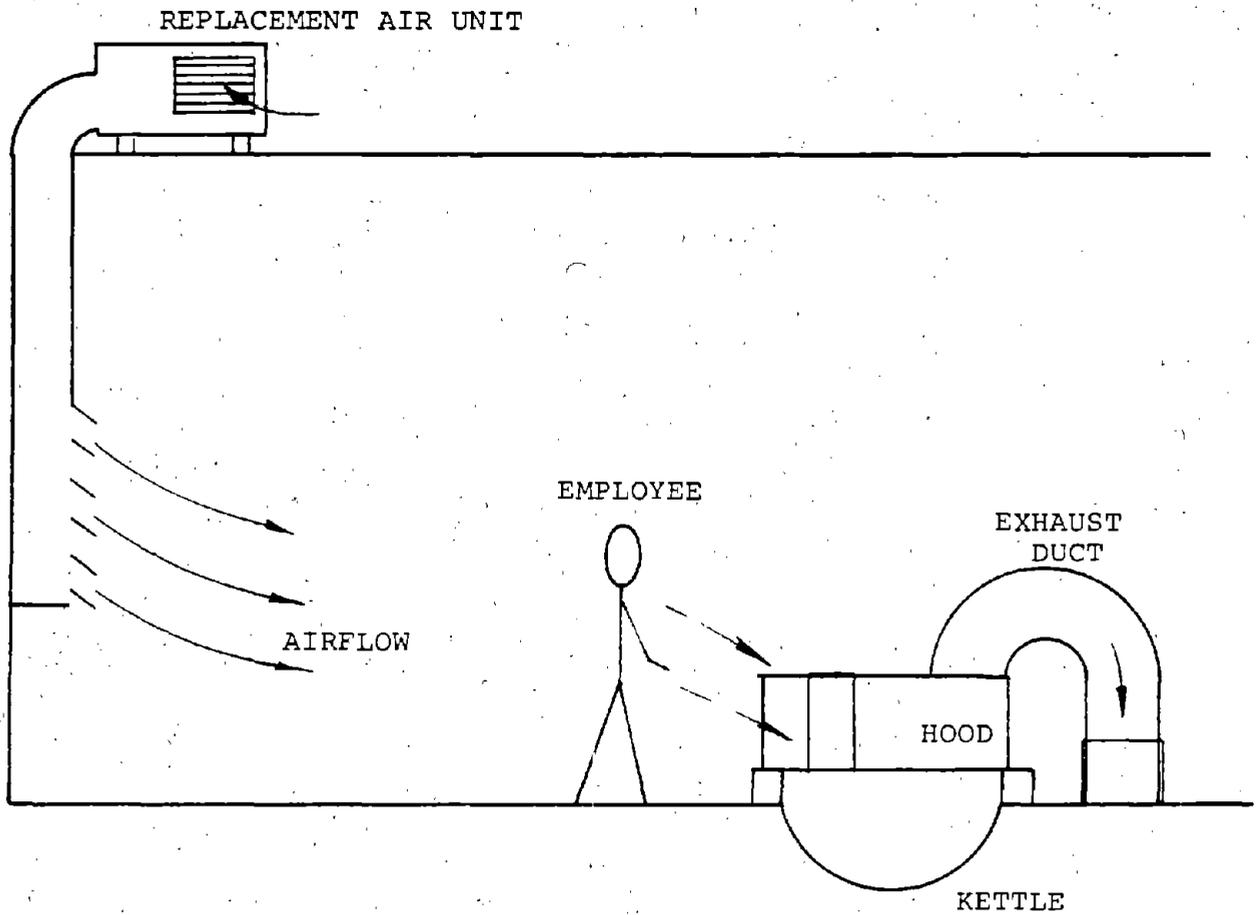


FIGURE 4. AIR FLOW FROM REPLACEMENT AIR OUTLET TO EXHAUST HOOD

### 3.0 DEMONSTRATION PROJECT SUMMARIES

Many demonstrations could have been performed as part of this project. Table 4 presents a summary of fourteen projects which were seriously considered. Ten of the fourteen projects were pursued, each of which met the following criteria:

- The project had potential application in most secondary lead smelters.
- A site was available to conduct the demonstration.
- Financial factors were favorable.
- Technical factors pointed to a relatively high probability of project success.
- Questions of compliance feasibility could be answered.
- The project could be completed in the allowed time.

The following paragraphs present a summary for each demonstration project.

#### 3.1 Summary of Demonstration Project No. 1, "Battery Breaking Emission Controls Using a Saturn® Shredder and Palletized Battery Handling"

There are many methods of breaking batteries, but most employ one or more of the following basic approaches: (1) breaking by shear or saw, (2) hammermill breaking, (3) flotation separation of battery parts, and (4) low-energy shredding. A demonstration of low-energy shredding was conducted which focused

TABLE 4. SUMMARY OF FOURTEEN DEMONSTRATIONS CONSIDERED

| DEMONSTRATION PROJECT NO. | PROJECT DESCRIPTION                              | DESCRIPTION OF OPERATION                         | PARTICIPATING COMPANIES       | TYPE OF PROJECT                   | CONCLUSIONS/ RESULTS                              |
|---------------------------|--|--|-------------------------------|-----------------------------------|---|
| 1                         | Saturn Shredder                                  | Battery Breaking                                 | GBC                           | Control Technology Application    | Successful Application                            |
| 2                         | Retrofit of Filtered Air Cab to Mobile Equipment | Front-End Loader in Yard Operation               | GBC/<br>Tonolli               | Control Technology Application    | Preliminary Evaluation - Positive and Encouraging |
| 3                         | Supplied-Air Island                              | Casting Skimmer's Work Station                   | GBC                           | Control Technology Application    | Successful Application                            |
| 4                         | Slag Granulation                                 | Furnace Slag Tap                                 | GBC                           | Control Technology Application    | Project Not Pursued                               |
| 5                         | Screw Drossing                                   | Kettle Drossing                                  | Tonolli                       | Control Technology Application    | Successful Application                            |
| 6                         | Central Vacuum System                            | Plant-Wide Housekeeping Operations               | Tonolli,<br>GBC               | Evaluation of Existing Technology | Descriptive Summary                               |
| 7                         | Flue Dust Recycling in Closed System             | Flue Dust Handling and Storage                   | GBC                           | Control Technology Application    | Moderately Successful Application                 |
| 8                         | Waffle Casting of Slag                           | Furnace Slag Tap                                 | GBC                           | Control Technology Application    | Project Not Pursued                               |
| 9                         | Reverb Curtains                                  | Reverberatory Furnace Operations                 | GBC                           | Control Technology Application    | Project Not Pursued                               |
| 10                        | Clothing and Shoe Cleaners                       | Plant-Wide Cleaning of Clothing, Shoes, and PPE  | GBC,<br>Tonolli,<br>East Penn | Evaluation of Existing Technology | Descriptive Summary                               |
| 11                        | Stand-by Pulpits                                 | Employee Enclosure at Various Locations in Plant | Tonolli,<br>GBC               | Evaluation of Existing Technology | Descriptive Summary                               |
| 12                        | Oxide Handling by Vacuum Dewatering              | Battery Breaking and Separation                  | Cal-West Metals               | Control Technology Application    | Project Not Pursued                               |
| 13                        | Tuyere Punching Controls                         | Blast Furnace                                    | East Penn                     | Control Technology Application    | Successful Application                            |
| 14                        | Pavement Cleaning                                | Yard Areas                                       | Tonolli,<br>East Penn         | Evaluation of Existing Technology | Descriptive Summary                               |

on control of airborne lead and acid emissions. The demonstration was conducted at the General Battery Corporation (GBC) smelter in Reading, Pennsylvania.

The overall approach to emission control included palletized battery handling, movement of materials by forklift, enclosed and exhaust-ventilated battery shredding, and good work practices and administrative controls such as wet-down methods, training, and preventive maintenance.

The battery shredder is located in a building by itself. The local exhaust ventilation used to control shredder emissions creates an inflow of air into the building, preventing escape of lead emissions into the smelter yard. Palletized batteries are transferred from trucks to the shredder by fork-lifts, eliminating manual handling. Shredded battery material is removed by front-end loader.

Previous battery breaking had been accomplished by hand separation, shearing, and hammermill operations. Production rates had been averaging 600 batteries per hour, requiring a crew of five. Lead exposures often exceeded  $500 \text{ ug/m}^3$  and averaged more than  $300 \text{ ug/m}^3$ . The new shredding method can break 1,600 batteries per hour and requires a crew of four. The mean lead exposure level has been reduced to  $160 \text{ ug/m}^3$ .

While not yet in compliance with the  $50 \text{ ug/m}^3$  standard, GBC has achieved a significant reduction in employee exposure. Recommendations were made for modifications and additional emission controls which should provide further and significant reductions in lead exposure. These included a re-designed entrance ramp, larger dock and storage area, conveyor handling of shredded battery scrap, and modifications to the local exhaust system to reposition the hood and to more completely enclose the shredder.

3.2 Summary of Demonstration Project No. 2, "Progress Report: Retrofit Application of a Controlled-Environment Operator's Cab to a Rubber-Tired Front-End Loader"

Use of controlled-environment cabs on mobile equipment has been suggested as one potential means of reducing operator exposures to lead. Industry experience in building controlled-environment cabs helped identify problems which would have to be solved during this effort: inadequate filter systems, under-powered fans and motors, improper distribution and return of air, inadequate control of temperature and noise, clearance and space problems, poor housekeeping, and improper operator practices, e.g. keeping windows and doors open.

To evaluate the potential for building and operating an effective, controlled-environment cab, Radian Corporation arranged for a cab to be designed, built, installed, and tested at General Battery Corporation's Reading, Pennsylvania smelter.

A Clark/Michigan 45C, rubber-tired, front-end loader was selected for cab retrofit. Palm Industries of Litchfield, Minnesota, received a contract from GBC to build the new cab. Donaldson Company of Minneapolis, Minnesota agreed to supply air filters for testing.

A cab was designed and built which used dual fans and hydraulic motors to provide air movement. Preliminary tests indicate the cab will function effectively when fully operational. However, unforeseen problems have delayed the project. The Final Technical Report is based on preliminary testing of the completed cab.

3.3 Summary of Demonstration Project No. 3, "Construction and Evaluation of a Supplied-Air Island at the Casting Skimmer's Work Station"

Use of supplied-air islands has been suggested as one means of lowering employee lead exposure in the secondary lead industry. To evaluate and document a supplied-air island's effectiveness, Radian Corporation and General Battery Corporation designed, built, and tested an island at GBC's Reading Pennsylvania plant.

The pig casting skimmer's job location was selected for application of the supplied-air island.

Equipment associated with the supplied-air island included a gas-fired make-up air heater, ductwork, a distribution plenum and hood, side baffles, and temperature controls at the work-site.

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

From the results of this demonstration study, Radian concluded that supplied air islands can be effective control devices in reducing exposure to airborne lead. Average Exposures at the skimmer's work location were reduced from 170 ug/m<sup>3</sup> outside the island to below 30 ug/m<sup>3</sup>.

The degree of effectiveness of a supplied-air island will vary with design, maintenance, extent of employee use, and

employee work practices. The results of this study support supplied-air island use as a major contributor to a comprehensive exposure control program.

Capital costs will vary with size and design. The GBC casting skimmer's island cost \$15,000 in initial and capital costs. Annual operating and maintenance costs were estimated at \$3,900 per year.

3.4 Summary of Demonstration Project No. 4, "Control of Slag Tap Emissions by Water Granulation"

Tapping of molten slag is a major potential source of fugitive lead emissions in every smelter. Water granulation of slag appears to be one method of control which might be feasible at larger smelters such as GBC's Reading facility.

Financial constraints prohibited the testing of this control method. The project was not pursued and no report was prepared.

3.5 Summary of Demonstration Project No. 5, "Dross Emission Controls Using a Screw Drossing Machine"

Drossing of kettles by hand is typically accompanied by lead emissions which are difficult to control. Associated exposures to dust, fume and heat make the job undesirable to employees. A demonstration was conducted of a mechanized drossing system which eliminated much of the hand work and greatly reduced emissions associated with drossing. The study was conducted at the Tonolli North America smelter located in eastern Pennsylvania.

A description of the mechanical drossing machine is summarized below:

- A hydraulic cylinder positions the screw.
- A perforated paddle lifts dross from the surface of the lead bath and deposits it in the screw conveyor housing.
- The screw conveyor moves the dross up to a drop chute.
- A removable dross container, with lid, is used to transport collected dross.
- An exhaust ventilation system keeps all components of the system under negative pressure.

It was concluded that the Tonolli screw drosser was effective in eliminating emissions during drossing, and that exposure contributions from drossing were substantially reduced.

The equipment could find application in a number of primary and secondary smelters. Limitations exist when dealing with wet drosses and small kettles.

No special skills are required to operate the drossing machine. Daily maintenance is required, but Tonolli estimates that as much as 2 man-days per operating day are saved when using the machine.

The estimated cost of construction, installation, and testing was \$20,000 (1981). Annual operating and maintenance costs are estimated to be \$4-5,000 per year.

Recommendations were made by Radian for further improvement in the approach. These included a different dross container housing, improved dross container handling procedures, improved housekeeping in the vicinity of the machine, and reduced openings between the machine and the existing kettle hood.

3.6 Summary of Demonstration Project No. 6, "Evaluation of Central Vacuum Systems for Exposure Control in Secondary Lead Smelters"

The OSHA lead standard specifies vacuuming methods for removal of lead dust. A field evaluation project was conducted which provides useful technical information for smelters interested in complying with this provision. On-site evaluations of central vacuum systems were made at Tonolli North America's plant in Nesquehoning, Pennsylvania, and at General Battery Corporation's plants in Reading and Hamburg, Pennsylvania. These field evaluations centered upon the effectiveness of the central vacuum system as a housekeeping tool.

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

- Drive motor
- Vacuum producer
- Air cleaning devices
- Vacuum inlet valves
- Flexible connecting hose
- Cleaning tools

The central vacuum systems studied were designed so that vacuum lines extend throughout the plant with inlet valves at convenient locations. The workers connect the flexible hoses and cleaning tools to inlet valves when performing clean-up work in an area served by the central system. Air-cleaning devices are located immediately upstream from the vacuum producer.

It was concluded that the central systems studied were convenient, and reliable, and that they enjoyed a high level of

acceptance by employees. The vacuum was effective in removing dust and dirt from the workplace in a number of observed cleanup operations. Typically, only one pass of the cleaning tool was required, but clumpy leady materials did not lend themselves to vacuum cleaning.

Capital costs of a system installed in a large secondary smelter were given as \$100,000. Annual operating and maintenance costs at another plant were estimated to run \$74,000 per year.

3.7 Summary of Demonstration Project No. 7, "Control of Emissions by Screw Conveying Flue Dust Directly to a Reverberatory Furnace"

Every smelter has the problem of handling collected flue dust from such sources as baghouses and cyclones. Most smelters return flue dusts to the charge preparation area for recycle. The handling and transport of flue dust creates high exposures for those doing the work. Additionally, flue dust transport creates housekeeping problems.

A demonstration project was conducted to evaluate and characterize an existing screw conveying system which returns baghouse flue dust directly to a reverberatory furnace. The study was conducted at General Battery Corporation's Reading, Pennsylvania, secondary lead smelter during October and December, 1981. Additional information was obtained from manufacturers and suppliers of screw conveying equipment.

GBC's basic approach to recycling flue dust is summarized below:

- Flue dust is maintained in an enclosed system which eliminates manual handling and associated emissions and employee exposures.

- Each of two process trains has its own air handling system and baghouse.
- Flue dust collected from each baghouse (and from auxillary equipment, e.g. cooling tubes) is conveyed by trough screw conveyors to a bucket elevator.
- A bucket elevator lifts the flue dust to an overhead screw conveying distribution/feed system.
- Overhead conveyors feed the flue dust to charging chutes over each reverberatory furnace.
- Flue dust is charged to the furnace by a ram-charge mechanism.

It was concluded that the approach, i.e., screw conveying of flue dust directly to the furnace, has significant merits because of reduced emissions, low operating costs, and potentially lowered employee exposures. The approach required significant amounts of maintenance and upkeep, however. Maintenance, both scheduled and unscheduled, averaged 20-hours per week. Major problems involved clogging of the conveyors, packing in elevators, and failure of hanger bearings and couplings.

### 3.8 Summary of Demonstration Project No. 8, "Waffle Casting of Slag"

Most smelters recycle all or part of the slag produced in the smelting furnace. The remainder is disposed of in various ways, e.g. shipped to a landfill. Storage, handling, and furnace preparation of cooled slag has proven to be a major source of fugitive emissions in many plants. One potential control is to cast slag into a waffle casting which can be easily broken, handled, transported, and charged to the furnace.

Initial evaluations indicated that various financial and equipment limitations rendered this project infeasible to pursue. No report was prepared.

3.9 Summary of Demonstration Project No. 9, "Reverb Curtains to Control Fugitive Emissions"

Many reverberatory furnaces are constructed of non-grouted, loosely fitted, heat-resistant bricks. Transient positive pressures in the furnace create "puffs": fugitive emissions from the top or sides of the furnace.

It was suggested that sheet metal curtains hung around the furnace would help contain and direct emissions to a collection system. Initial evaluations led to the conclusions that the project was trivial in an engineering sense, and that it was not necessary to demonstrate the control.

3.10 Summary of Demonstration Project No. 10, "Evaluation of Airshowers and Shoecleaners as Exposure Controls in Secondary Lead Smelters"

This project evaluated airshowers and automatic shoecleaners as employee exposure control options in secondary lead smelters.

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 effectiveness 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 was 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.

3.11 Summary of Demonstration Project No. 11, "Use of Supplied-Air Control Rooms and Stand-by Pulpits to Control Airborne Lead Exposure"

Use of supplied air control rooms or stand-by pulpits has been suggested as an effective means of lowering employee lead exposure. To evaluate and document such enclosures' effectiveness, Radian performed on-site evaluations at General Battery Corporation's 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, Radian 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 varies 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 were reportedly minimal at GBC, while Tonolli carried a maintenance agreement with the Lintern Corporation at a cost of \$800 per month.

3.12 Summary of Demonstration Project No. 12, "Oxide Handling by Vacuum Dewatering"

When batteries are broken, the lead oxide and lead sulfide paste (known in the industry as "oxide") is dried and mixed with other charge materials. Storage and handling creates emissions and exposures to the finely divided powder.

Cal-West Metals, a California-based recycler of batteries developed an experimental method of vacuum-dewatering and packaging of oxide such that emissions were reduced.

The equipment, while effective in tests, was not made operational on a production basis in time for a study to be performed. No report was written.

3.13 Summary of Demonstration Project No. 13, "Construction and Evaluation of Emission Controls on Blast Furnace Tuyeres"

Lead emissions generated from clearing blast furnace tuyere nozzles have been suspected as major contributors to furnaceman lead exposures. 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.

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 indicated that tuyere punching may account for as much as half of a furnaceman's lead exposure. Three major emission sources contributed 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 developed and tested numerous engineering and work practice controls for use on blast furnace tuyeres. The most effective of these was a hydraulically-powered tuyere punching device which seals the tuyere outlet during punching. This device eliminated employee exposures from furnace or punch

rod emissions and dust entrained in blast air escaping the tuyere.

East Penn considers its hydraulic tuyere punch a state-of-the-art control for blast furnace tuyeres. The Company planned 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 included 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 was as effective as the hydraulic punch. Additionally, many proved to be either technically or economically infeasible, and several demonstrated serious maintenance problems.

3.14 Summary of Demonstration Project No. 14, "Evaluation of Pavement Cleaning Methods and Equipment for Exposure Control in Secondary Lead Smelters"

Lead dust that accumulates in smelter yard and building areas can be a significant source of fugitive dust emissions and employee exposure to lead. One approach to controlling this source of exposure is to pave traffic areas and implement a program for pavement cleaning. The primary objectives of this study were to characterize pavement cleaning methods and equipment, to investigate pavement cleaning practices in the secondary lead industry, and to evaluate the effectiveness of various pavement cleaning methods and equipment through site-visit demonstrations.

Pavement surfaces may be cleaned by sweeping, washing, or vacuuming. Since dry sweeping can itself generate high dust concentrations, sweeping methods are generally combined with

vacuuming or washing to provide acceptable control of dust emissions. Mobile vacuum sweeper machines are widely used at secondary lead smelters for pavement cleaning. Alternative methods used by some companies include use of central vacuums and water wash techniques. Smelter operators report varying degrees of success and satisfaction with the equipment and methods they use for pavement cleaning.

Site visits were made to three secondary lead smelters to observe various pavement cleaning methods and equipment. Use of medium-size vacuum sweepers (with and without an enclosed operator cab), a truck-mounted vacuum sweeper, and a water-wash technique were evaluated. Operator exposure during the water-wash technique was lowest; exposure during operation of the truck-mounted sweeper was highest. Use of a standard, fully-enclosed cab provided little dust exposure protection for the operator: an average lead-in-air concentration of  $425 \text{ ug/m}^3$  was measured during sweeper operation.

All pavement-cleaning methods studied were effective in reducing dust emissions from pavement surfaces. Measurements made with a direct reading dust monitor before and after pavement cleaning showed a substantial reduction in dust emissions from vehicular traffic.

#### 4.0 RECOMMENDATIONS

The secondary lead smelter industry has accomplished much in the way of controlling emissions, exposures, and blood lead levels in the past four years. The industry is to be commended for its willingness to share control technology among its members; NIOSH for its willingness to assist in the development of control technology.

Radian recommends that funds be made available to conduct additional control technology demonstration projects.

Examples of emission/exposure source controls yet needing development and evaluation include:

- Wet dross emission controls
- Kettle controls
- Pavement emission controls
- Oxide handling controls
- Small kettle controls
- Waffle-casting of slag
- Mobile vehicle emission controls
- Acid misting controls in battery storage piles
- Breaking of industrial batteries
- Plastic and rubber handling
- Evaluation of MA Engineering® battery breaker
- Tunnel enclosures of tapping and cooling
- Slag granulation in water
- Conveyor transport, preparation, and charging of broken batteries
- Whole battery charging

## 5.0 REPORTING

The primary purpose of performing this project was to provide information which smelter operators could use to reduce employee exposures in secondary lead smelters. Accordingly, Radian prepared all reports and presentations in formats which would be of most use to smelter operators, designers, and industrial hygienists. Radian sent copies of Demonstration Project Technical Reports to all secondary smelters for review and comment. Additional copies were made available to the Secondary Lead Smelter Association (SLSA) and to the Lead Industries Association (LIA).

Oral presentations summarizing the project were presented at meetings of the Secondary Lead Smelter Association in 1982 (Tampa, Florida) and 1983 (New Orleans, LA). Progress reports were also presented at the national American Industrial Hygiene Conferences of 1982 and 1983.

Findings of individual Demonstrations were presented orally at regional and national AIHA meetings in 1982 and 1983.

Demonstration Project Technical Report No.'s 1, 2, 3, and 5 are included in Volume I of the Final Report. Demonstration Project Technical Report No.'s 6, 7, 10, 11, 13, and 14 are found in Volume II.



REPORTS, VOLUME I

- 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 Dressing Machine".

**Demonstration  
No. 1**

BATTERY BREAKING USING A  
SATURN<sup>(R)</sup> SHREDDER  
AND PALLETIZED BATTERY HANDLING

Final Technical Report  
Demonstration Project Number One

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NIOSH Contract No. 210-81-706

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

June 1982



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\* Figures are placed at the end of each  
major section.

1.0 PURPOSE AND OBJECTIVES OF THE STUDY

The purpose of this study is to investigate, evaluate and characterize a new approach to battery breaking which minimizes emissions.

The objectives of the study are (1) to determine the level of control provided by this operation, as compared to the former operation, and (2) to provide useful technical, cost, and operational information to other smelter operators, government agencies, consultants, and labor unions, for the purpose of determining the transferrability of the demonstrated technology to other smelting locations.

## 2.0 INTRODUCTION

In this report, we describe the results of a study funded by the National Institute for Occupational Safety and Health, and conducted by Radian's Occupational Safety and Health Division. The study was performed at the General Battery Corporation (GBC) secondary lead smelter located near Reading, Pennsylvania. This report presents the findings of a study of a reduced-emissions battery-breaking operation recently installed at GBC's Reading smelter.

GBC's basic approach to battery breaking includes:

- o Palletized battery handling by fork lift trucks
- o Enclosed and exhaust-ventilated battery breaking operations
- o A low-energy shredder supplied by MCA Corporation ("Saturn")
- o Administrative controls, e.g. preventive maintenance, housekeeping, and employee training
- o Movement of shredded batteries by front-end loader

Radian conducted on-site studies during October and December, 1981, and again in January, 1982. Much of the technical data were supplied by GBC and Saturn. Measurements of air flows and exposure levels were obtained by Radian. Samples were analyzed by Radian's AIHA-certified lab in Austin, Texas.

## 2.1 BATTERY BREAKING CURRENTLY IN USE IN THE SMELTER INDUSTRY

There are as many ways to break batteries as there are secondary smelters in the U.S.A. (about 50). However, all breaking operations can be categorized and assigned to one of the following basic approaches:

(a) Whole battery charging. This technique, developed by the Bergsoe smelter in Denmark, purposely emphasizes as little battery breaking as possible (only about 20% of the battery mass needs to be broken). The acid is drained from the battery before charging. "Whole" batteries are mixed with other charge materials on concrete beds using a rubber-tired front end loader. After the charge is prepared, it is loaded into the furnace by front-end loader. Although it may seem to be a low-level emitting process, emissions and exposures are still a significant problem. Few smelters in the USA use this approach because of the large furnace size required and the resultant poor economics.

(b) Battery breaking by shear or saw. Many smelters dismantle batteries in a hand operation in which employees (1) separate plastic and rubber batteries, (2) cut the top of the battery off, (3) empty the contents of the battery onto a pile. Typically, front-end loaders then move the battery parts to storage and disposal. This operation is labor intensive, creates significant emissions during cutting and handling, and has traditionally been a physically tiring, irritating (acid mist), and high lead exposure job.

(c) Hammer-mill Battery-Breaking. In order to speed up the process, remove employees from exposure, and utilize plastic battery cases for fuel or resale, many plants use hammer mills to break batteries. Unfortunately, this approach continues to require hand separation of plastic and rubber cased batteries and manual handling of rubber-cased batteries. Furthermore, the hammer mill is a high-energy machine which creates high levels of lead and acid mist emissions.

(d) Flotation-type separators. A number of flotation-type battery-breakers are currently employed in today's smelters. The technique uses shears, saws, and/or hammer mills to reduce battery scrap to small pieces. The separator produces output

streams of hard lead (grids and posts), oxide and sulfate sludge, plastic, and rubber. The advantages of this system are (1) positive control of furnace feed enables use of more sophisticated furnaces, e.g. rotary, and (2) separate recycling of plastic case material which, as of December 1981, was selling for 15-17 cents per pound. Unfortunately, as with other approaches, emissions are significant and exposures are high.

(e) Low-energy shredders. At least five secondary smelters have (or, have had) low energy shredders installed for breaking batteries. This system uses a low-rpm, low energy shredding device to slowly shred batteries into chargeable or separable pieces.

This report describes an integrated approach to emission control which was built by GBC around a low-energy shredder for battery breaking.

## 2.2 DESCRIPTION OF THE GBC SMELTER

In order for other smelter operators to determine the compatibility of the GBC approach to their own operations, a brief description of GBC's operations are presented below. The information presented is a compilation of data gathered from the plant and derived from other studies.

General Battery Corporation's (GBC) smelter is located in the Reading, PA metropolitan area. The plant produces hard and soft lead ingots and antimonial alloys in two similar blast furnace-reverberatory furnace installations. Scrap industrial and SLI\*

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\* SLI - Starting, Lighting, Ignition

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 a second reverb and additional process gas handling and sanitary ventilation/gas treatment systems were added.

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.

Figure 1 is a plot plan of the 30-acre plant site which is in a basin remotely surrounded by high hills on all sides. At the west property line is St. Michael's monastery. Residential and commercial (small business) areas surround the plant property. The smelter is situated on the western boundary of the plant. North of the smelter is a paved area approximately 300 x 600 feet in dimension where scrap batteries are stored.

#### Processing Description

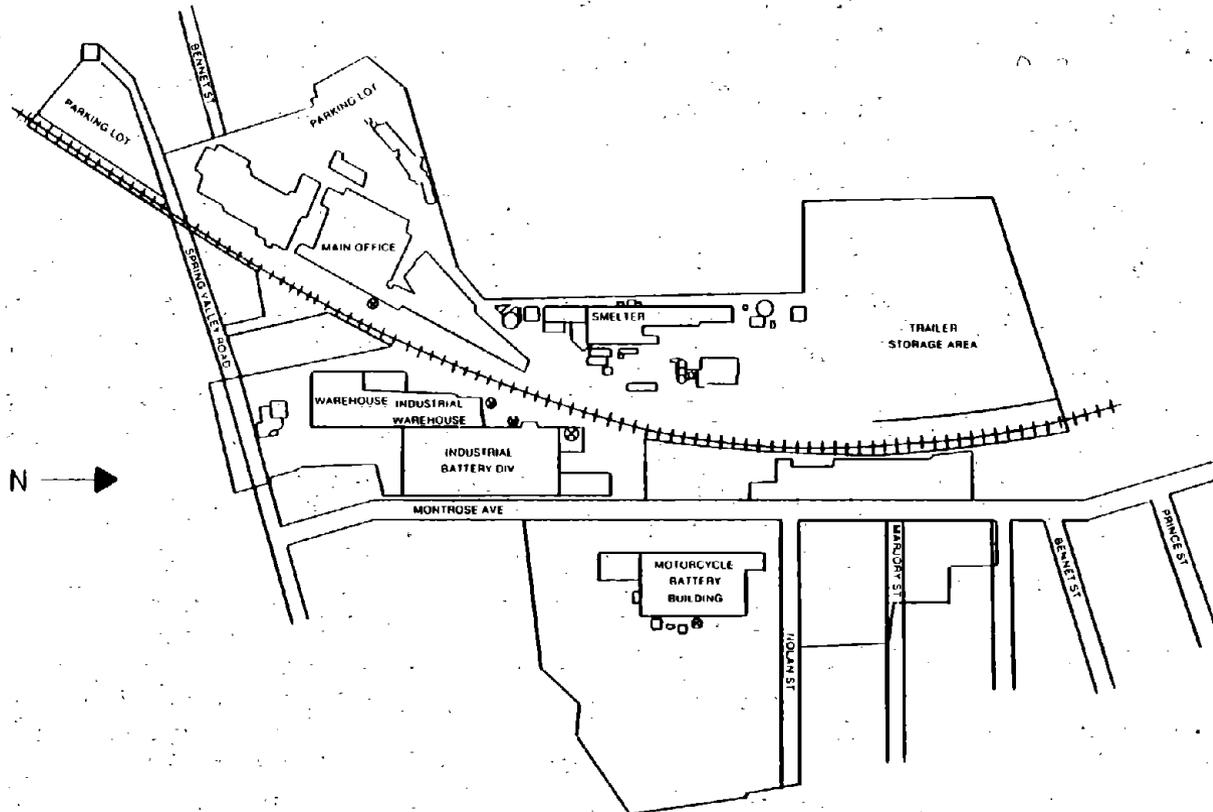
The smelter currently charges all plastic-cased batteries and the tops of rubber-cased batteries\* to two blast and two reverberatory furnaces, each of which has a rated capacity of 65-80 tons/day. Each of the two blast-reverb combinations shares a process gas and ventilation gas treatment system. Flue dust is charged to the reverb furnaces and reverb slag is charged to the blast furnaces.

As shown in Figure 2, 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.

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\* GBC intends to charge all portions of the rubber batteries when the percentage of rubber batteries has consistently dropped to below 25% of the total.

smelting/refining/casting operations, and slag storage. Reverb furnace slag is transported from the south storage area back to the storage area for blast furnace feed.



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FIGURE 1. PLOT PLAN FOR GENERAL BATTERY CORPORATION SHOWING LOCATION OF SMELTER.

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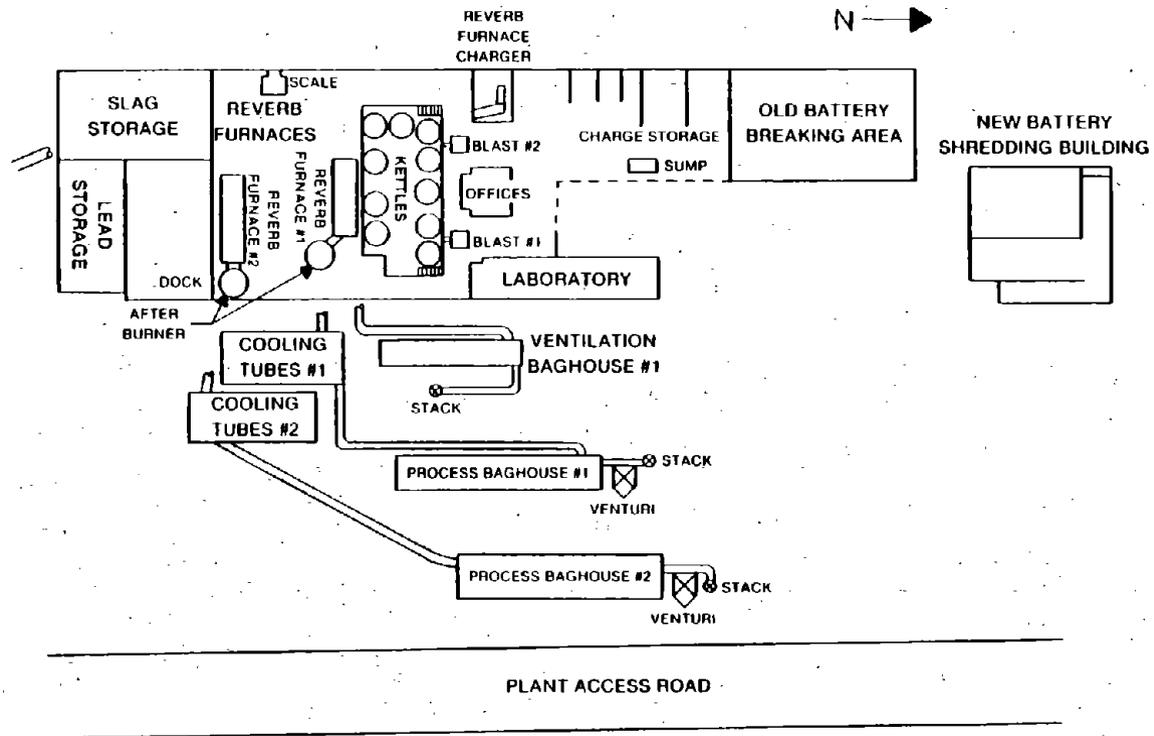


FIGURE 2 SMELTER PLOT PLAN FOR GENERAL BATTERY

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### 3.0 BATTERY BREAKING AT GBC, PREVIOUS OPERATIONS

Until recently at GBC, batteries had been prepared for furnace charging by (1) separating rubber and plastic batteries (a hand operation), (2) shearing the top of the rubber batteries and emptying the battery contents onto a pile (hand operations); and (3) breaking the plastic batteries in a high-energy hammer-mill. Battery scrap was moved from the battery area to the storage area by a rubber-tired, front-end loader. Lead exposure levels\* to battery breakers often exceeded  $500 \mu\text{g}/\text{m}^3$  and averaged more than  $300 \mu\text{g}/\text{m}^3$ . Acid exposure was also heavy - necessitating the wearing of face shields, rubber aprons, rubber boots and gloves, etc. (The location of the old operation is shown in Figure 2.)

The old system was capable of breaking 600 batteries per hour using a crew of five men which consisted of one driver, one shear-man, two battery unloaders, and one helper.

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\* GBC sampling data

#### 4.0 DESCRIPTION OF SHREDDING OPERATION

##### 4.1 INTRODUCTION

During 1981, GBC designed and installed a new battery breaking facility which was developed for the purpose of reducing emissions. The basic principles of control include:

- (1) Controlled Battery Handling. Batteries are handled on pallets, which reduces the exposure of handling and dropping of individual batteries. All batteries delivered to the plant must be strapped on wooden pallets.
- (2) Low-energy breaking. Batteries are broken by a low-energy machine. In this case GBC elected to purchase and install a Saturn<sup>(R)</sup>-brand shredder. The operating principal of the Saturn shredder is the high torque and low speed revolution of two counter rotating shafts. Each stainless steel shaft is equipped with stainless steel teeth. No hammering, pounding, ripping, or other high-energy breaking force is employed. Consequently, the generation of acid mist and lead particulate is generally low.
- (3) Local exhaust ventilation. Capture of emissions during the breaking operation is accomplished with a local exhaust hood installed on the shredder.
- (4) Isolation and enclosure of fugitive emissions. The breaking operation is housed in a building which is under negative pressure. Any fugitive emissions are theoretically retained in the building.

- (5) Training of employees, housekeeping, preventive maintenance. GBC has developed an administrative control program which emphasizes employee training and correct work practices, housekeeping and contamination control, and preventive maintenance of equipment. This program helps maintain stable environmental conditions and minimizes upsets and emission excursions.

#### 4.2 SHREDDER DESCRIPTION

Figure 3 presents a plan view of the new battery breaking operation. Components of the operation are listed below. (Numbers refer to locations marked on Figures 3 and 4.) Figure 5 presents five photographs of the shredder operation.

1. Battery unloading area and dock. Batteries are delivered to the plant in semi-truck trailers. All SLI batteries are strapped to wooden pallets. Pallets are removed from trailers by fork-lift trucks.
2. Concrete platform. The platform is used for temporary pallet storage. The surface is easily washed down.
3. Ramp. Forklifts carry pallets of batteries into the shredder building via the ramp.
5. Hood. The shredder is equipped with a canopy exhaust hood.
6. Scrubber. Exhaust air is drawn through a venturi scrubber to a fan, and then exits through an exhaust stack. Exhaust air is transported through a 24" FRP duct to a Chemico-brand venturi scrubber.

7. Building enclosure. Air exhausted from the hood creates a slight negative pressure in the building and maintains a flow of air into the building.

#### 4.3 OPERATIONS

The new battery operation is less labor intensive than the old. In fact, twice as many batteries/labor hour can be broken as compared to the old system.

A crew of four, consisting of one driver, two forklift operators and one helper, can shred 1,600 batteries per hour.

Drums of wet and dry dross and other leady materials are fed directly to the shredder, eliminating unloading, handling, spills, etc.

At the present time, any steel-clad industrial batteries are dismantled by hand and stacked on pallets, prior to introduction to the shredder.

#### 4.4 MAINTENANCE

The shredding operation had been operating for six months at the time of Radian's visit in December, 1981. The first major overhaul of the shredder took place at that time. The major overhaul involves a 1-2 day shutdown and consists of replacing all cutters with sharpened blades. GBC maintains two sets of cutters which can be interchanged. Other maintenance required during the first six months included the replacement of three bearings which failed due to acid leakage.\* Daily maintenance consists of inspection, cleaning, greasing, etc.

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\* New bearing seals should correct this problem.

Maintenance requires about 1 man-day per week, (as compared to 10 man-days per week in the old system.)

#### 4.5 EQUIPMENT DESCRIPTION

Shredder. The shredder is a Model 52-32 Saturn<sup>(R)</sup> shredder. The shredder is powered by 2-150 HP hydraulic motors which drive the two cutting shafts at 30-40 RPM.

Hopper and Hood. The hopper and hood are constructed of mild steel which has not shown good service. These were replaced with stainless steel during the major overhaul.

#### 4.6 SKILL LEVELS/EMPLOYEE ACCEPTANCE

Labor skill-level requirements are greater than that required during the previous operation (which primarily required strength and endurance). With the shredding operation, employees must be trained to operate a forklift truck. A job description for each job is included in the Appendix.

Radian interviewed GBC personnel to obtain their impressions of the work associated with the new battery breaking operation. Most employees felt that the new approach to battery breaking was easier, reduced physical labor considerably, and reduced exposures.

#### 4.7 HOUSEKEEPING

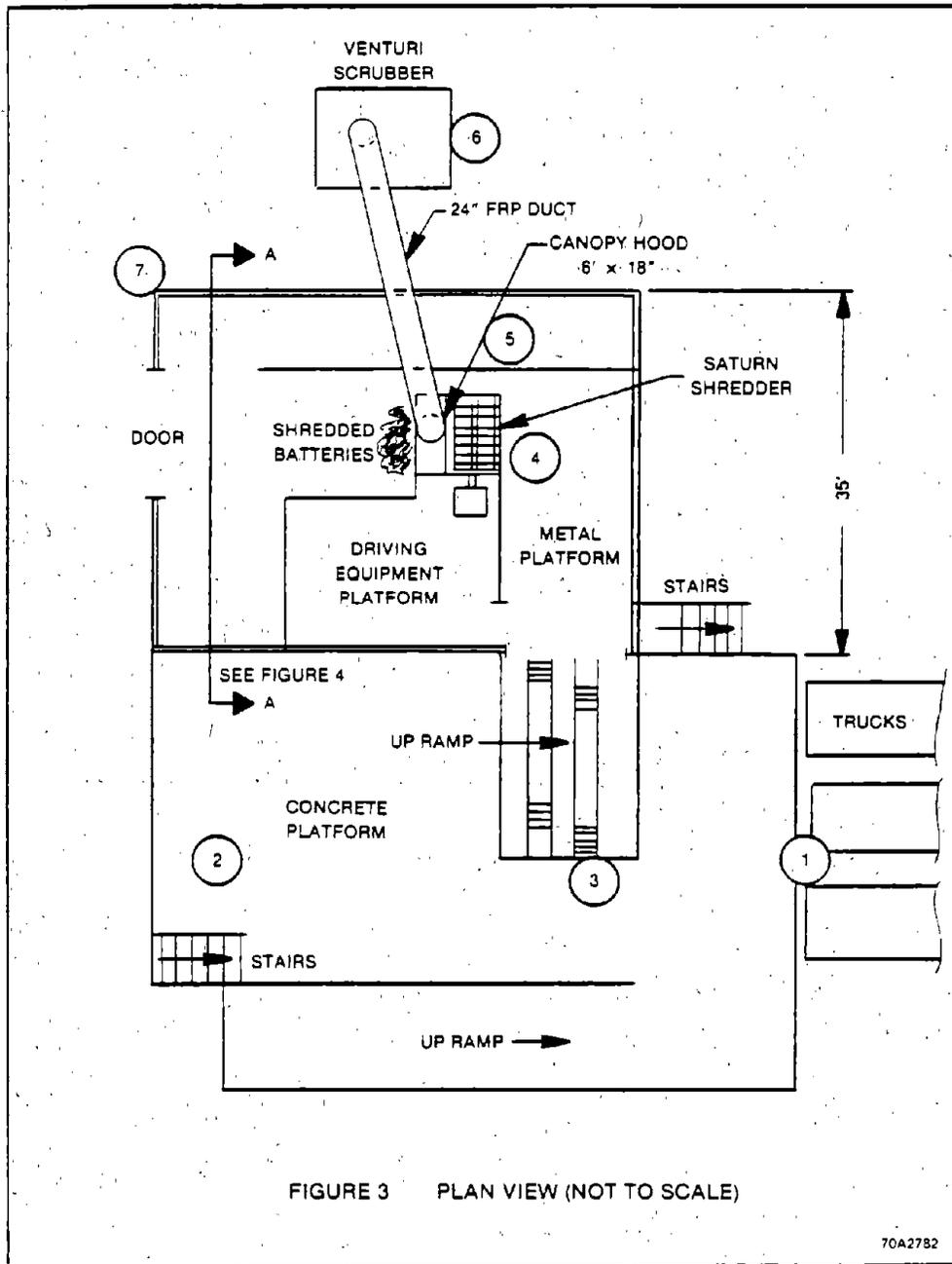
Housekeeping and cleaning are much easier in the new system. All equipment is built with water protection. Water wash down with a two inch hose and nozzle is performed at least once per shift and includes the cleaning of all surfaces.

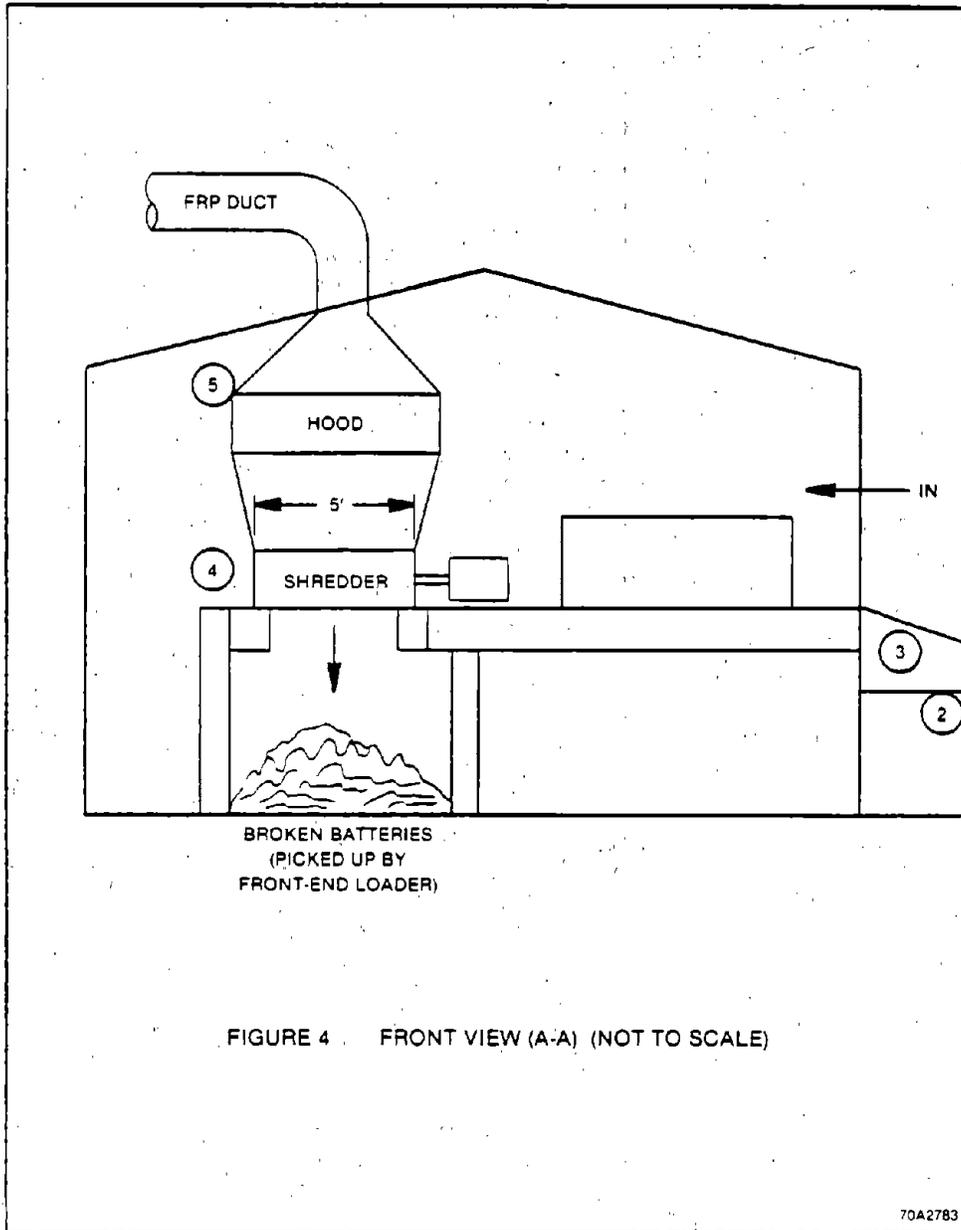
Water, acid, and particulate are drained to and collected in a sump on the north side of the building. Water and acid are sent

to the plant water treatment facility. Periodically, the settled particulate will be removed from the sump for recycling.

#### 4.8 BROKEN BATTERY SCRAP HANDLING

GBC continues to use a rubber-tired front-end loader to transport broken batteries to the storage area. This method of transport creates high levels of uncontrollable lead emission. Future plans call for modifying materials handling practices in the plant, e.g. using conveyors.





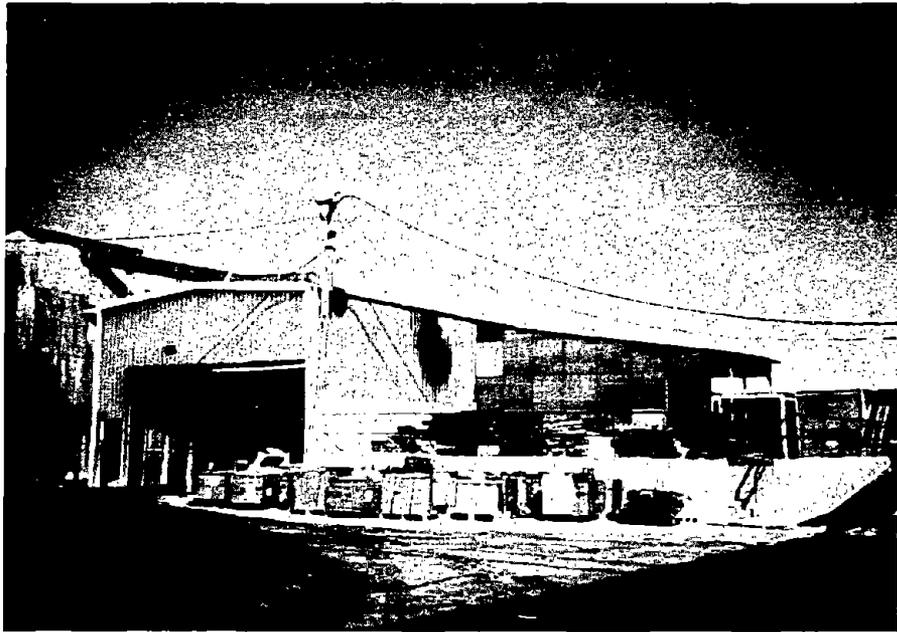


FIGURE 5A SHREDDER BUILDING



FIGURE 5B UNLOADING PALLETS

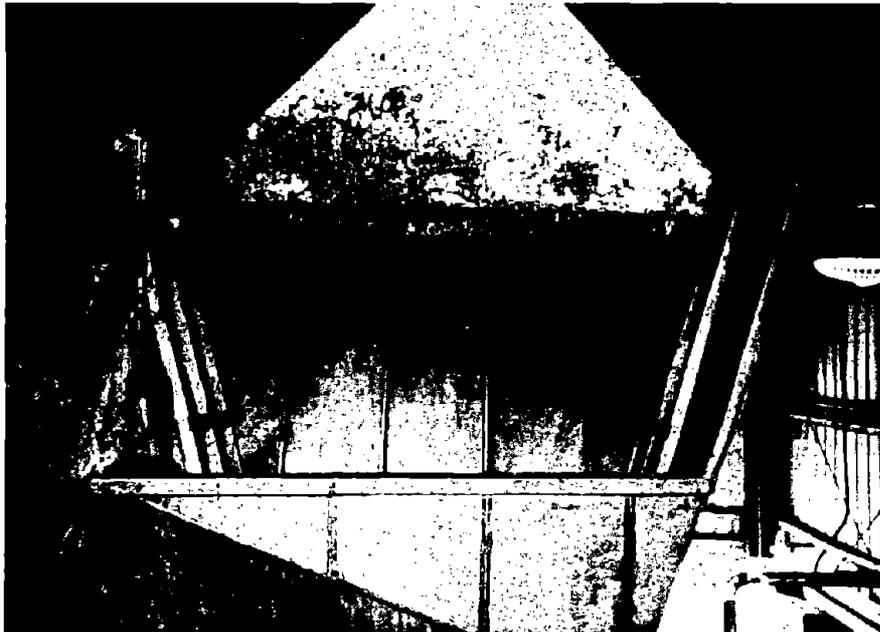


FIGURE 5C RECEIVING HOPPER AND HOOD



FIGURE 5D DUMPING BATTERY PALLET INTO HOPPER



FIGURE 5E SHREDDED BATTERIES BELOW SHREDDER

## 5.0 WORKPLACE ENVIRONMENTAL ASPECTS

This section describes Radian's observations and measurements of conditions effecting emissions, employee exposure, and safety in the new shredding operation. No observations or measurements were made on the old system, which is in the process of being dismantled. However, GBC did provide exposure data for the old system, which is presented in a later paragraph.

### 5.1 EMISSION SOURCES AND EMISSION CONTROL

Emissions during battery shredding occur at the following locations, or during the following operations:

- o Delivery of batteries to the shredding area.
- o Removal of pallets from semi-truck trailers.
- o Movement of rubber-tired forklift trucks in the area.
- o Dumping of pallets into shredder.
- o Shredding or breaking of batteries.
- o Battery parts falling from the shredder to the pile below.
- o Front-end loader operations (moving shredded battery parts to the storage area).
- o Vibration of equipment which causes secondary emissions of settled lead particulate.
- o Acid misting of broken batteries.

GBC has provided control of these emissions by:

- o Keeping the area clean through water-wetting and water cleaning.
- o Installing local exhaust ventilation on the shredder hopper.
- o Providing building enclosure and exhaust ventilating the building.

## 5.2 VENTILATION

Figures 6 and 7 show the shape and size of the hopper and collection hood. Figure 8 shows the exhaust ductwork. Figure 9 shows the positioning of exhaust ventilation in the shredder operation. Figure 10 shows a schematic diagram of the Chemico scrubber layout. Figure 11 shows the velocities measured at the hood face and in the exhaust duct during optimum operating conditions.

The Chemico Venturi scrubber is designed to handle 11,600 ACFM. The pressure drop across the venturi throat is designed to be 40 inch W.G. The scrubber utilizes 45-55 gallons of water per minute. The scrubber is equipped with a Robinson 913H fan, size 60 inch x 2 inch, designed to move 11,000 ACFM at 55 inch W.G., and is driven by a 150 HP motor.

The scrubber system is estimated to be capable of 99% collection efficiency of acid mist and particulates.

## 5.3 EXPOSURES

GBC supplied breathing-zone personnel monitoring data for exposure to lead for both the old and the new battery breaking operations. Lead samples collected at the old shear operation from 1973 through 1981 ranged from 34  $\mu\text{g}/\text{m}^3$  to 1,533  $\mu\text{g}/\text{m}^3$ .\* The mean exposure was 300  $\mu\text{g}/\text{m}^3$  (Standard Deviation = 325  $\mu\text{g}/\text{m}^3$ , N = 34) and the median exposure was 215  $\mu\text{g}/\text{m}^3$ . If the single high and low exposure measurements are eliminated, the mean exposure drops to 270  $\mu\text{g}/\text{m}^3$  (Standard Deviation = 246, N = 32).

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\* Not all samples are time weighted average measurements, particularly those taken in the earlier years. However, non-TWA samples are thought to be close to actual TWA exposures.

Eight TWA personal samples had been taken during the first four months of operation of the shredder operation. Exposure measurements ranged from 17  $\mu\text{g}/\text{m}^3$  to 733  $\mu\text{g}/\text{m}^3$ . The mean exposure was 180  $\mu\text{g}/\text{m}^3$  (Standard Deviation = 230  $\mu\text{g}/\text{m}^3$ , N = 8). The median exposure measurement was 125  $\mu\text{g}/\text{m}^3$ . If the high and low exposure measurements are eliminated, the mean exposure is 115  $\mu\text{g}/\text{m}^3$  (Standard Deviation = 43, N = 6).

Exposure measurements of the front-end loader operator before and after installation of the shredder are almost identical: 243  $\mu\text{g}/\text{m}^3$  vs 215  $\mu\text{g}/\text{m}^3$ . This is not unexpected since the method of transporting broken battery scrap is essentially the same as before.

#### 5.3.1 Discussion of Measurements

Although no statistical comparisons have been performed on the data, it appears that exposures are lower in the new shredding operation by about 50%. While not yet in compliance with the OSHA standard of 50  $\mu\text{g}/\text{m}^3$ , a significant improvement in working conditions has been accomplished by GBC. Further reductions in lead exposure can be expected when suggested improvements or modifications are implemented (see Section 7).

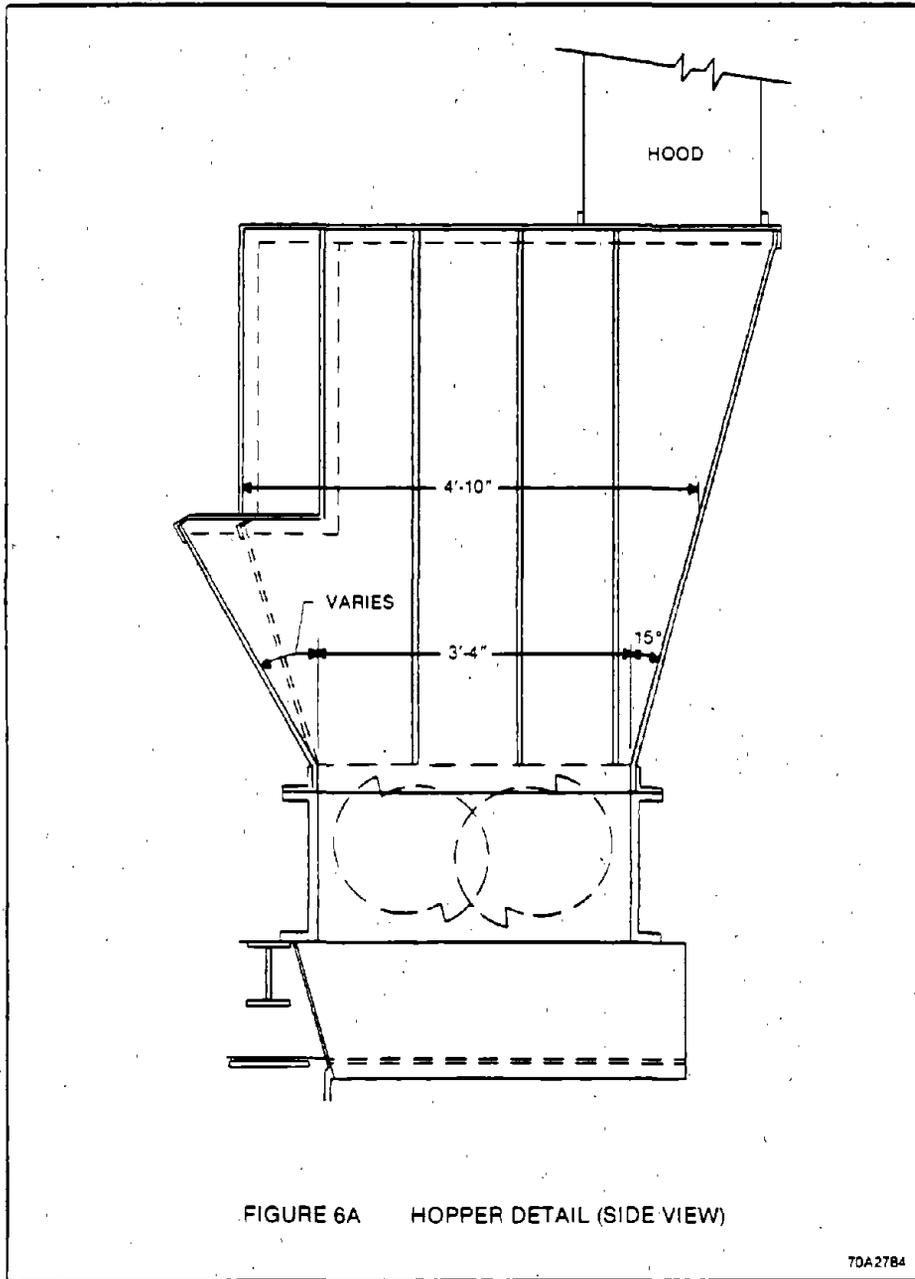
#### 5.4 SULFURIC ACID AND NOISE

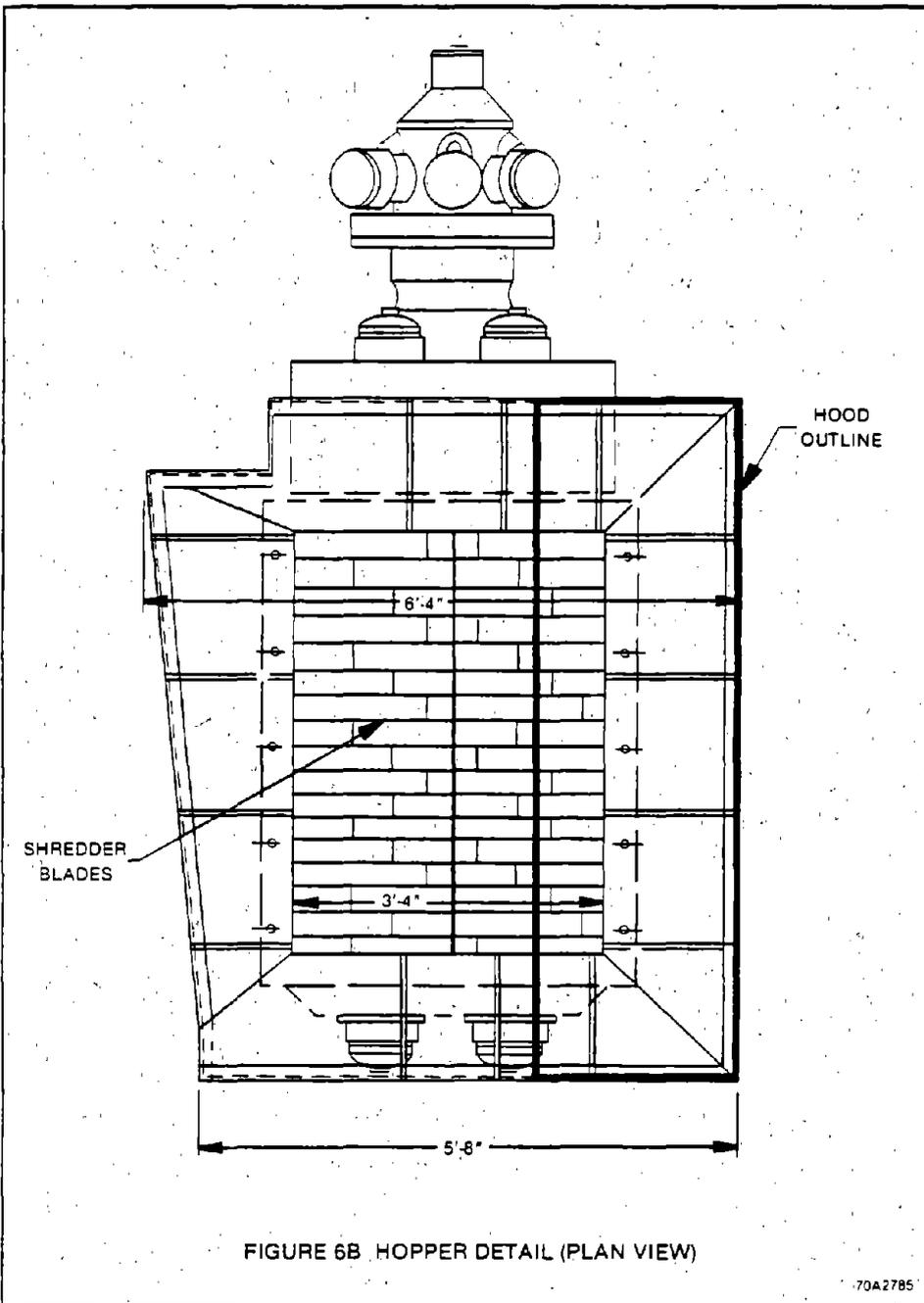
Skin contact with sulfuric acid has all but been eliminated.

#### 5.5 SAFETY

In the old operation, major safety problems involved acid burns and the pinch point of the shear. In the new system, the shredder and the forklifts are major potential safety hazards.

The shredder safety problem has been dealt with by installing a four-foot high inlet hopper wall. All forklifts are equipped with roll-over protection, (ROPS). In the first six months of operation, GBC experienced no lost-time accidents at the shredder operation.





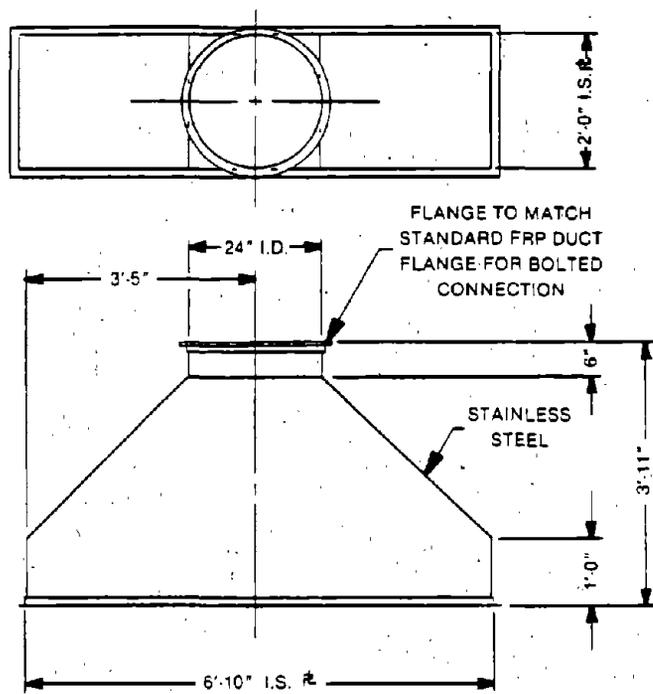
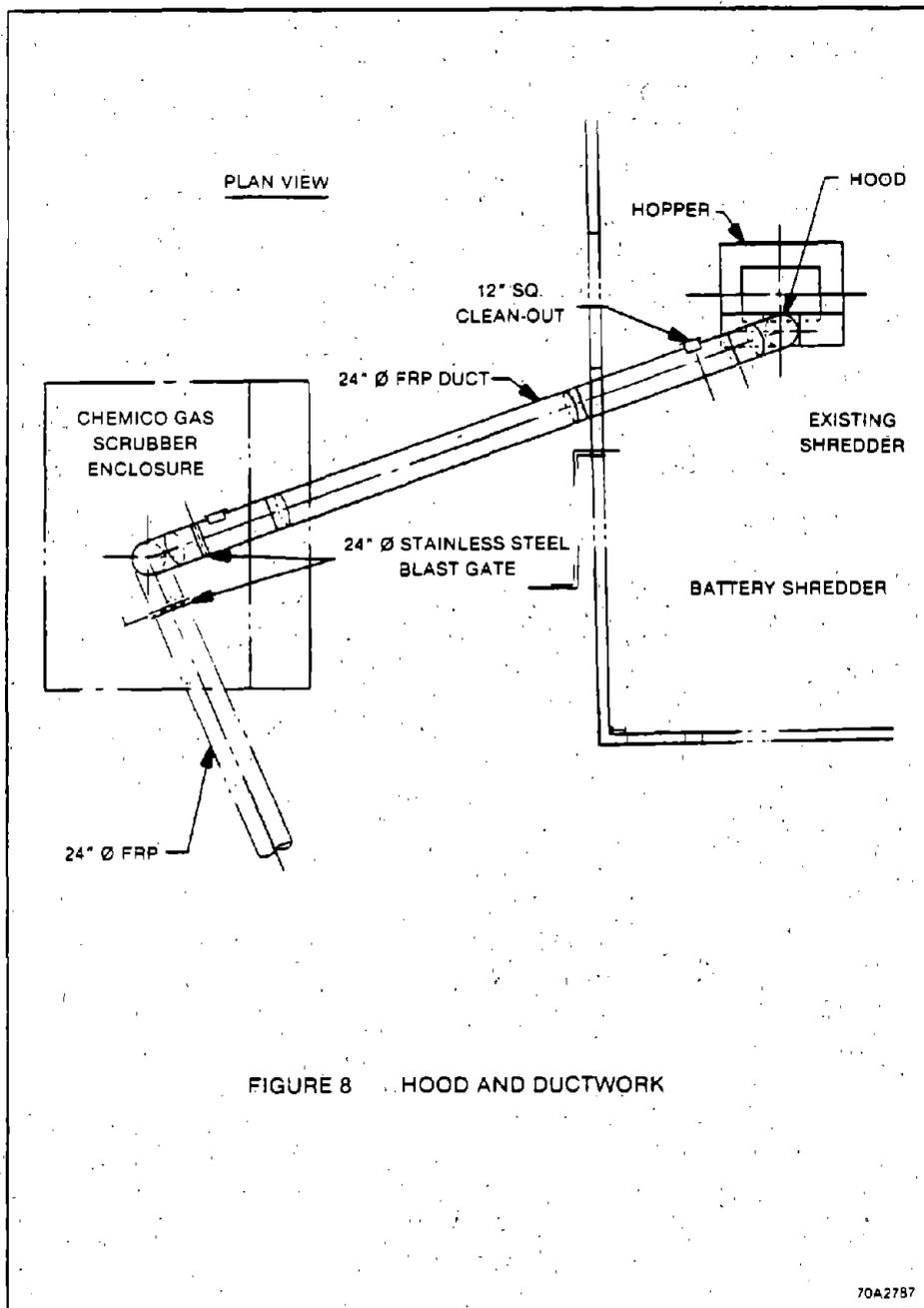
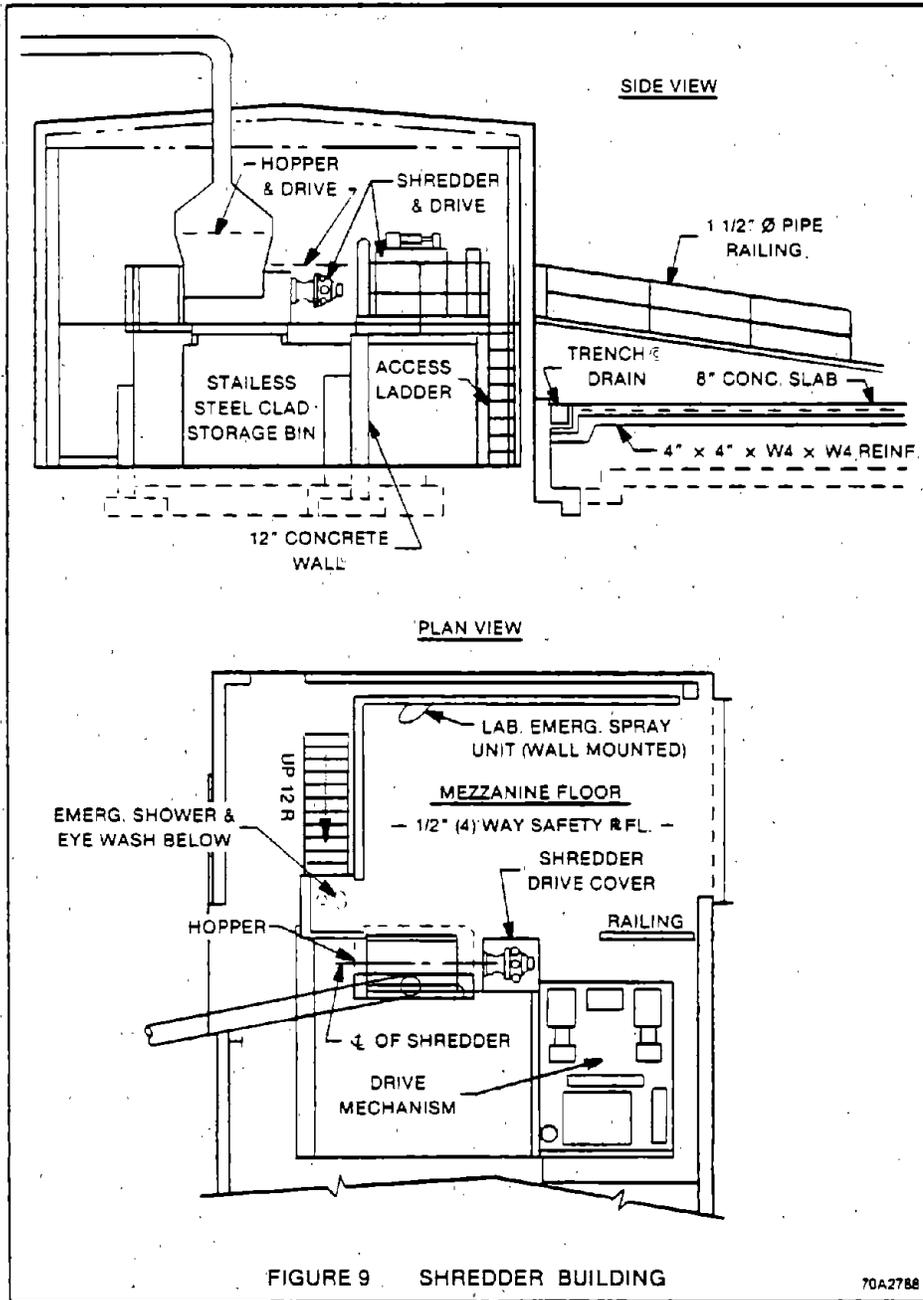


FIGURE 7 HOOD DETAIL

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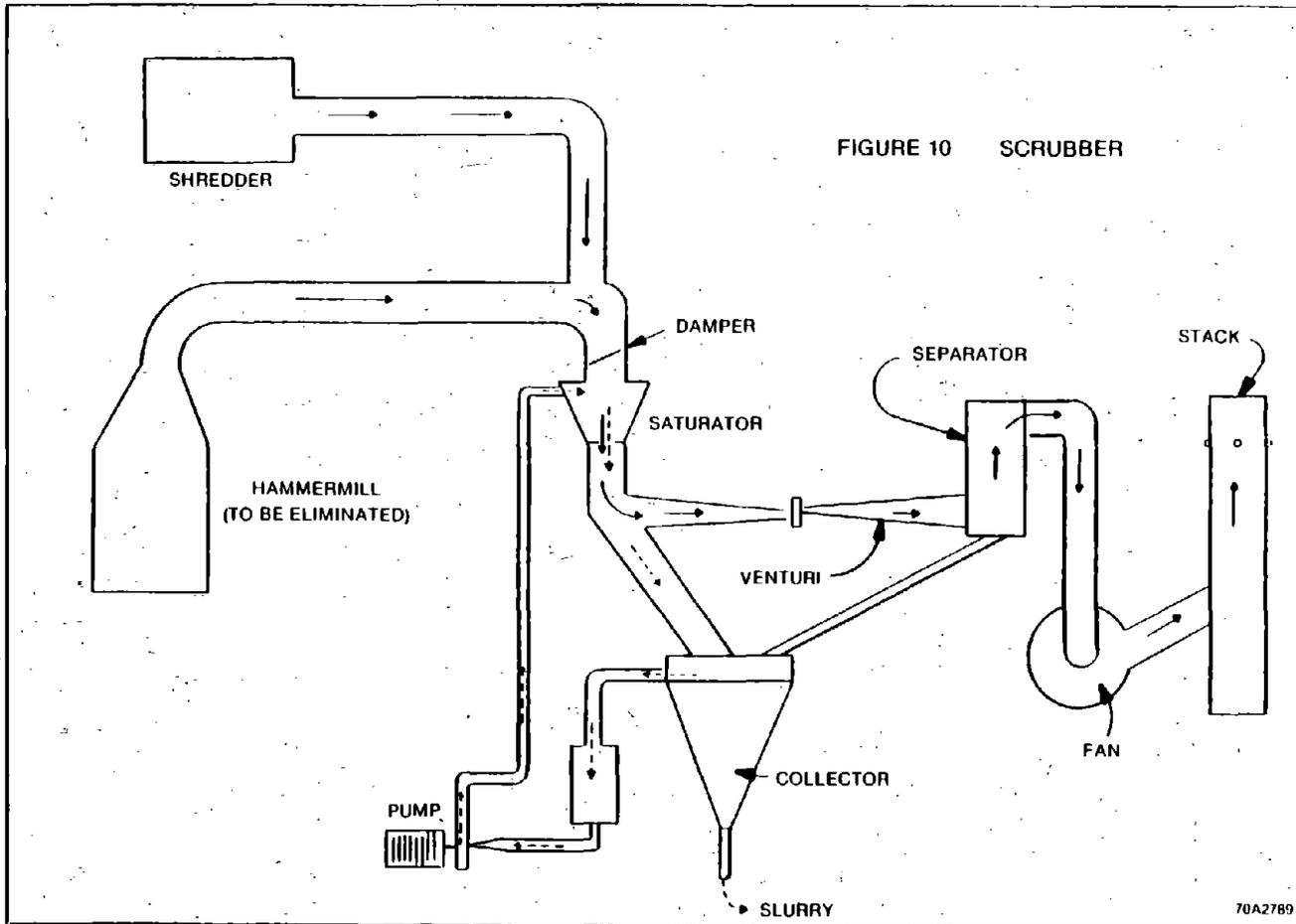
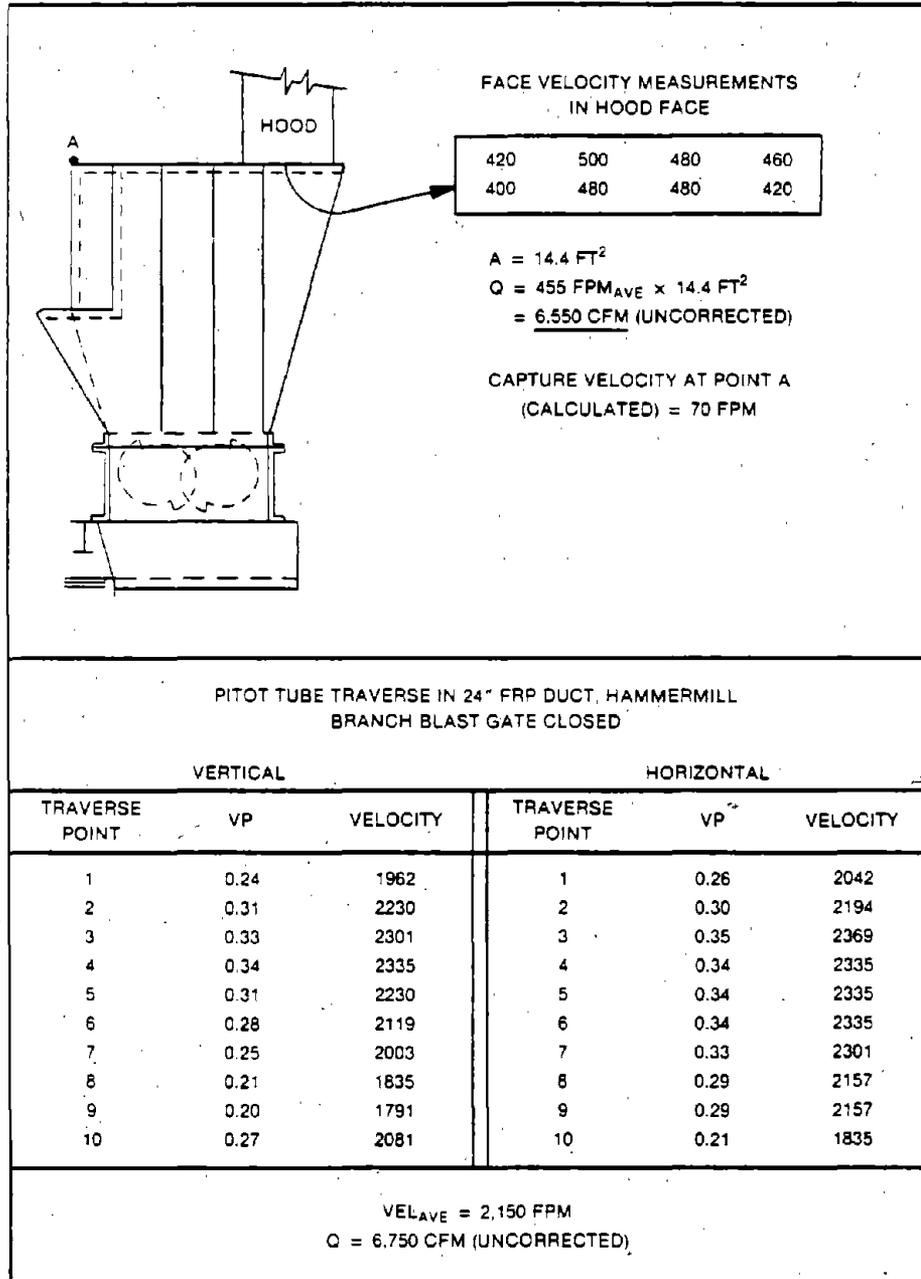


FIGURE 10 SCRUBBER

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FIGURE 11 VENTILATION MEASUREMENTS

6.0 COSTS

The entire project including design, construction, and testing cost \$450,000 (1981), of which procurement and installment of the shredder and support equipment cost \$200,000.\*

A single set of spare, stainless steel cutters costs \$30,000.

Maintenance costs for replacing three bearings totalled \$5,000.

Overall, the plant manager estimated that actual operating costs were about 50% less than for previous operations. (This does not include amortization of capital expenditures for the new system, however.) Cost savings are found in lower labor-hours-per-battery, and less maintenance labor. Energy consumption is about equal to the former operation.

The time for construction (from decision to on-line) is estimated at one year.

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\* Costs do not include cost of Chemico scrubber which was purchased in 1974 at a cost of \$84,000. Annual O & M costs associated with the scrubber are estimated by GBC at \$8,000/year (1980).

## 7.0 SUMMARY DISCUSSIONS

Based upon our observations and measurements, we would conclude that the principles of emission control demonstrated in GBC's new battery shredding operation have proven to be a significant factor in reducing employee exposures. In the following paragraphs we explore potential applications, limitations, problems and possible improvements.

### 7.1 APPLICABILITY TO OTHER OPERATIONS

The principles of low-energy shredding, isolation and enclosure, local exhaust ventilation, and employee training would find application in almost every smelting process which requires battery breaking. The shredder is capable of producing almost any size of battery scrap particle. Financial feasibility might be a problem at small smelters. Low production rates might be a problem at very large smelters.

### 7.2 LIMITATIONS AND PROBLEMS

In order to be effective, the GBC approach requires batteries to be delivered on pallets, or for batteries to be automatically unloaded from trucks and introduced to the shredder without intensive labor support. These requirements may be difficult for some smelters to accomplish.

If the batteries are old and bone-dry (no acid residual), the shredder tends to become a larger source of dust.

### 7.3 POSSIBLE IMPROVEMENTS

Radian and GBC suggest several modifications which would enhance existing operations: (See Figure 9.)

- (1) The sloped entrance ramp should be at a more shallow angle. As it is now, drivers have a difficult time navigating the ramp.
- (2) The dock and storage area should be built with a larger surface area to minimize traffic congestion, and to provide a larger area for temporary storage.
- (3) GBC suggests that a dual-entrance, "race-track" system of traffic would be safer and faster.
- (4) Movement of broken battery scrap should be made by conveyor, rather than front-end loader. GBC has this on their planning agenda.
- (5) To avoid falling and splashing emissions, GBC could install a ramp, or slide, under the shredder discharge. See Figure 12.
- (6) Better capture characteristics might be attained by repositioning the capture point of the hood, or by enclosing the hopper more completely. An example is shown on Figure 13.

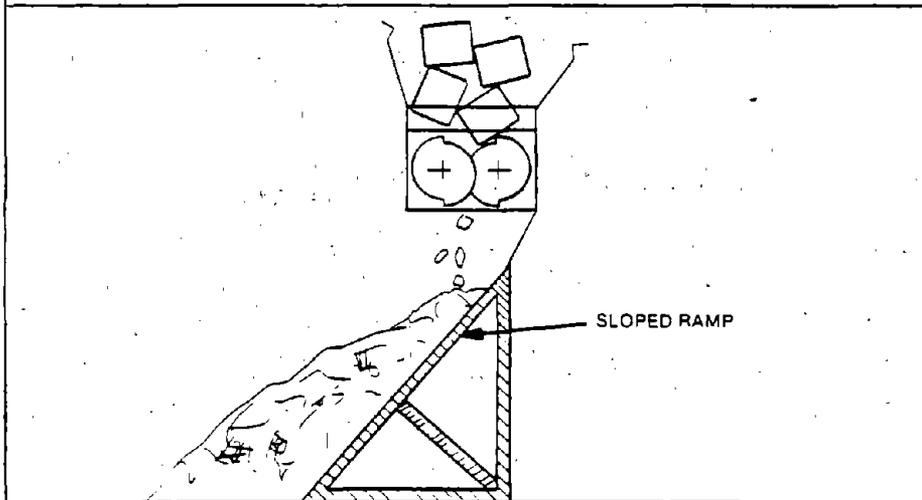
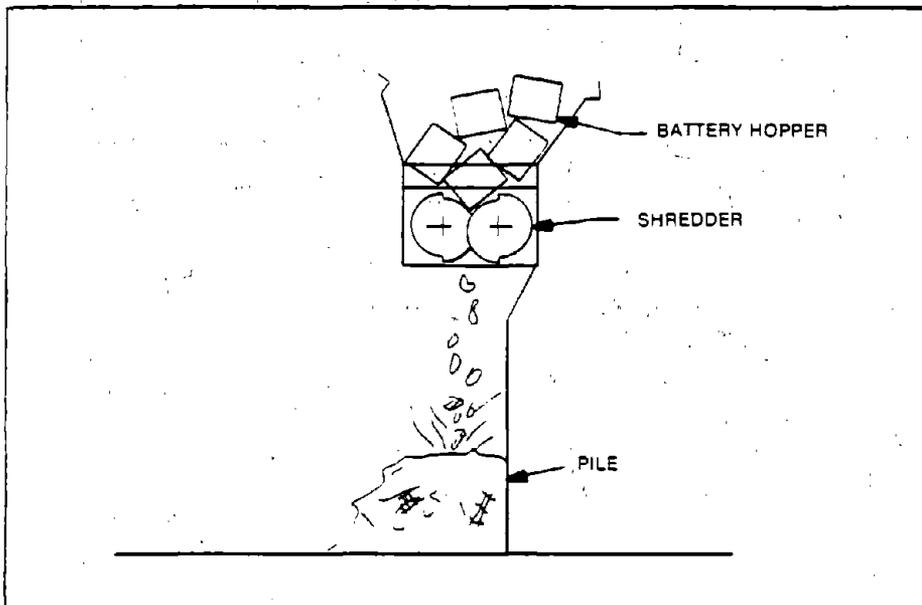
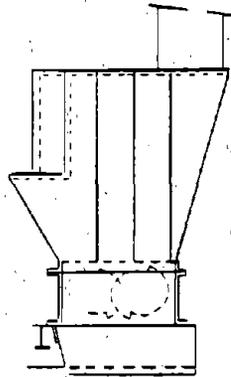


FIGURE 12 USE OF SLOPE TO MINIMIZE CONVERSION OF KINETIC ENERGY TO EMISSION ENERGY

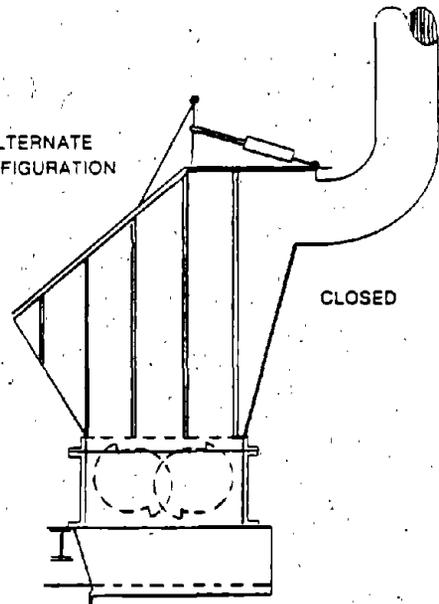
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FIGURE 13 ALTERNATE HOODING



EXISTING CONFIGURATION

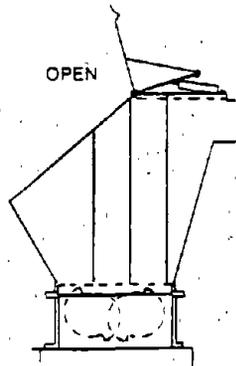
ALTERNATE CONFIGURATION



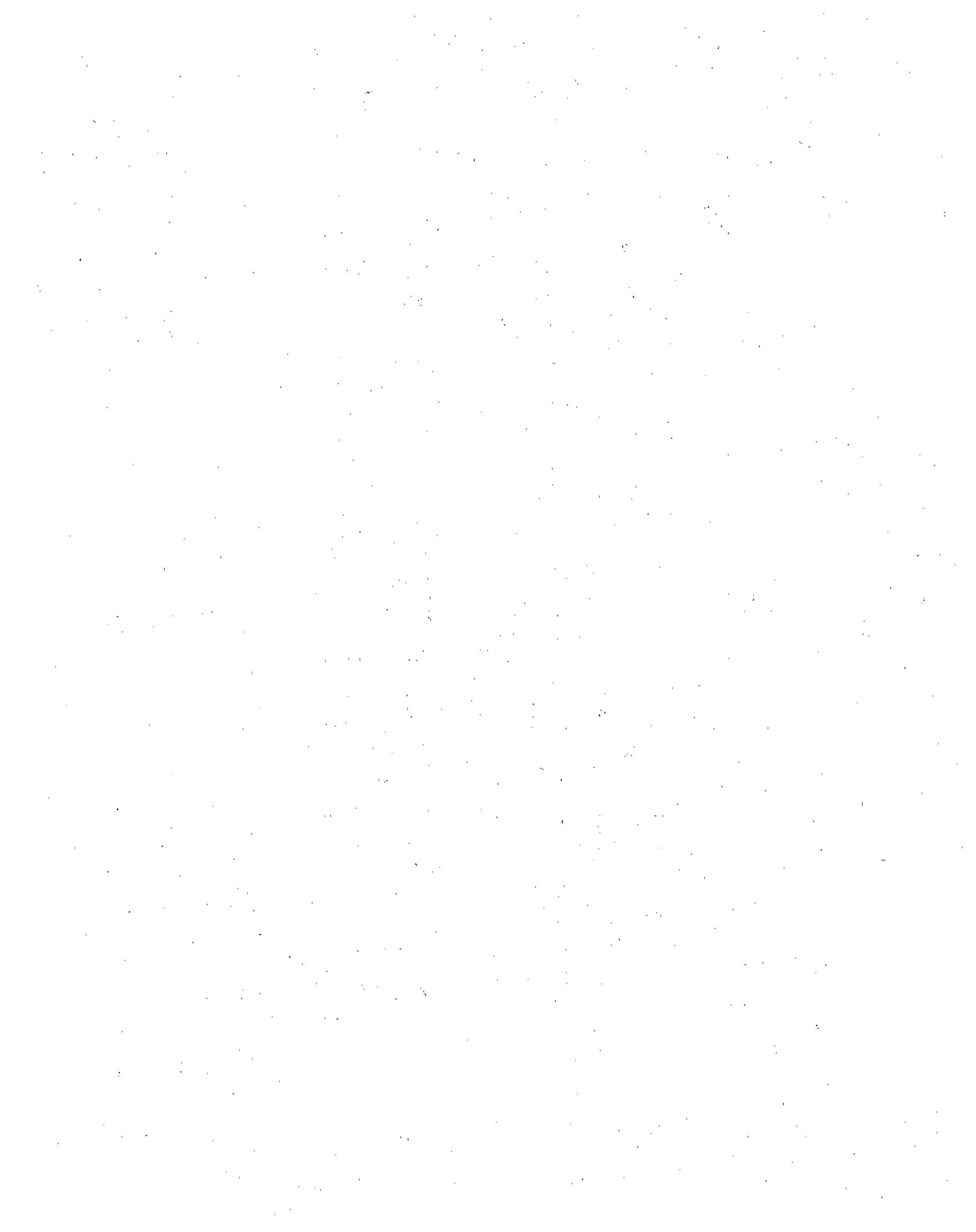
CLOSED

HYDRAULIC DOOR  
OPENS FOR LOADING,  
CLOSES FOR  
EMISSION CONTROL  
DURING SHREDDING

OPEN



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A P P E N D I X



JOB DESCRIPTION AT SHREDDER OPERATION

JOB TITLE: Battery Breaker

PRIMARY DUTY: Remove scrap from junk batteries.

WORKING PROCEDURE: Unload batteries from truck or yard and place onto conveyor. Turn batteries on side, under shear, actuate battery breaking machine, shearing the cover. Completely dump metal bearing material from sheared cases and place empty cases on conveyor to be crushed. Batteries unable to be sheared will be moved to acid draining area, dumped and where possible remove metal bearing material. At the end of the shift wash the entire conveyor and machine. Clean the work area. At times unload scrap groups from trailer and pile or pick up junk batteries. Clean acid sumps as necessary. At times dismantle industrial batteries. Perform other miscellaneous duties as necessary to the operation.

JOB TITLE: Battery Breaker Leader

PRIMARY DUTY: Coordinate the work, direct and assist crews in all phases of the Battery Breaker.

WORKING PROCEDURE: Check the operation and give instructions concerning work to be performed. Assign crew members to various miscellaneous duties as required to facilitate obtaining maximum production. Position trucks loaded with batteries to be broken, remove empty trucks to proper location. Insure that battery plates, tops, crushed cases and industrial scrap are removed to proper location. See that acid sumps are kept operating and acid flow lines are clear. Direct and assist in cleaning the equipment and work area. Perform maintenance work where possible and assist smelter maintenance department when necessary. Perform any job on the operation and any other miscellaneous duties as necessary to the operation.

JOB TITLE: Material Handler - Battery Breaking

PRIMARY DUTY: Position full semi-trailers at breaker unloading conveyor and remove when emptied.

WORKING PROCEDURE: Hook up full trailer and pull to scale at gate.

Weigh full trailer and pull to stand-by area.

Unhook trailer and drive to empty trailer.

Remove empty trailer from conveyors and pull to scale.

Weigh empty trailer and pull to storage area to be washed and cleaned out.

Hood up and position full trailer at breaker unloading conveyors.

Use front-end loader to clean-up and dispose of wet groups from cases.

Maintain acid sump and flow lines.

Cut strapping in truck.

Move empty skids.

Assist in handling poly or truck and bus batteries.

Set up or adjust extra lengths of conveyor.

JOB TITLE: Yard Laborer - Driver

PRIMARY DUTY: Operate trucks and lift trucks and perform a variety of unloading, loading, transferring and cleaning duties.

WORKING PROCEDURE: Varies, depends on work being performed. Operate tractor trailer, panel truck, etc. as required and assist in performing the following duties: Unload, transfer, and dispose of soda ash bags. Use hand truck to transfer drums of caustic soda. Use electric hoist to raise caustic drums to second floor level. Return empty drums to storage area. Unload coke and iron ore. Unload junk batteries, and pile in yard. Unload scrap groups from drums or bulk load. Unload lead wherever needed in smelter or plant. Use derrick to dismantle industrial batteries. Reload junk batteries to transfer to battery breaker. Load, unload and transfer any materials that are required for smelter. Take counts or check weights

of all materials trucked to smelter and report same to smelter office. Use electric jack truck to transfer lead from storage to all usage areas throughout the plant. Remove scrap lead from production areas, weigh, record weight and transfer to smelter. Unload new cases. Segregate rejected cases for inspection by the supplier. Gather and segregate pallets. Unload, transfer, gather and load returnable drums as required. Clean yard areas. Perform other miscellaneous duties as required.

JOB TITLE: Saturn Crusher - Yard Jockey

PRIMARY DUTY: Position loaded semi-trailers at Saturn Crusher dock and remove when required.

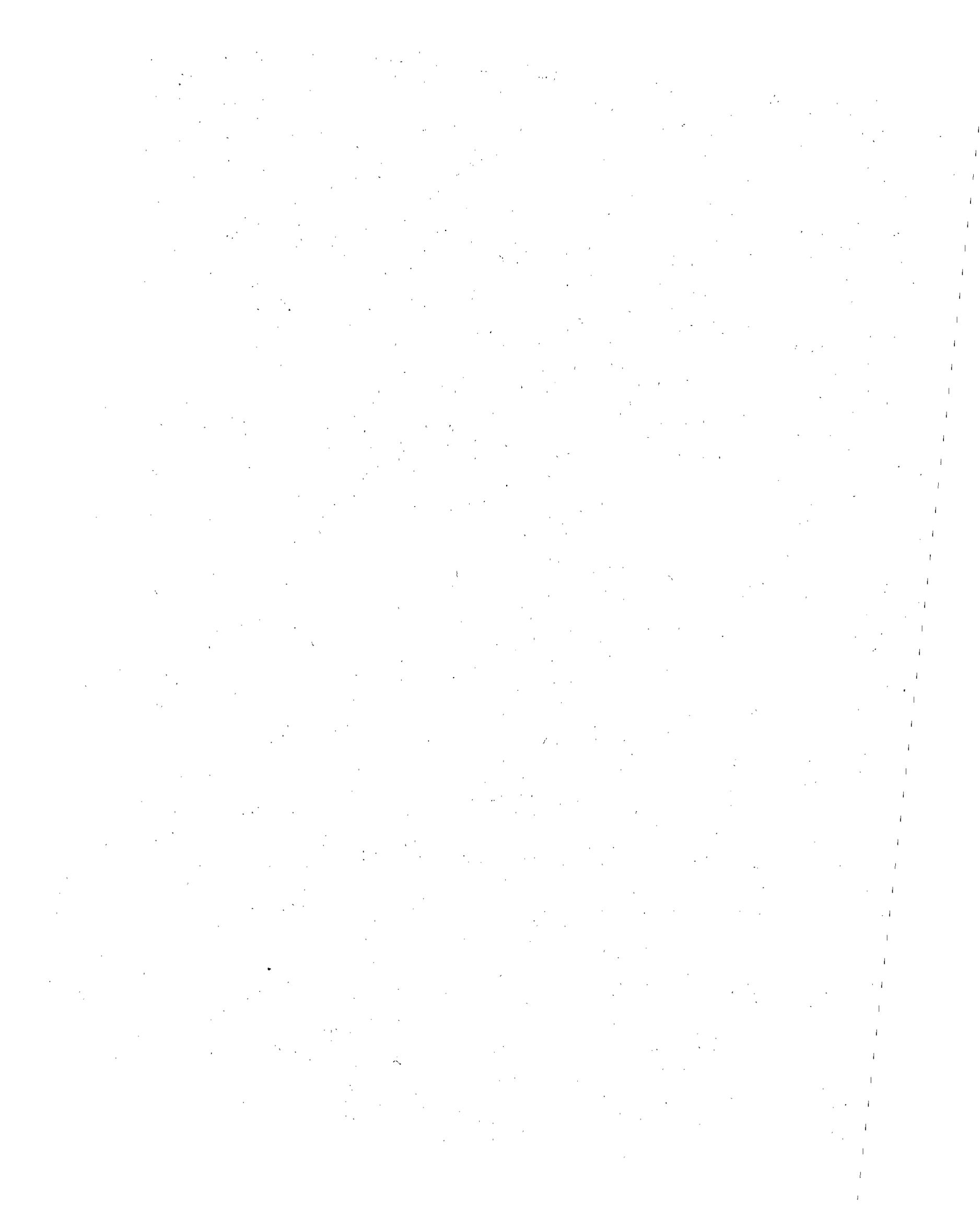
WORKING PROCEDURE: Hook up loaded trailer and transport to weigh station. Weigh trailer and return to trailer staging area. Drop loaded trailer and hook up to empty trailer at Saturn Crusher dock. Transport empty trailer to weigh station, weigh trailer and return it to wash rack at saturn area. Hook up full trailer and spot at Saturn Crusher dock. Additional duties include performing routine driver maintenance to assigned vehicle, assisting in handling poly, truck and bus batteries, using front end loader to maintain area and disposing of wet groups from cases, monitor acid sump and flow lines and to removing empty skids. Perform miscellaneous duties as necessary to the operation. All work performed must be done within the guidelines of established safety rules and regulations.

JOB TITLE: Yard Laborer

PRIMARY DUTY: Perform a variety of unloading, loading, transferring and cleaning duties throughout the plant.

WORKING PROCEDURE: Varies depending on the work being performed. A group of employees perform the following duties: Get 50 pound bags of lime and empty into lime machine. Dispose of empty bags. Use hand truck to transfer drums of oxide from mill to platform at mixing operation. Use electric hoist to raise drums to 2nd floor level. Return empty drums to the Mill. Use electric jack truck to transfer lead from storage to all usage areas throughout the plant. Remove scrap lead from production areas, weigh record weight and transfer to the smelter. Unload coal, coke and iron ore. Unload junk batteries and pile in yard, unload scrap groups either from drums or from bulk loads requiring the use of a wheelbarrow to move to end of truck and dump. Unload new cases by moving skid loads to end of truck for pick up by lift truck. Unload and pile in storage or place on skids. Unload master pack acid, cartons, caustic soda, etc. Unload bus and industrial batteries. Unload steel for spark plugs. Use derrick to dismantle industrial batteries. Reload junk batteries for transfer to the breaker. Gather, and segregate pallets. Segregate rejected cases for inspection by supplier. Clean yard areas and incinerator. Gather and load returnable drums. Load and unload and transfer any item as required. Perform other miscellaneous duties as required.





DCN# 81-204-023-04

RETROFIT APPLICATION OF A  
CONTROLLED-ENVIRONMENT OPERATOR'S CAB  
TO A RUBBER-TIRED FRONT-END LOADER

Demonstration No. 2  
Final Technical Report

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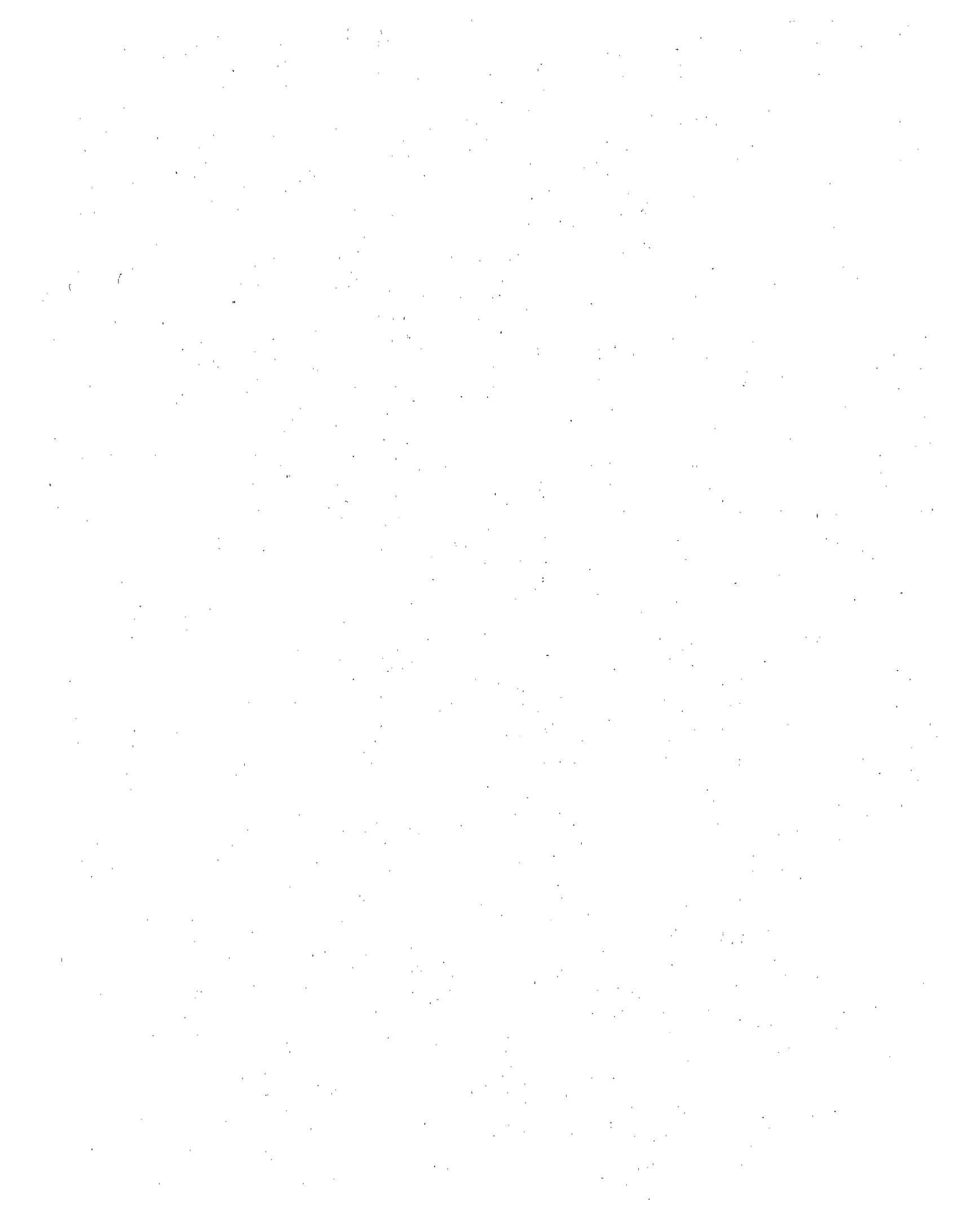
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## ACKNOWLEDGEMENTS

Radian Corporation greatly appreciates the work of General Battery Corporation, Palm Industries, and Donaldson Company. Special thanks go to John Bitler and Neal Lebo at General Battery, to Robert Kløver and Mike Bramyl at Palm, and to John Hacker at Donaldson.



## 1.0 INTRODUCTION

This report describes the progress of a demonstration project to design, build, and evaluate a retrofitted, controlled-environment operator's cab on a front-end loader (hereafter referred to as a "CE cab"). A CE cab provides tempered clean air to the operator's breathing zone. Basic components of a CE cab include temperature control equipment, air cleaning devices, and air-moving equipment.

### Background to the Project

The OSHA standard mandates the control of employee exposures to below 50 ug lead/m<sup>3</sup> air.

Employers are encouraged to comply through engineering and administrative controls, e.g. local exhaust ventilation, housekeeping, employee rotation, and process modifications. One effective engineering control approach is to provide small "islands" of clean, fresh air. (See Demonstration Project No. 3, Supplied-air Islands, and Demonstration Project No. 11, Stand-by Pulpits.) The same approach is possible for the protection of mobile equipment operators. Typical mobile equipment in use at secondary smelters includes front-end loaders, forklifts, trucks, and sweepers, all of which are equipped with operator's cabs or overhead guards.

Radian's contact with the secondary smelter industry suggests that a few smelters have attempted to build exposure-protective cabs, but have had little lasting success. Major problems have included:

- Under-designed filter systems.
- Under-powered air moving equipment.

- Inadequate placement of air distribution and return systems.
- Inadequate operator control of temperature and air velocity.
- Excessive noise.
- Under-designed heating and cooling systems.
- Inadequate clearance and space within the mobile equipment for installation of environmental systems.
- Poor operator practices, e.g. keeping windows and doors open.
- Poor housekeeping.

These problems and their potential solutions as studied in this project are discussed in Section 3.

#### Objectives of the Project

The project was designed to investigate, design, build, evaluate, and characterize the operation of a controlled-environment operator's cab retrofitted to a front-end loader.

The objectives of the project were (1) to determine the level of lead exposure control provided by the CE cab, and (2) to provide useful technical, cost, and operational information to smelter operators to help them evaluate the transferability of the demonstrated technology to other smelting locations.

#### Approach to the Project

Table 1 provides a summary of eleven tasks Radian planned to perform during the project.

As described in detail in Section 3, General Battery Corporation (GBC) agreed to fund the construction and

Table 1. SUMMARY OF PROJECT TASKS

| <u>Task No.</u> | <u>Task</u>   |
|-----------------|---|
| 1               | Planning (site-visits, task plan development, equipment selection)                |
| 2               | Literature Search   |
| 3               | Industry Contact (Who has already built such equipment?)                          |
| 4               | Mobile Equipment Manufacture Contact (Who has built such equipment?)              |
| 5               | Initial On-site Study (exposure levels, equipment evaluation)                     |
| 6               | Selection of Subcontractors (design, construction, and installation of equipment) |
| 7               | Conceptual Designs  |
| 8               | Construction and Pre-installation Testing   |
| 9               | Installation and Shakedown  |
| 10              | Post-installation On-site Study and Evaluation                                    |
| 11              | Reporting   |

installation of a CE cab. Subsequently, Clark Equipment Corporation, Palm Industries, and Donaldson Company all participated in the construction of the CE cab.

Unfortunately, due to unforeseen problems and delays, Tasks 9 and 10 were not fully completed as of the close of Radian's contract with NIOSH. However, pre-installation tests of the CE cab suggest that all of the major obstacles have been overcome and that the cab should perform effectively after installation and shakedown.

This report presents the progress to date and a summary of project activities and findings.

#### Results of Industry Contacts and Literature Search

Twenty-three secondary lead smelters were contacted regarding the use of environmental cabs on forklifts and other mobile equipment for reduction of lead exposure. Nineteen responses were received. Of the 19 smelters responding, four use or have used environmental cabs. Of these four, one indicated that the cab seemed to "work well" when first operating, but all four said they had experienced operating and maintenance problems. One source complained that workers considered the cab uncomfortable and would not usually use it. Currently, no secondary smelter has an operating, effective CE cab.

Of eleven contacts with cab and mobile equipment manufacturers and suppliers, none could point to a successful, currently operating retrofitted cab. (New equipment has been successfully designed and built with environmentally controlled cabs, however.)

A literature search was conducted but yielded little relevant information. Two reports of studies performed on

controlled-environment cabs used on mining equipment were received from the Bureau of Mines, however, neither report contained information directly useful to this project.\*

---

\* Kaisko, W. J. Develop and Test Canopy Air Curtain Devices, Bureau of Mines, Publication No. PB-246-041, June 1975. (Available from NTIS, Wash. D.C.)

Billmeyer, H. J. and Hacker, J. Engineering Evaluation of Environmental Cabs for Control of Dust and Other Health and Safety Factors, Bureau of Mines, Nov. 1981. (This document is in a draft stage and is not generally available for duplication or reproduction, and has not been quoted or used in this report.)

## 2.0 EQUIPMENT SELECTION

GBC supported the project by supplying a piece of mobile equipment at its Reading, Pennsylvania plant, and assumed the cost of the retrofit.

To assist smelter operators in determining the transferability of the technology to their plants, a short description of GBC's Reading plant is provided below.

### Plant Description

General Battery Corporation's Reading plant is located in eastern Pennsylvania. The plant produces hard and soft lead ingots and antimonial alloys in two identical blast furnace-reverberatory furnace installations. Scrap industrial and SLI batteries are the major raw materials.

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. Lead emissions from battery manufacture as well as vehicular traffic contribute to high ambient lead levels around the plant.

Figure 1 is a plot plan of the 30-acre plant site. The plant is in a north-south valley. The smelter is situated on the western boundary of the plant. North of the smelter is a paved area approximately 300 x 600 feet where batteries are stored. Vehicular traffic is fairly heavy in and around the plant, especially around the southern and eastern boundaries. A major plant access road runs north and south immediately to the east of the smelter. The road is paved except for points where it crosses the battery storage and former landfill areas.

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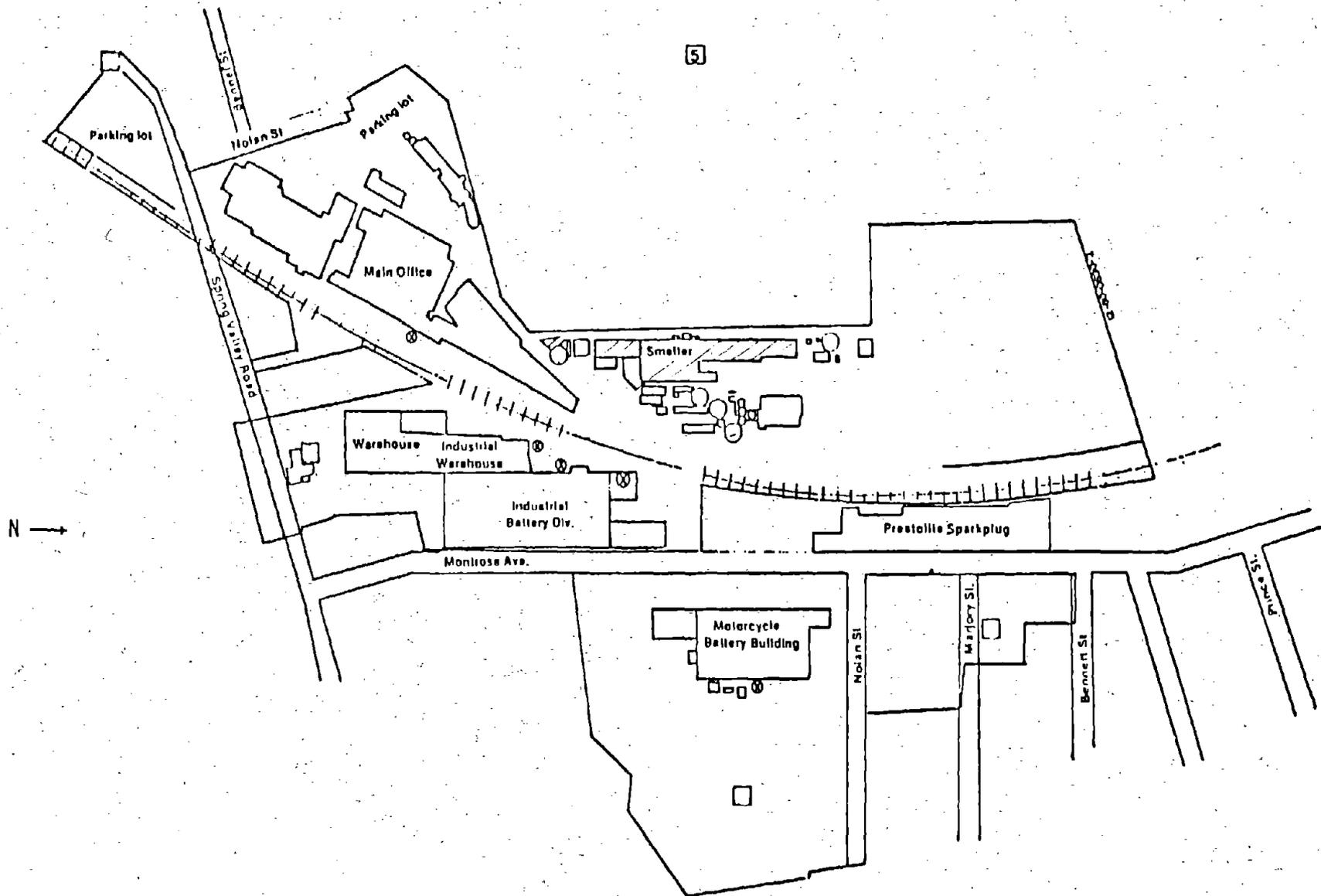


FIGURE 1. PLOT PLAN FOR GENERAL BATTERY CORPORATION'S READING PLANT.

As shown in Figure 2, material flow through the smelter generally occurs 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.

#### Selection of a Front-end Loader

The smelter uses a variety of mobile equipment. Table 2 presents a summary of the numbers and types of mobile equipment used for materials transport in the storage yard. Figure 3 shows pictures of the equipment.

In order to select a suitable piece of equipment for retrofit, Radian conducted an on-site investigation of the mobile vehicles in use. The Walden machines and the Datsuns were determined to be poor candidates because of their small size, small engines, and restricted access to power trains. Furthermore, employee work practices did not lend themselves to protection through engineering controls, i.e., only a small percentage of a worker's time was spent using the mobile equipment. Both Clark machines appeared to be acceptable candidates for a retrofit application of ventilation. The Michigan 45C is used one shift per day (allowing 16 hours per day for modifications) and its operator is the most consistent operator, i.e., he stays in the machine most of the shift.

Therefore, Radian recommended a project to retrofit a Clark/Michigan 45C with an EP cab.

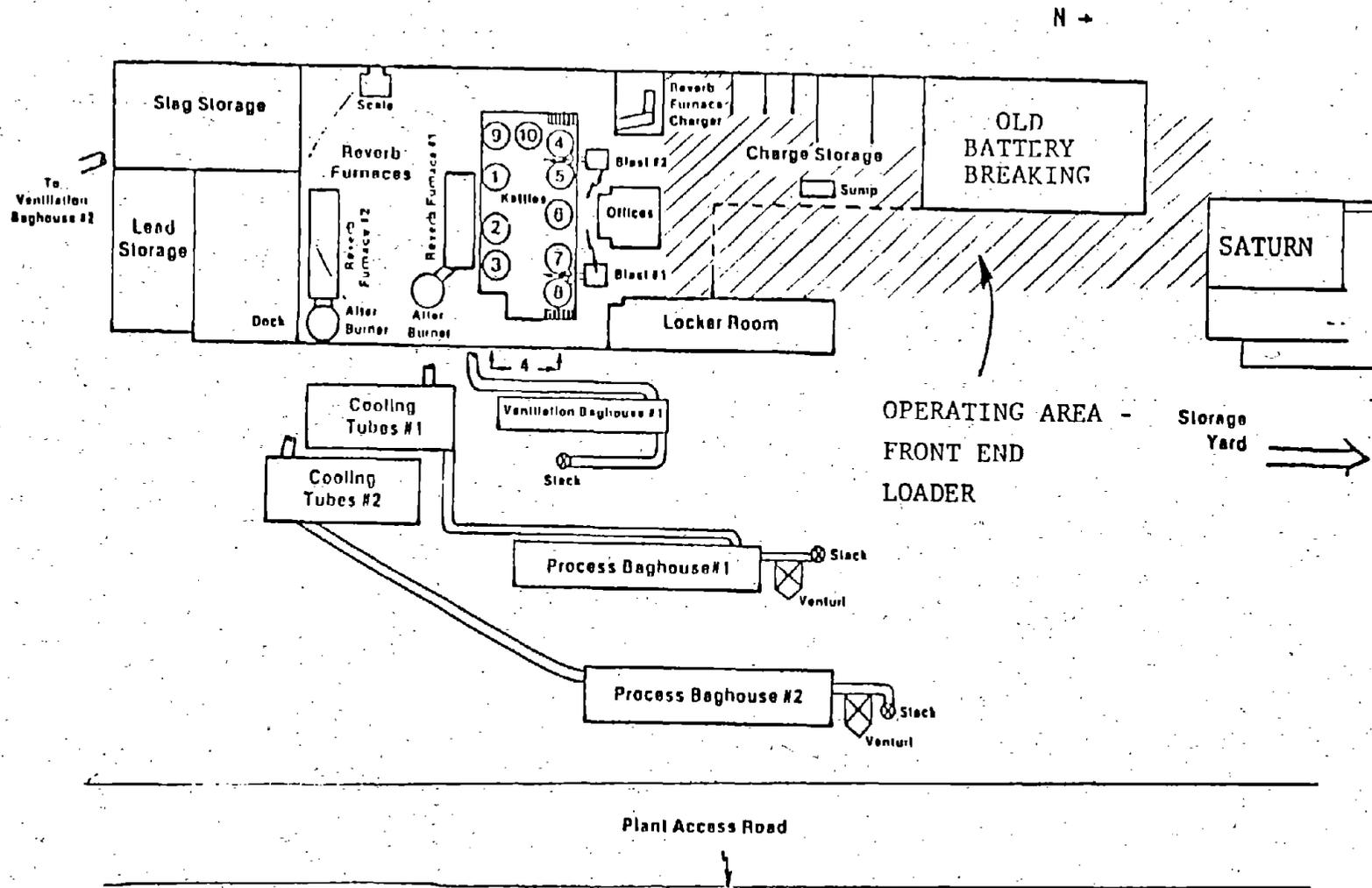


FIGURE 2. SMELTER PLOT PLAN FOR GENERAL BATTERY

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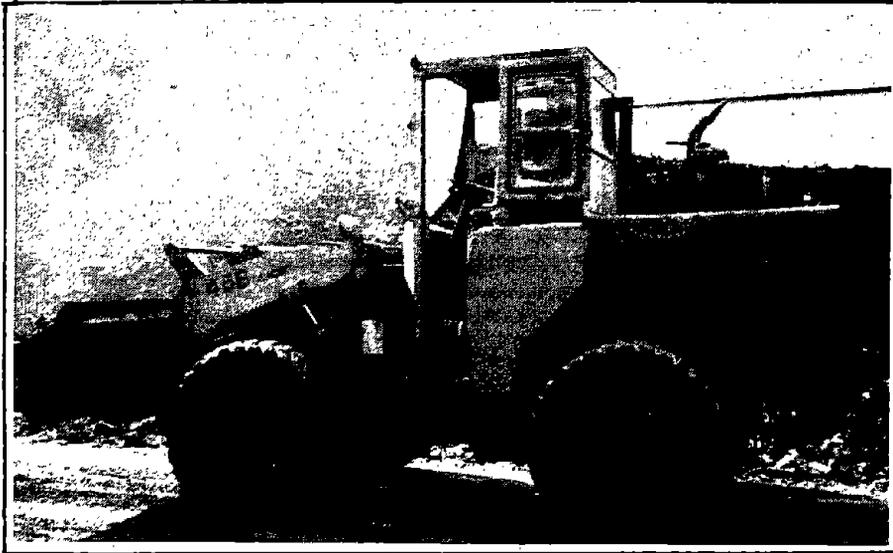
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Table 2. MOBILE EQUIPMENT\*

| <u>Brand Name</u>          | <u>No. of Wheels</u> | <u>Center Articulated</u> | <u>ROPS/Cab**</u> | <u>No. of Vehicles</u> | <u>Type of Vehicle</u> |
|----------------------------|----------------------|---------------------------|-------------------|------------------------|------------------------|
| Walden                     | 4                    | Yes                       | No/No             | 2                      | Fork-lift              |
| Walden<br>6000             | 4                    | Yes                       | Yes/No            | 1                      | Scoop/Bucket           |
| Michigan<br>45B<br>(Clark) | 4                    | Yes                       | Yes/Yes           | 1                      | Front-end<br>Loader    |
| Michigan<br>45C<br>(Clark) | 4                    | Yes                       | Yes/Yes           | 1                      | Front-end<br>Loader    |
| Datsun<br>6000<br>(Nissan) | 4                    | No                        | Yes/No            | 4                      | Fork-lift              |

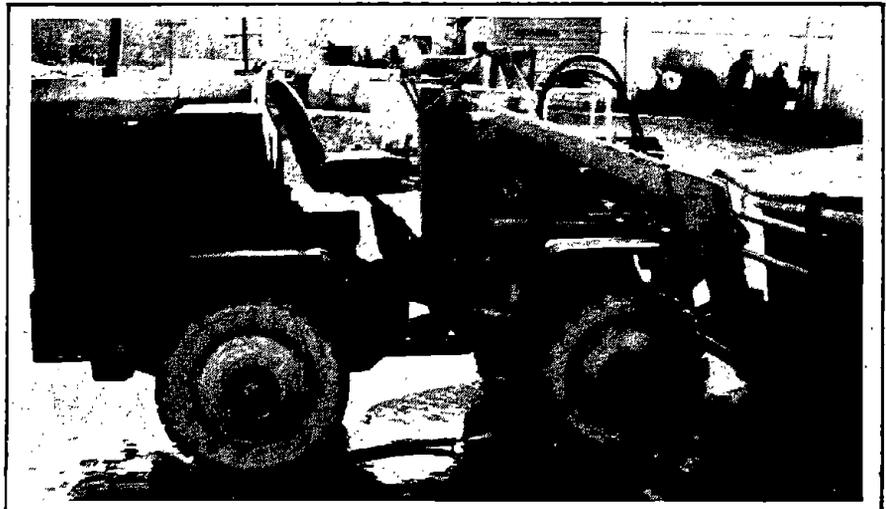
\* All vehicles are rubber-tired. None have ventilated cabs.

\*\* Roll-over protective structures attached.



CLARK/MICHIGAN  
45B,C

FIGURE 3. MOBILE EQUIPMENT AT GBC



WALDEN



DATSUN

### 3.0 DESIGN AND CONSTRUCTION

This section describes design and construction approaches used to build a CE cab for the Clark/Michigan 45C front-end loader. Section 1.0 briefly introduced problems which must be overcome in order to assure protection of the equipment operator. This section expands on those problems and describes the steps taken to solve them.

#### Environmental Considerations

Prior to design, it is necessary to understand the required effectiveness of the control equipment.

Table 3 presents the results of air-sampling performed by GBC and Radian.

Based on data presented in Table 3, the following conclusions can be reached:

- (1) Average breathing zone concentrations must be reduced by 97% to achieve compliance (i.e., 1,775 ug/m<sup>3</sup> reduced to 50 ug/m<sup>3</sup>).
- (2) Peak breathing zone concentrations must be reduced by 99% to achieve compliance at all times (i.e., 6,755 ug/m<sup>3</sup> reduced to 50 ug/m<sup>3</sup>).
- (3) Average outside lead-in-air concentrations must be reduced by 90% to reach the P.E.L (i.e., 525 ug/m<sup>3</sup> reduced to 50 ug/m<sup>3</sup>).
- (4) Inside-the-cab lead-in-air concentrations must be reduced by 80% to reach the P.E.L. (i.e., 255 ug/m<sup>3</sup> reduced to 50 ug/m<sup>3</sup>).

Table 3. Air Sampling on Front-end Loader

| <u>Date of Sampling</u> | <u>Source</u> | <u>Type of Sample*</u> | <u>Location of Sample</u> | <u>Lead-in-air ug/m3</u> |
|-------------------------|---------------|------------------------|---------------------------|--------------------------|
| Dec. 1981               | Radian        | Area                   | Outside Cab               | 644                      |
|                         |               |                        | Inside Cab                | 255                      |
|                         |               |                        | Outside Cab               | 409                      |
| June-Oct. 1981          | GBC           | BZ, TWA                | (Worn by                  | 132                      |
|                         |               |                        | Operator,                 | 6,755                    |
|                         |               |                        | working in                | 3,168                    |
|                         |               |                        | and out of                | 91                       |
|                         |               |                        | cab.)                     | 303                      |
|                         | 196           |                        |                           |                          |
|                         |               | BZ AVERAGE             | 1,775                     |                          |

\* Area - Area Samples.  
 BZ, TWA - Breathing Zone, Personal Samples,  
 Time-weighted Average exposure.

These data point to a final conclusion that effective and efficient air cleaning is required if compliance is to be approached.

### Selection of Filter

In order to be effective over time, it was determined that the air cleaning system must meet the following conditions:

- (1) The filter system must be capable of 95-99% collection efficiency.
- (2) It should be easily accessible and easily replaced.
- (3) It should be reliable and have a relatively long life, e.g. remain in service for several weeks before replacement.
- (4) It should be reasonably inexpensive.
- (5) It must be able to withstand a light load of sulfuric acid.

Radian and GBC arranged for filter development by the Donaldson Company of Minneapolis, which, in conjunction with the cab design people, developed three filters for testing - one off-the-shelf filter, one order-required filter, and one special-construction HEPA filter.

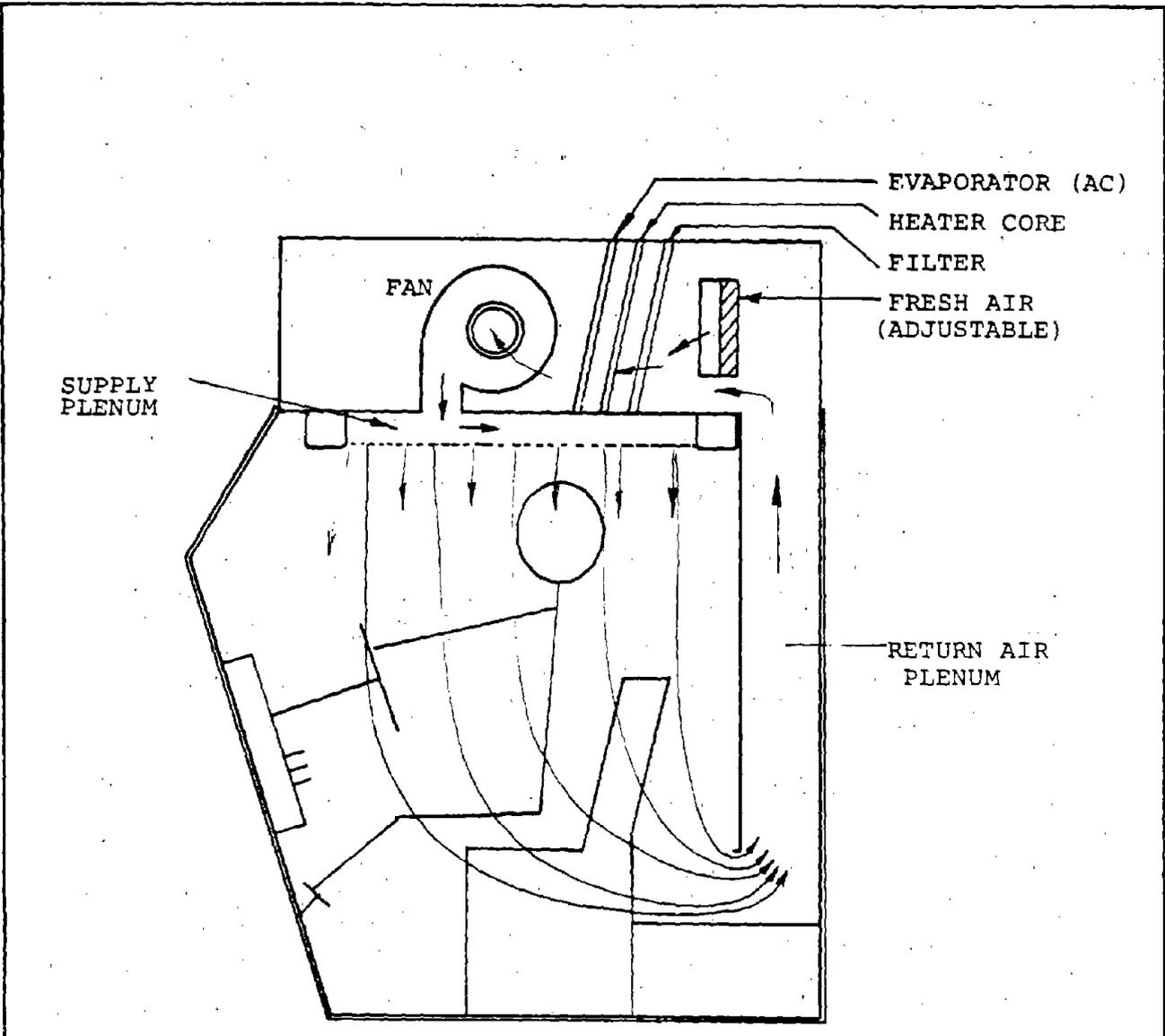
Filters are of the canister type and are easily handled and replaced. (See Figure 10.)

## Air Distribution and Return in the Cab

An "island" of fresh/filtered and tempered air is the exposure protection mechanism. Air flow must be designed to maintain the integrity of the island during all normal operating conditions.

Figure 4 shows the approach taken. Features of the design include:

- (1) A distribution plenum and perforated plate is used to provide even air flow across the cab. The perforated plate fits over most of the roof area of the cab. The pressure drop across the 20% open, perforated plate distributes the inlet static pressure across the entire face of the plate, providing an even distribution of supply air across the face area of the cab at the operators head.
- (2) Design air flow volume is 100 fpm per square foot of face area ( $Q = 100 \text{ fpm}/10 \text{ sq. ft.} = 1000 \text{ cfm}$ ).
- (3) The supply system is equipped with an adjustable fresh air supply valve capable of supplying 0-100% fresh air. This approach serves three purposes: it allows for conservation of energy at low or high ambient temperatures, it allows a positive pressure to be created in the cab thus avoiding infiltration of contaminated, outside air, and it minimizes filter buildup.
- (4) The return-air plenum inlet is located near the bottom of the cab. This assists in maintaining a constant down-flow of air at the operators breathing zone.



CAB

FIGURE 4. AIR DISTRIBUTION (SCHEMATIC)

- (5) Other potential sources of air movement are eliminated. One of the big problems of past cab ventilating efforts has been mixing turbulence in the cab and the resultant contamination of the breathing zone, i.e., contaminated air from the floor area is able to mix vertically with incoming air, causing lead levels to increase at the breathing level. Figure 5 shows situations in which this can occur.

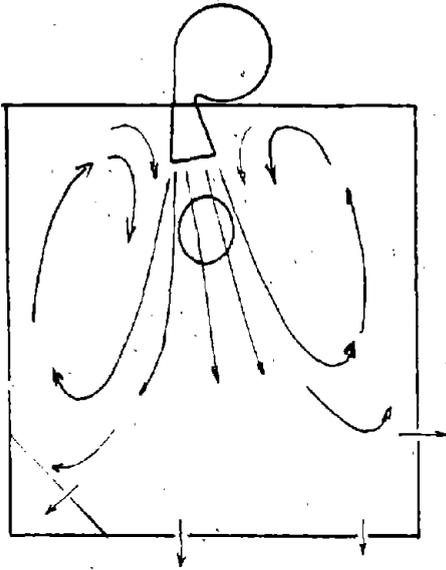
All holes in the cab were closed or covered. Windows and doors were made air-tight. Small cooling fans were removed. Auxiliary heaters were disconnected and removed.

#### Fans and Motors

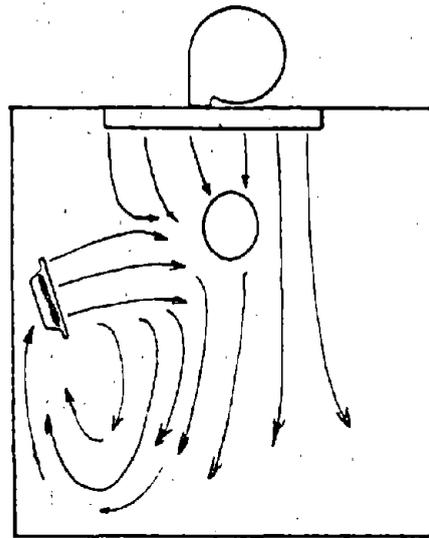
Selection and specification of motors and fans proved difficult but the eventual selection represents a major innovation of the GBC system.

In specifying a fan and motor several conditions were to be met:

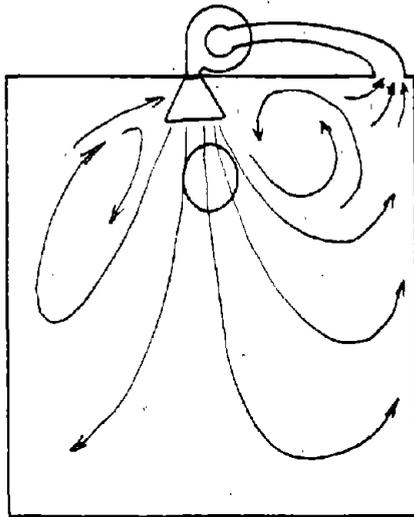
- (1) Static pressure requirements were high. Because of the distribution plenum, high-velocity return plenum, and the high-efficiency filter, it was estimated that up to 6" of static pressure would be required at the fan. (See appendix for calculated estimate.)
- (2) Height requirements mandated that the ventilation equipment housing extend no more than one foot above the existing roof line.



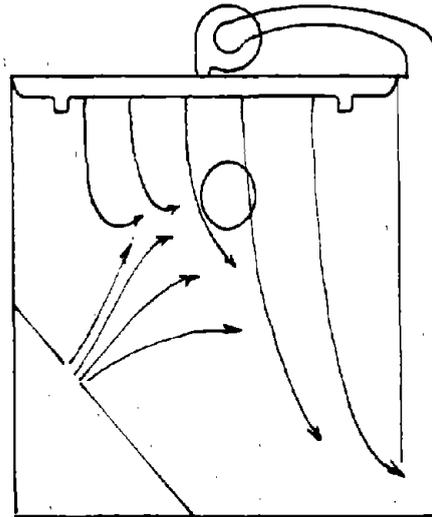
Poor inlet distribution;  
no return ducts.



Cooling fan mixes conta-  
minated air with inlet  
air.



Poorly placed return  
air inlet.



Negative pressure in cab  
creates mixing, turbulence.

FIGURE 5. ADVERSE AIR MOVEMENT CREATES INCREASED  
MIXING, TURBULENCE, AND EXPOSURE

- (3) The drive motor would be required to supply up to 4 hp, estimated as follows.

$$\text{Power Requirement} = \frac{\text{FTP} \times \text{Q}}{6356 \times \text{N}_f} \times \text{K}_m$$

where FTP = Fan total pressure = 6"

Q = 1000 cfm

N<sub>f</sub> = Fan efficiency = 0.50

K<sub>m</sub> = Drive loss factor = 1.8 (Hydraulic)

therefore

Power Requirement = 3.4 hp.

Palm Industries, constructors of the CE cab, determined that generators and electric motors of sufficient horsepower and suitably small size were unavailable. Furthermore, space limitations would not allow for the installation of a single fan capable of the flow and static pressure required. Based on these limitations, Palm elected to install two forward-curved, radial fans, each driven by a hydraulic motor. Figure 6 shows a schematic of the final design. Figures 8 thru 24 show pictures of the finished cab on a test stand at the Palm Industries plant.

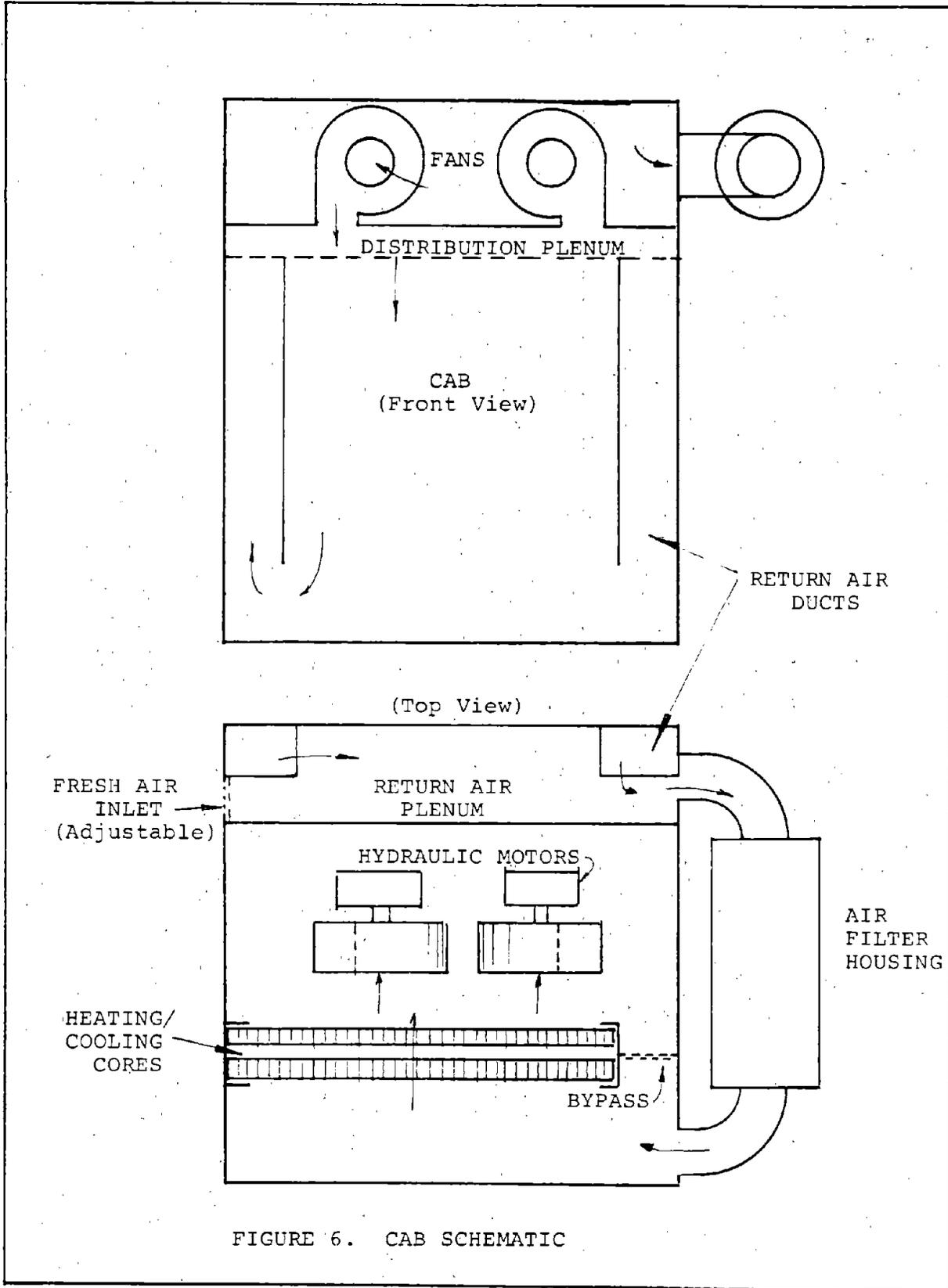


FIGURE 6. CAB SCHEMATIC

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Figure 7. ORIGINAL CAB  
ON MICHIGAN 45C

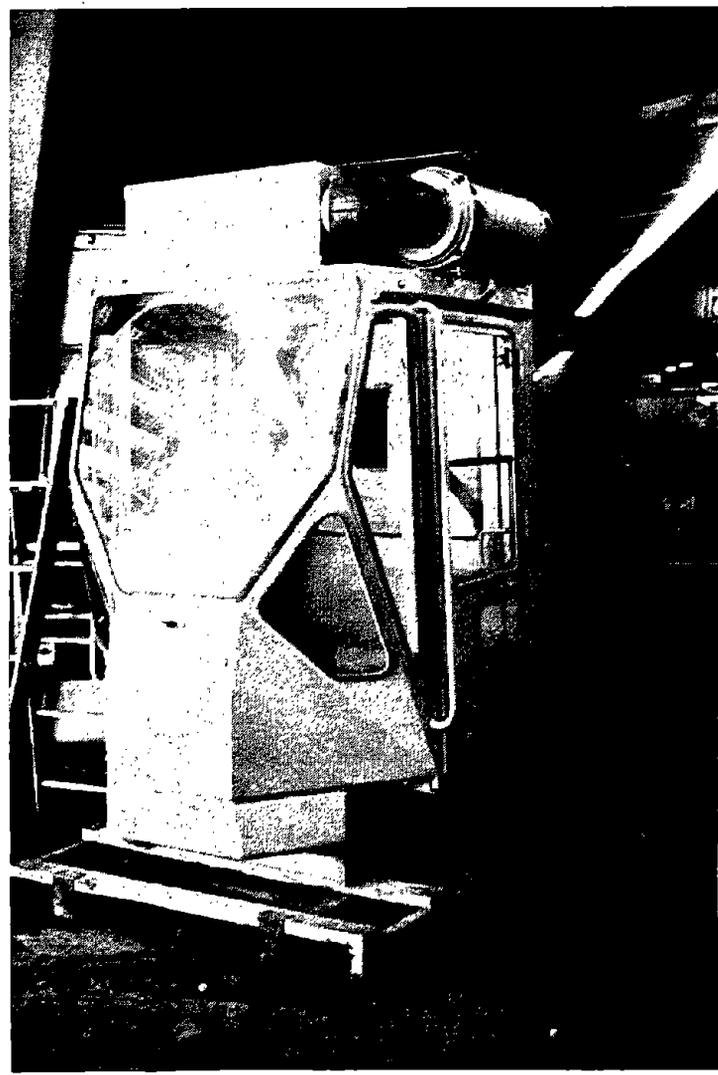
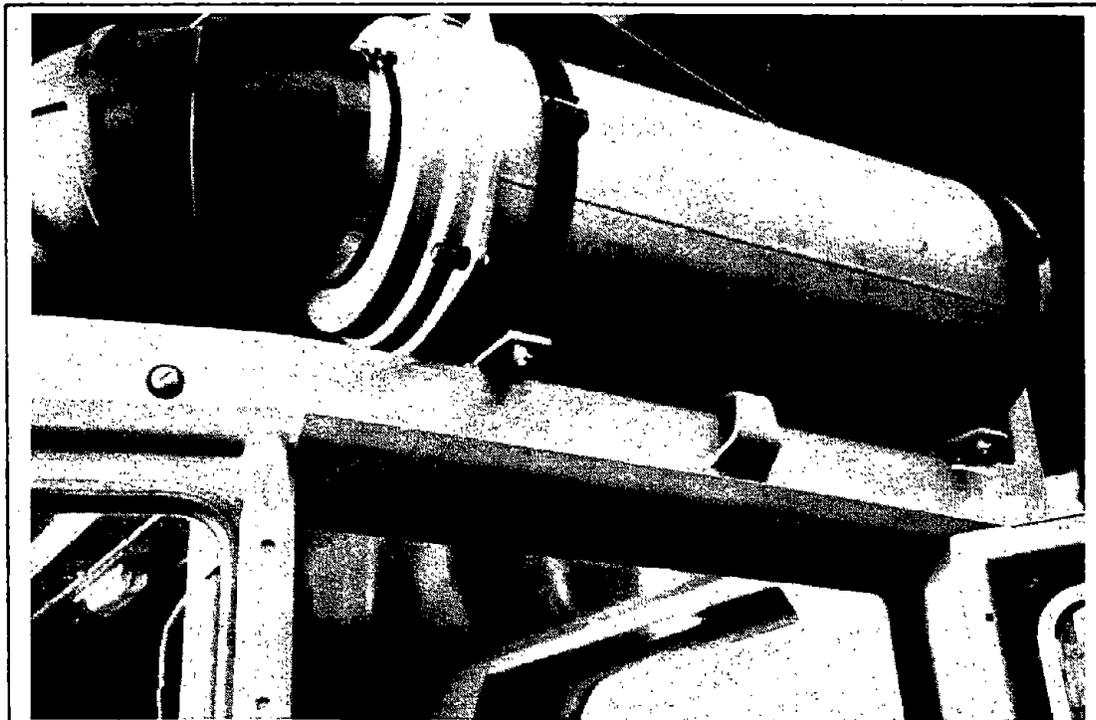


Figure 8. NEW CAB ON  
TEST STAND

Figure 9. PLACEMENT OF VENTILATION EQUIPMENT ON TOP OF CAB



Figure 10. AIR FILTER HOUSING WITH QUICK RELEASE/REPLACEMENT CAPABILITY



ra

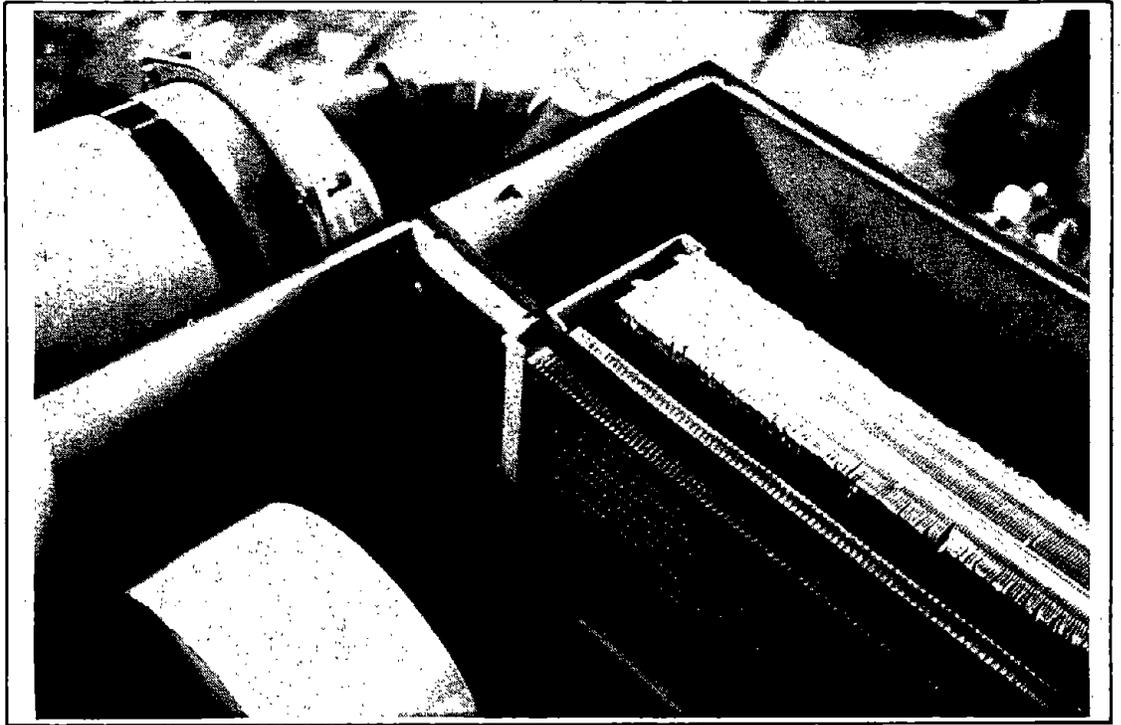


Figure 11. TOP VIEW SHOWING FILTER OUTLET, HEATING AND COOLING COILS, AND COIL BYPASS

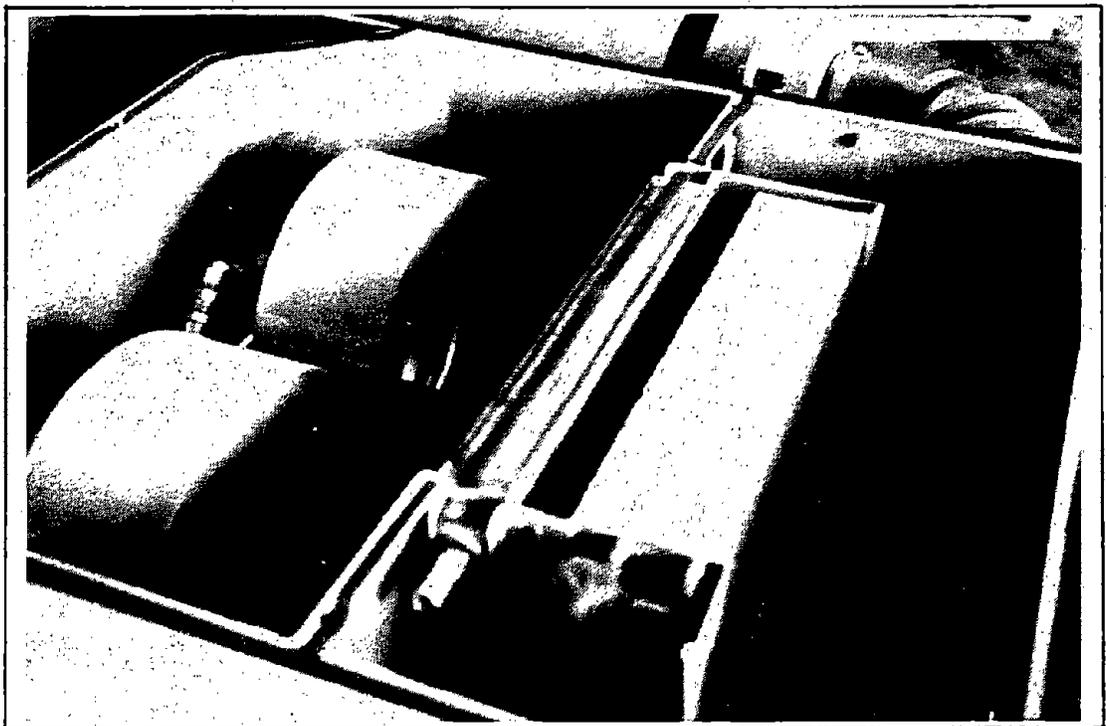


Figure 12. HEATING AND COOLING COILS AND DUAL FAN INLETS

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Figure 13. FAN OUTLETS  
INSIDE CAB AT  
PLENUM LOCATION  
(PERFORATED  
DISTRIBUTION  
PLATE REMOVED)

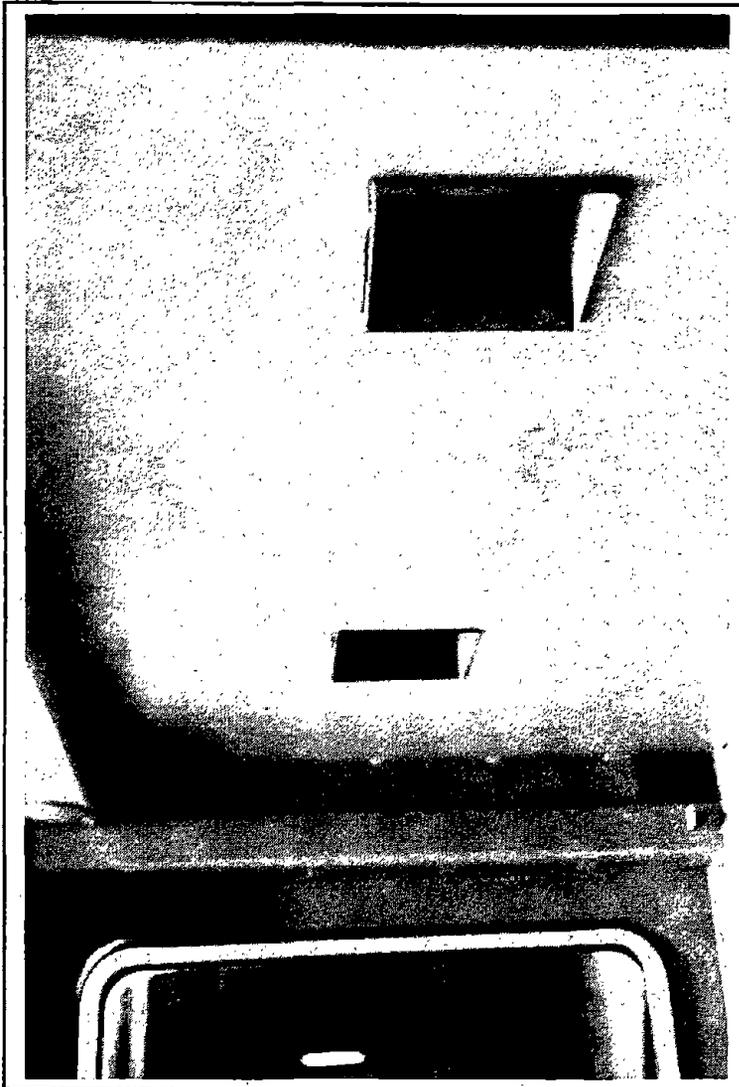


Figure 14. PERFORATED  
DISTRIBUTION  
PLATE IN CAB





Figure 15. FRONT VIEW OF PERFORATED PLATE

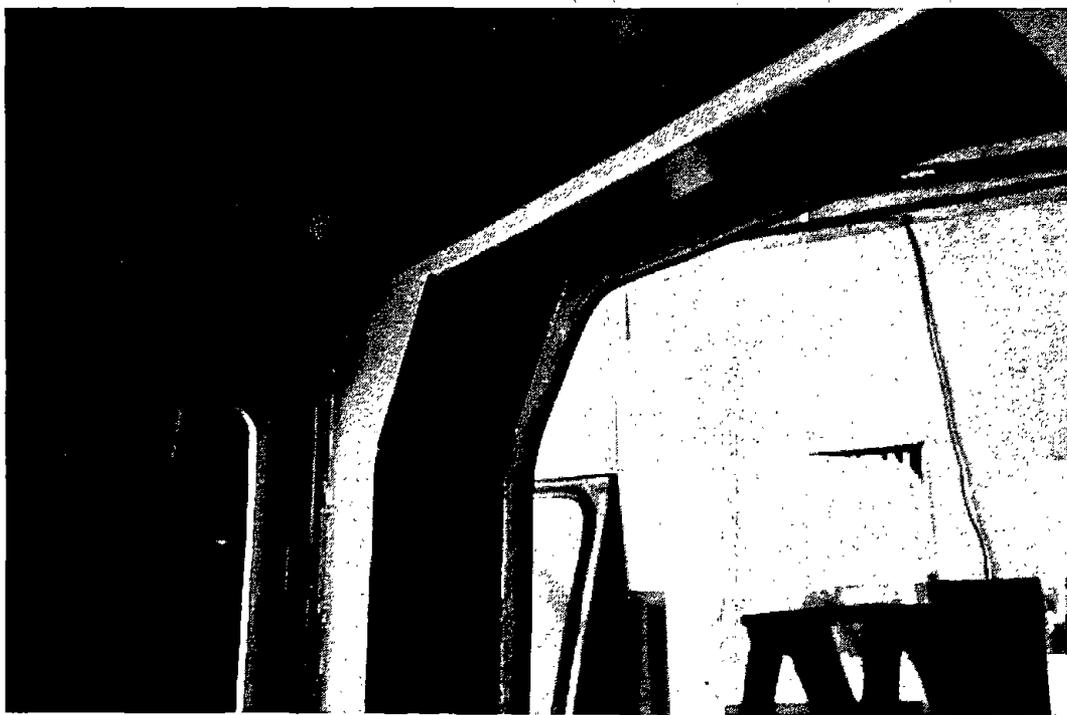


Figure 16. REAR VIEW OF PERFORATED PLATE WITH WIRE MESH

Figure 17. RETURN AIR  
INLET AND  
DUCT (ONE ON  
EACH SIDE OF  
CAB)



Figure 18. RETURN AIR  
DUCT GOING  
THROUGH CAB  
ROOF



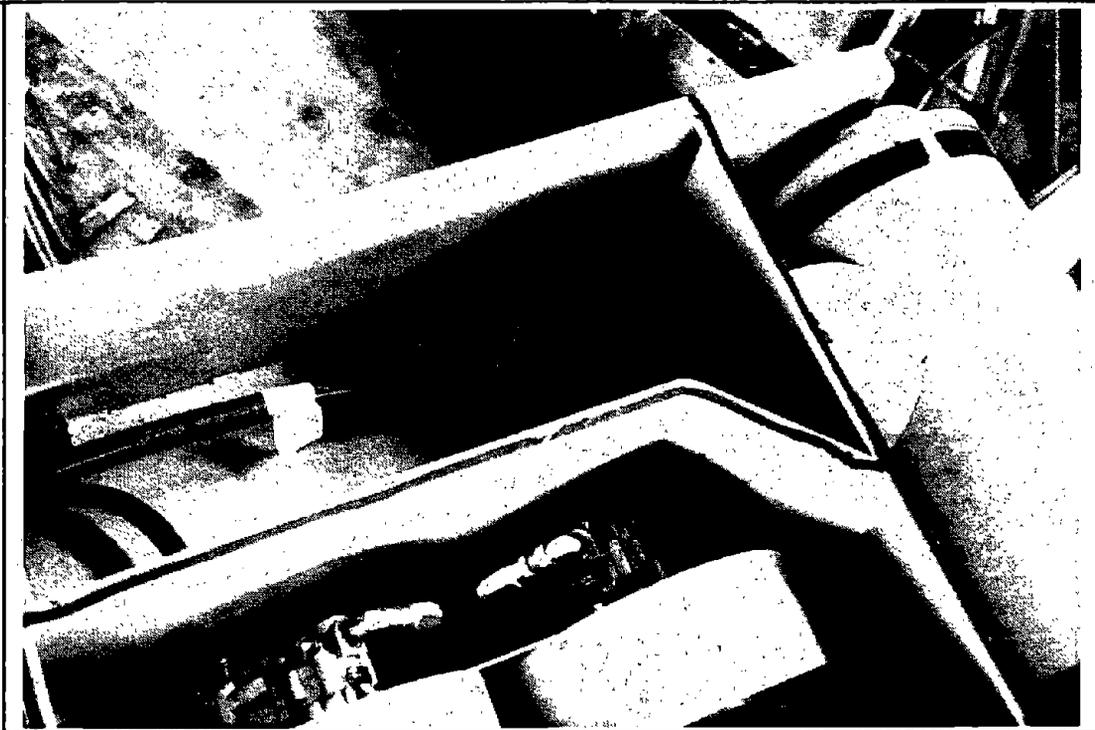


Figure 19. RETURN AIR  
PLENUM AND  
INLET TO AIR  
CLEANER



Figure 20. OUTSIDE VIEW  
OF RETURN AIR  
DUCT AND EXPANDED  
CAB WALL TO  
ACCOMMODATE  
DUCTWORK

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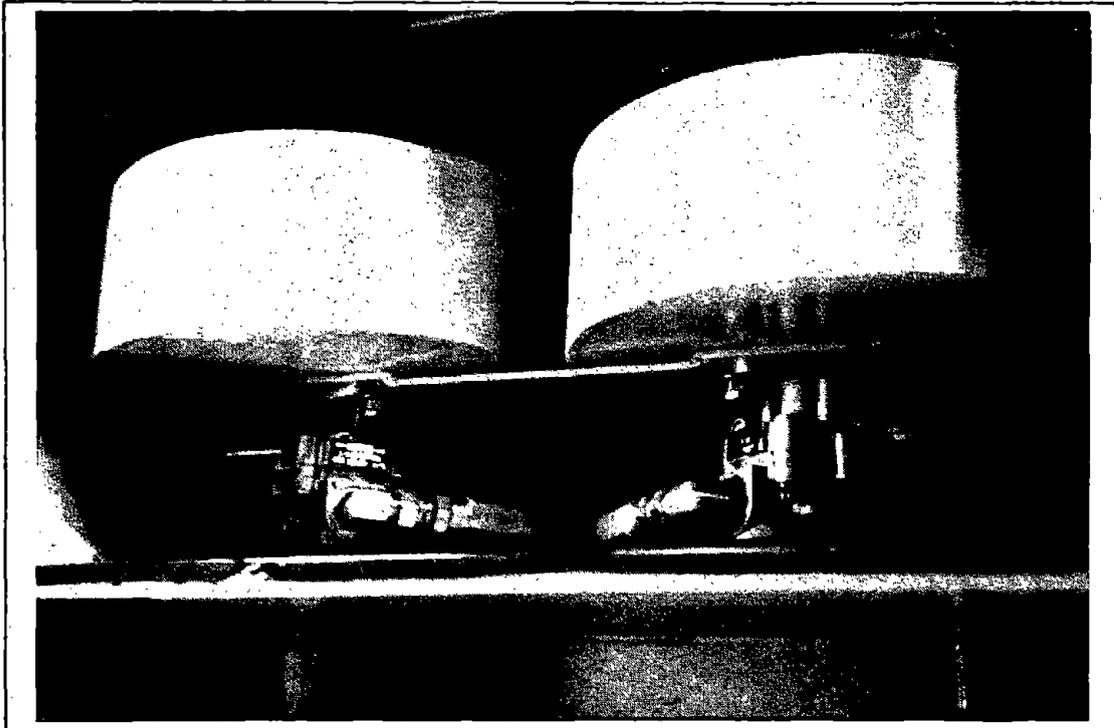


Figure 21. HYDRAULIC MOTORS AND FANS



Figure 22. HYDRAULIC VALVE WHICH REGULATES FLOW TO HYDRAULIC MOTORS

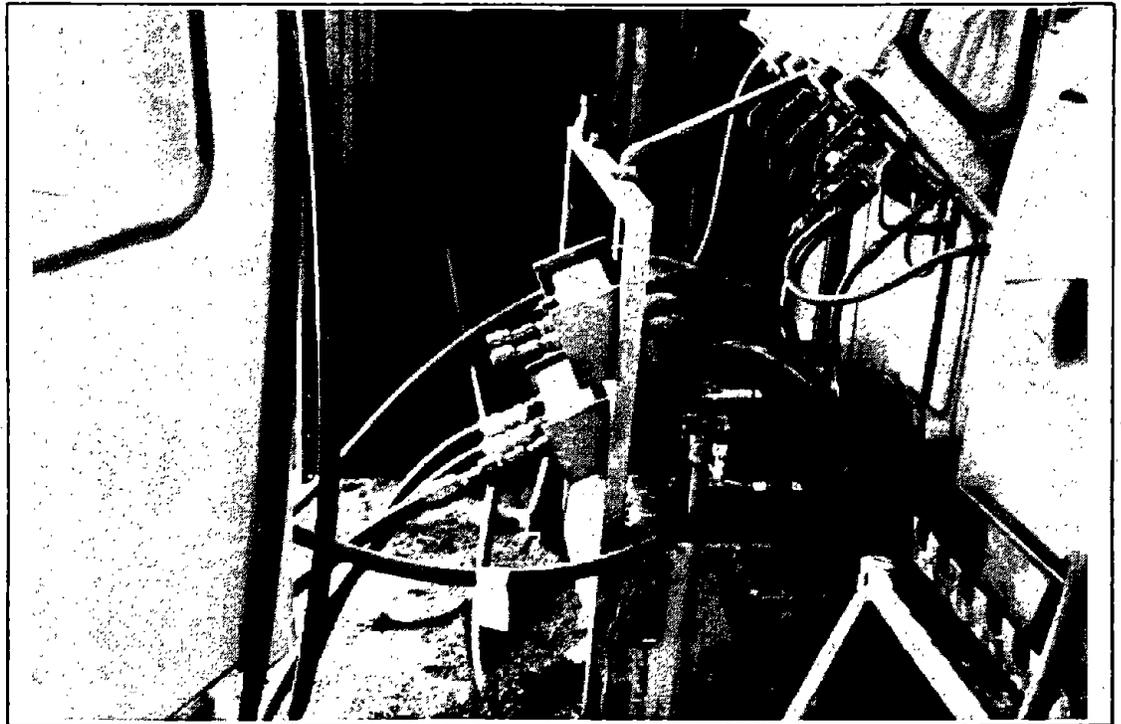


Figure 23. HYDRAULIC PUMP AND LINES ON TEST STAND

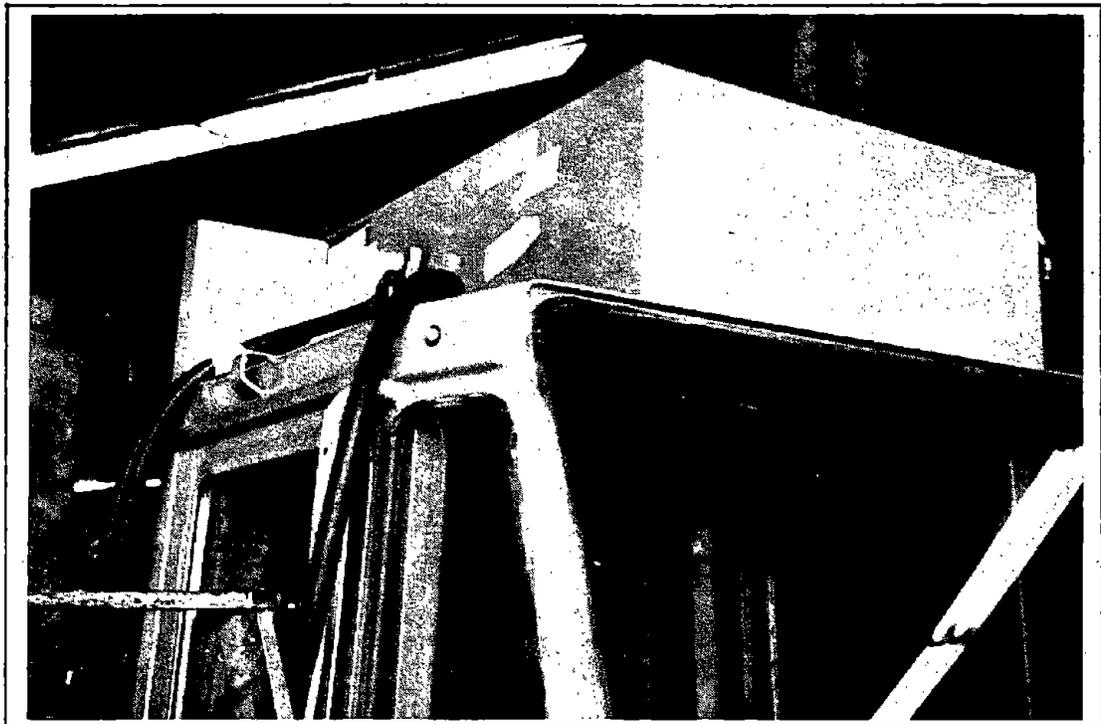


Figure 24. HYDRAULIC LINES FROM TEST STAND PUMP

#### 4.0 DISCUSSION OF PROGRESS TO DATE

As of the date of this report, the cab had been shipped to Reading and installed on the front-end loader. Tests performed by the local Clark shop indicated a problem with driving the ventilation system with the existing hydraulic system. Therefore GBC decided to install a separate, constant flow hydraulic pump dedicated solely to the ventilation system.

Prior to shipment, tests performed on the test stand at Palm Industries indicated all systems were working. However, because the test stand was capable of providing only about 1/3 of the necessary flow (5 gals/min. vs. a required 15 gals/min. at 1500 psi), tests at design RPM were not performed.

##### Evaluations Yet to be Performed

When the equipment is operational, the following evaluation and tests should be performed:

- (1) A full characterization of the air handling system should be performed to include:
  - Static pressure measurements at inlets and outlets to fans and air cleaner.
  - Face and duct velocities.
  - Air flow characteristics through the operator's breathing zone.
  - Volume flow rates at various motor rpm.

- (2) An analysis of the efficiency and effectiveness of the three filters supplied by Donaldson. This can be accomplished by measuring inlet/outlet lead concentrations and static pressures. Filters will load up and become more efficient as time passes. The time interval between required replacement should be determined, e.g., at a total static pressure drop across the filter of 3 inches W.G., change the filter.
- (3) Measurement of the operators exposure level should be performed to determine the effectiveness of controls. Work practices and housekeeping should be monitored and specific guidelines established.

#### Costs

Total construction funds expended to date by GBC have exceeded \$13,000. It is anticipated that total costs of design, construction, and evaluation will exceed \$30,000. However, additional similar cabs could be built and installed for less than \$10,000.

#### Safety Considerations

Structurally, the new cab was not modified, thus maintaining the integrity of the ROPS system. All other conditions within the cab remain the same.

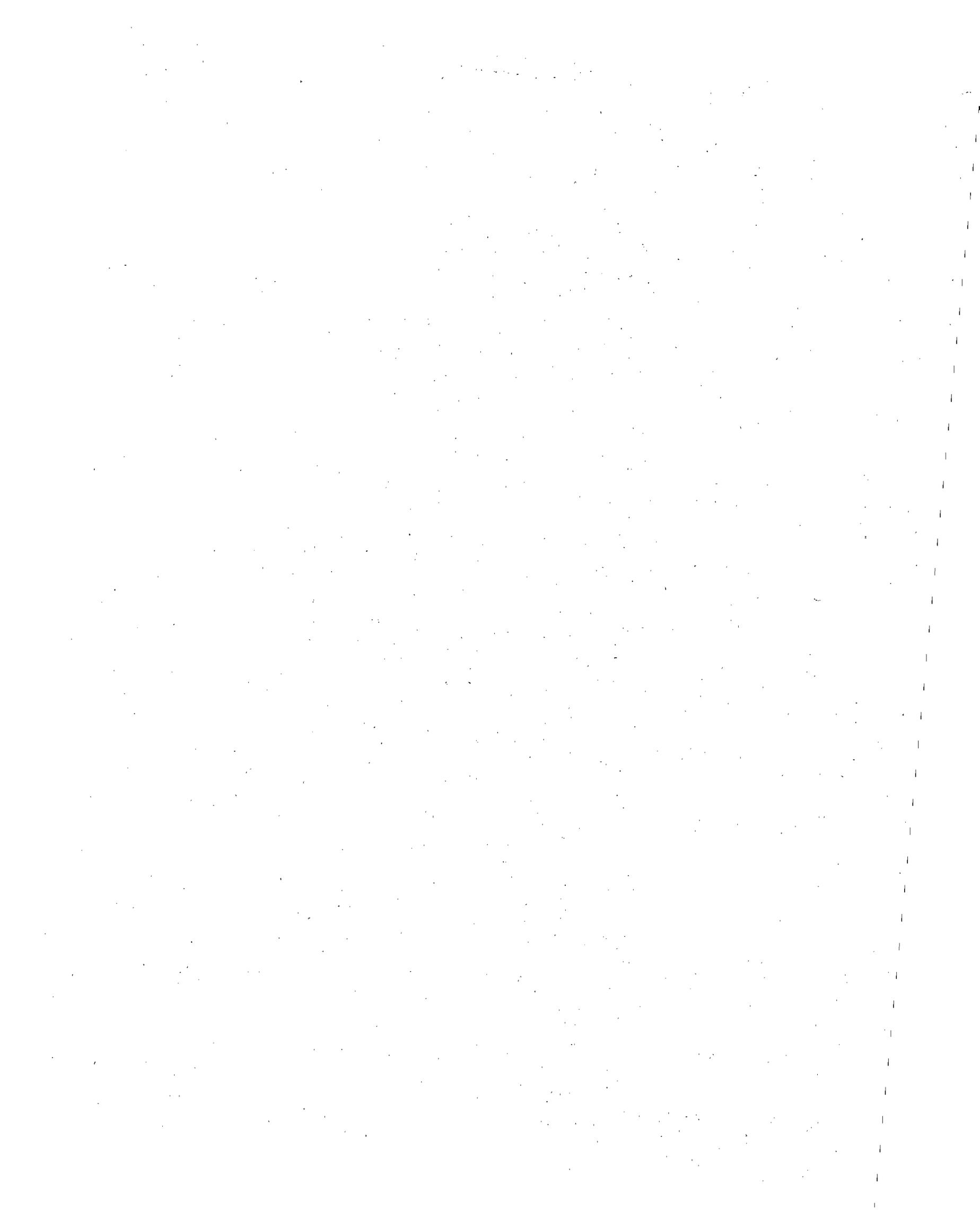
#### Potential Improvements

Based upon the limited and subjective evaluation of the completed cab, Radian can make the following suggestions:

- (1) A separate, dedicated hydraulic pump should normally be provided to drive the fan hydraulic motors.
- (2) Use of a separate gasoline engine-powered system as an alternative to a hydraulic motor should be considered. This would provide the power required but adds problems of gasoline tanks, gasoline handling, noise, and mounting space.
- (3) Fans of a straight blade radial type might be preferable because of their rugged construction and self-cleaning operation. The fans installed on the GBC system will operate near their maximum allowable rpm and will have shortened lives, will generate noise, and be less efficient.

## APPENDIX

- o Static Pressure Design Estimates
- o Preliminary Test Results (June 23, 1983)



BY J. BURTON DATE \_\_\_\_\_  
 CHKD. BY \_\_\_\_\_ DATE \_\_\_\_\_

SUBJECT STATIC PRESSURE  
LOSSES IN CAB  
VENTILATION SYSTEM

SHEET NO. 1 OF 1  
 JOB NO. 204-023-12

RADIANT CORPORATION

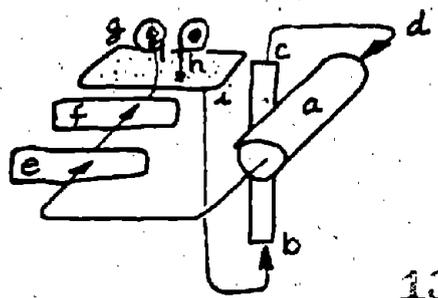
(DESIGN ESTIMATES @ Q = 1000 CFM)

| LOSS ITEM                             | APPROX VEL. (FPM) | VP INCH W.G. | LOSS FACTOR * | TOTAL ESTIMATED LOSS INCH W.G. | REF ** |
|---------------------------------------|-------------------|--------------|---------------|--------------------------------|--------|
| FILTER                                | -                 | -            | -             | 1 - 3                          | a      |
| RETURN ENTRY                          | 3450              | 0.75         | 0.93          | 0.70                           | b      |
| CONTRACTION AT ENTRY TO RETURN PLENUM | 4450              | 1.24         | 0.25          | 0.31                           | c      |
| FILTER ELBOWS (2)                     | 3,450             | 0.75         | 0.28          | 0.21<br>0.21                   | d      |
| HEATER CORE                           | 1200              | 0.09         | 1.78          | 0.16                           | e      |
| COOLER CORE                           | 1200              | 0.09         | 1.78          | 0.16                           | f      |
| FAN INLET                             | 3,450             | 0.75         | 0.20          | 0.15                           | g      |
| FAN OUTLET                            | 3,450             | 0.75         | 0.20          | 0.15                           | h      |
| PLENUM LOSS (2)                       | 1,250             | 0.39         | 2.3           | 0.45<br>0.45                   | i      |
| FRICTION LOSS                         | NEG.              | -            | -             | -                              | j      |

TOTAL STATIC PRESSURE DEMAND = 4-6 INCH W.G.

\* FIG 6-10, ACGIH VENT MANUAL

\*\* SEE SCHEMATIC →



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RESULTS OF PRELIMINARY TESTING AT  
PALM INDUSTRIES, LITCHFIELD, MINN.,  
JUNE 23, 1983. D. J. BURTON

TEMP. - 75°F

REL. HUM. - 80%

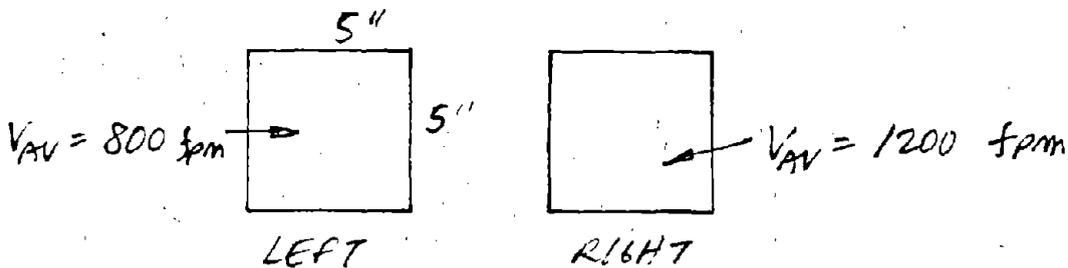
WINDS - "LIGHT, VARIABLE"

CONTACT - MIKE BRAMYL, PALM IND.

TEST STAND WAS CAPABLE OF SUPPLYING UP TO  
 5 GPM HYDRAULIC FLUID (ABOUT 35% OF  
 REQUIRED FLOW.)

MEASUREMENTS

- FAN OUTLET TO CAB

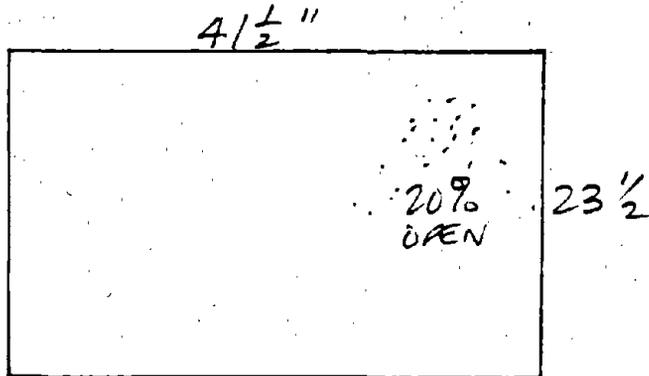


$$A = 0.2727 \text{ FT}^2$$

$$Q = VA = 272 \text{ CFM}$$

$$\text{@ } Q = 1000 ; V = 3676 \text{ FPM}$$

• AIR FLOW THROUGH DISTRIBUTION PLATE



$A = 6.773 \text{ FT}^2$

$V = \frac{Q}{A} = 40 \text{ fpm}$

$V_{\text{ORIFICE}} = 201 \text{ fpm}$

• DESIGN  $Q = 1000 \text{ cfm}$

$V = 147 \text{ fpm}$

$V_{\text{ORIFICE}} = 740 \text{ fpm}$

• AIR FLOW IN FILTER

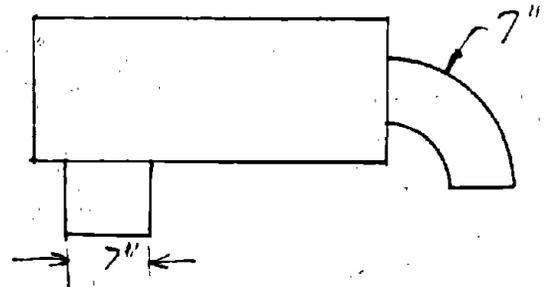
$A = 0.2673 \text{ FT}^2$

•  $Q = 272 \text{ cfm}$

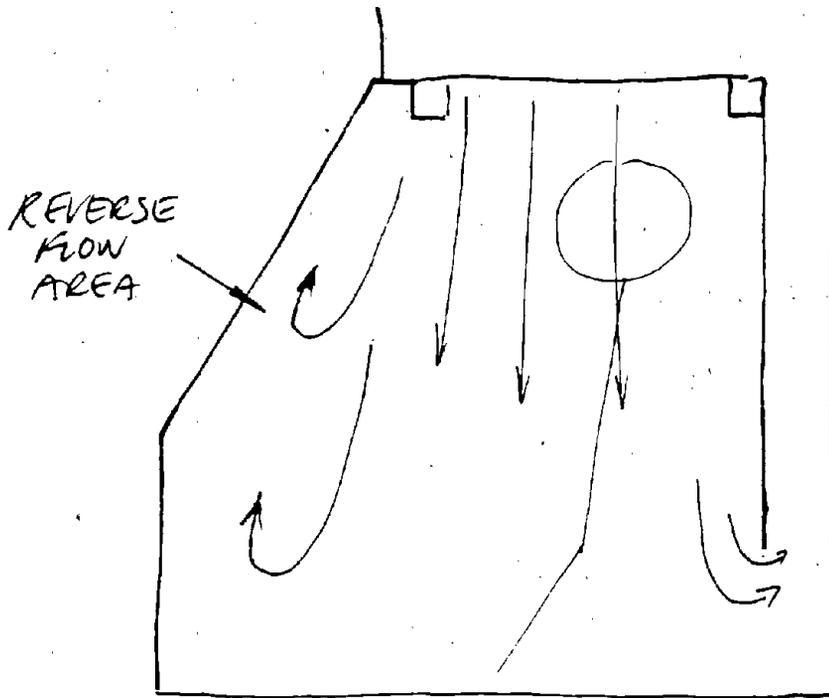
$V = 1010 \text{ fpm}$

•  $Q = 1000 \text{ cfm}$

$V = 3745 \text{ fpm}$



• SMOKE OBSERVATIONS IN CAB



• NOISE LEVELS

OUTSIDE CAB - 71 dBA

INSIDE CAB - 82 dBA

• FAN RPM

RPM (AVERAGE) = 1230 RPM

@ RPM = 4000 ; CFM = 885 CFM

(BY FAN LAWS)





CONSTRUCTION AND EVALUATION OF  
A SUPPLIED-AIR ISLAND AT THE  
CASTING SKIMMER'S WORK STATION

Final Technical Report  
Demonstration Project Number Three

D. Jeff Burton  
Radian Corporation  
Occupational Safety and Health Division  
Salt Lake City, Utah 84115

NIOSH Contract No. 210-81-706

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

July, 1983



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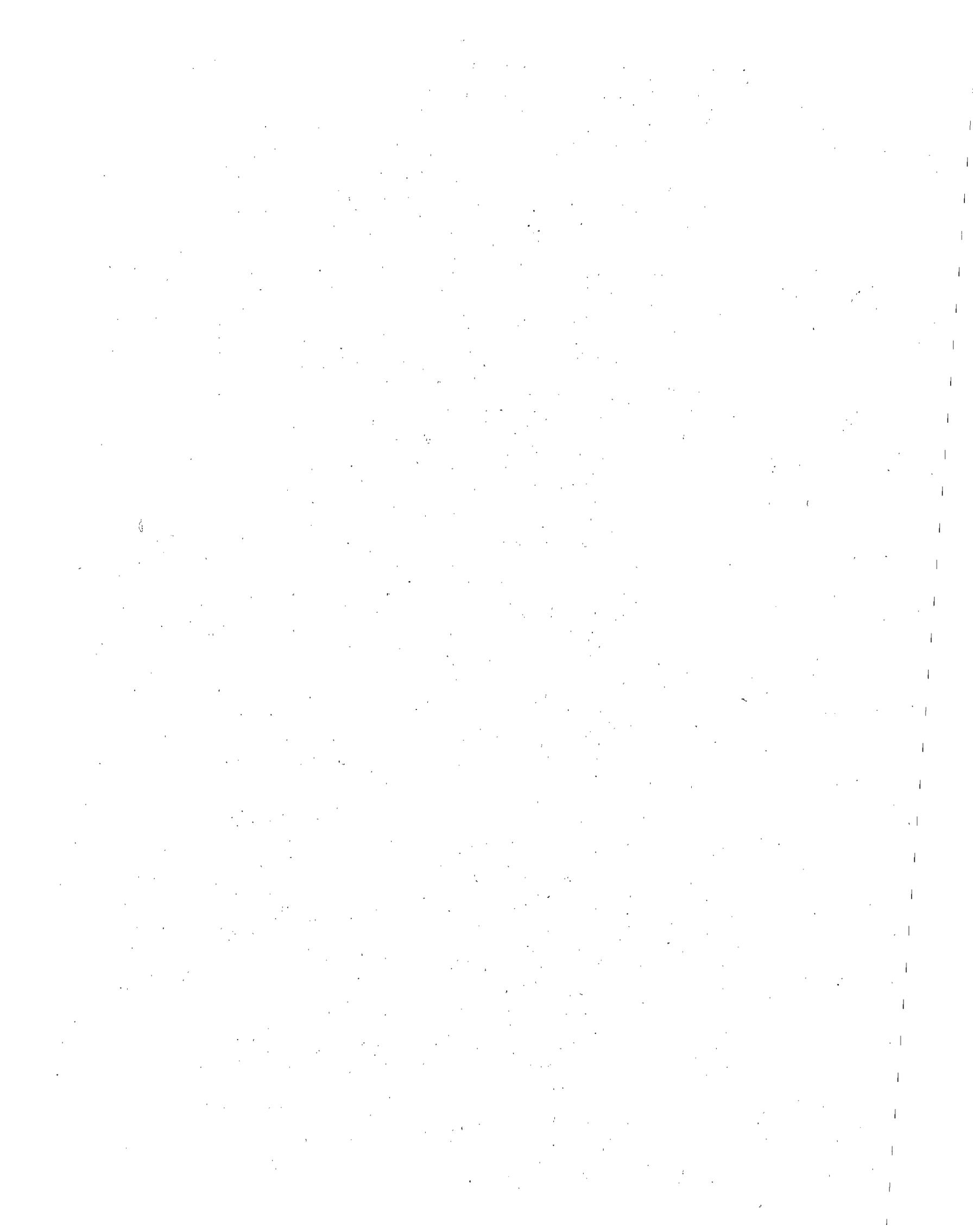
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1.0 . OBJECTIVES OF THE PROJECT

The objective of this project was to design, construct, investigate, evaluate, and characterize the operation of a supplied-air island at the castings skimmer's work location.

The goals of the project were (1) to determine the level of control provided by supplied-air islands, and (2) to provide useful technical, cost, and operational information to other smelter operators, government agencies, consultants, and labor unions, for the purpose of determining the transferability of the demonstrated technology to other smelting locations.

## 2.0 INTRODUCTION

This report describes a NIOSH-funded project to design and construct a supplied-air island at a casting skimmer's work station at General Battery Corporation's secondary lead smelter in Reading, Pennsylvania.

Radian conducted on-site studies during December, 1981, and again in May and June, 1983. The island was designed by Radian and built by GBC. Measurement of air flows and exposure levels were obtained by Radian. Samples were analyzed by an AIHA-certified lab.

### 2.1 Plant Description

In order for other smelter operators to determine the compatibility of a supplied-air island in their operations, a brief description of GBC's operations is presented below. The information presented is a compilation of data gathered from the plant and other sources.

General Battery Corporation's (GBC) smelter is located in the Reading, PA metropolitan area. The plant produces hard and soft lead ingots and antimonial alloys in two similar 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 a second reverb and additional process gas handling and sanitary ventilation/gas treatment systems were added.

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.

#### Plant Environment

Figure 1 is a plot plan of the 30-acre plant site which is in a basin remotely surrounded by high hills on all sides.

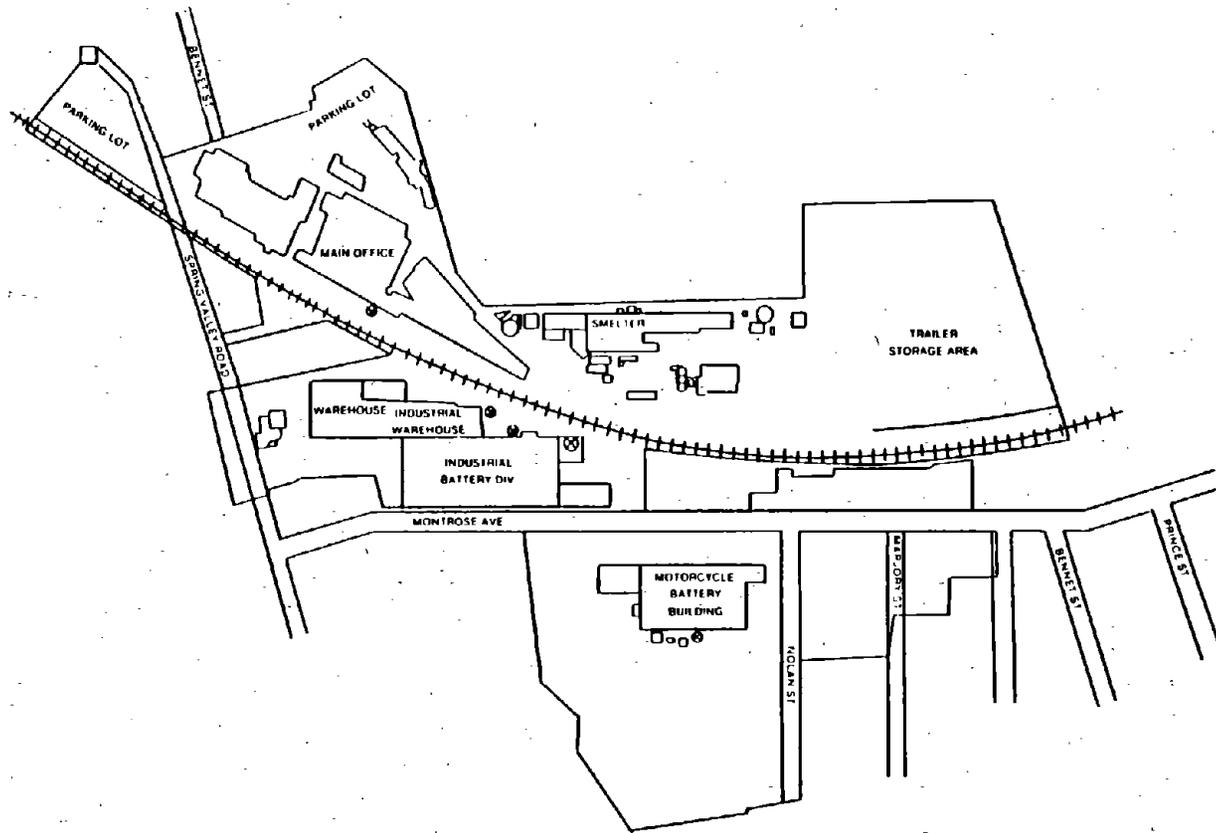
#### Processing Description

This plant charges entire (crushed) plastic-cased batteries and tops (grids and posts) of rubber-cased batteries to two blast and two reverberatory furnaces, each of which has a rated capacity of 65-80 tons/day. Each of the two blast-reverb combinations shares a process gas and ventilation gas treatment system.

As shown in Figure 2, material flow through the smelter occurs generally from the north to the south end. The operations

4

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FIGURE 1 PLOT PLAN FOR GENERAL BATTERY CORPORATION SHOWING LOCATION OF SMELTER.

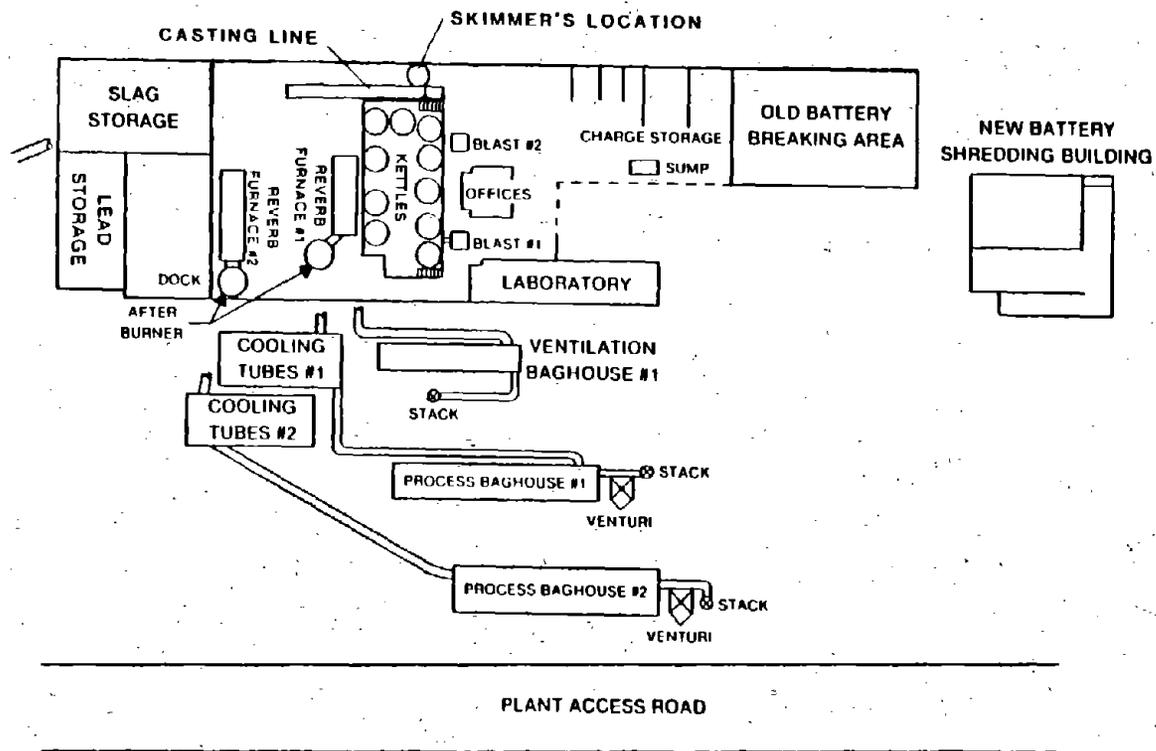


FIGURE 2 SMELTER PLOT PLAN FOR GENERAL BATTERY

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5  
137<

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. Figure 2 shows the location of the Casting Skimmer's work location in the plant.

## 2.2 Casting Skimmer's Job Description

Figures 3, 4, and 5 present views of the casting line and the skimmer.

Lead is pumped from a refining kettle to a star-wheel caster which fills an ingot. The ingot line moves automatically past the skimmer's work station. The skimmer removes the oxide dross from the still-molten pig with a small hand scrapper. Note on Figure 4 that the skimmer has five ingots in front of him, any of which he can skim. Skimmings are placed in a small container for recycling.

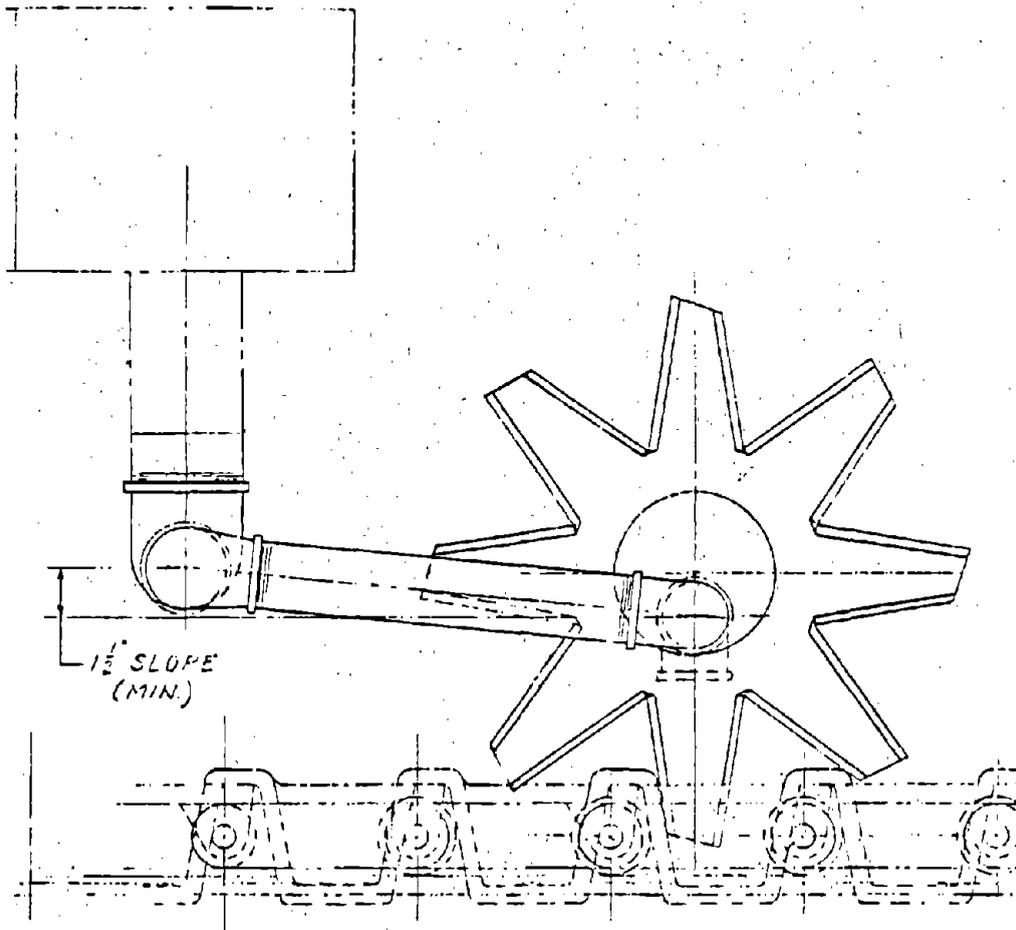
Exposure levels in 1981 were quite high, ranging from 90-6,600 ugPb/m<sup>3</sup> with an average exposure of 422 ug/m<sup>3</sup> (24 samples).



Figure 3. Casting Line Skimmer



Figure 4. Skimming Operation



**Figure 5. Star Wheel Casting Machine**

### 3.0 SUPPLIED-AIR ISLANDS, GENERAL CONCEPTS

This section describes general concepts associated with the design and operation of supplied-air islands.

#### Design Considerations

Although supplied-air islands are not new, little has been reported in the literature regarding optimum flow rates, face velocities, temperature control, employee acceptance, and so forth.

As its name suggests, the supplied-air island is intended to provide an "island" of fresh, tempered, and clean air within which an employee may work, protected against air-borne-contaminants found in the ambient, work-place environment.

Table 1 lists conditions we have found conducive to the application of a supplied-air island for employee protection.

#### Types of Islands

Figure 6 shows two basic types of supplied-air islands: (1) the adjustable nozzle, and (2) the fixed island. The moveable nozzle allows the employee some flexibility in position. The fixed island allows a larger area to be protected.

TABLE 1. CONDITIONS SUITED TO THE APPLICATION OF A SUPPLIED-AIR ISLAND TO EXPOSURE CONTROL

| <u>Condition</u>                                      | <u>Need</u>   |
|---|---|
| Employee remains in stationary position               | Important because the more time an employee remains in the island, the lower the TWA exposure   |
| A supply of fresh, clean air is available             | Outside air may not require cleaning and costs will be lower. If no outside source of clean air ( $<20 \text{ ugPb/M}^3 \text{ air}$ ) is available, intake air should be cleaned.        |
| The air can be tempered                               | Employees will not remain in an environment which is either too hot or too cold. The incoming air must be tempered; or alternatively, employees must be rotated in and out of the island. |
| Many emission sources contribute to employee exposure | It may be more effective and economical to provide direct emission control where only a few emission sources contribute to exposure.  |

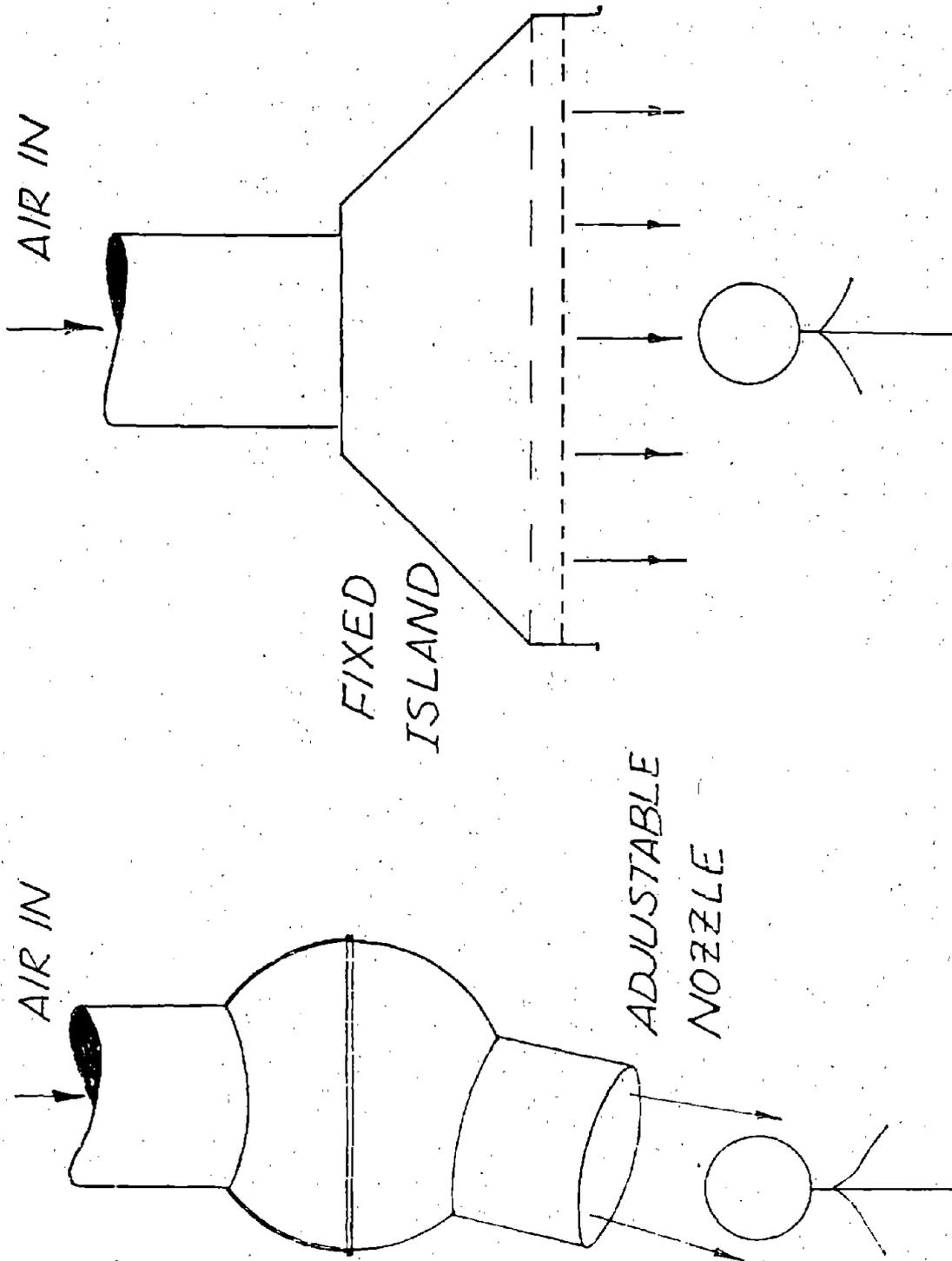


FIGURE 6. TYPES OF SUPPLIED-AIR ISLANDS

Figure 7 shows the typical expansion and contamination of the air stream from a supplied-air island. As can be seen, the larger the hood face diameter, the larger the zone of protection, and the more "safe" space is created.

Table 2 provides suggested air velocities in the zone of protection. Velocities are those found to be acceptable to most employees. Air moving over the face of an employee can be uncomfortable and even irritating if the air is too hot, or cold, or lacks humidity. The best equipment arrangement provides temperature controls at the supplied-air island so the employee can adjust the temperature.

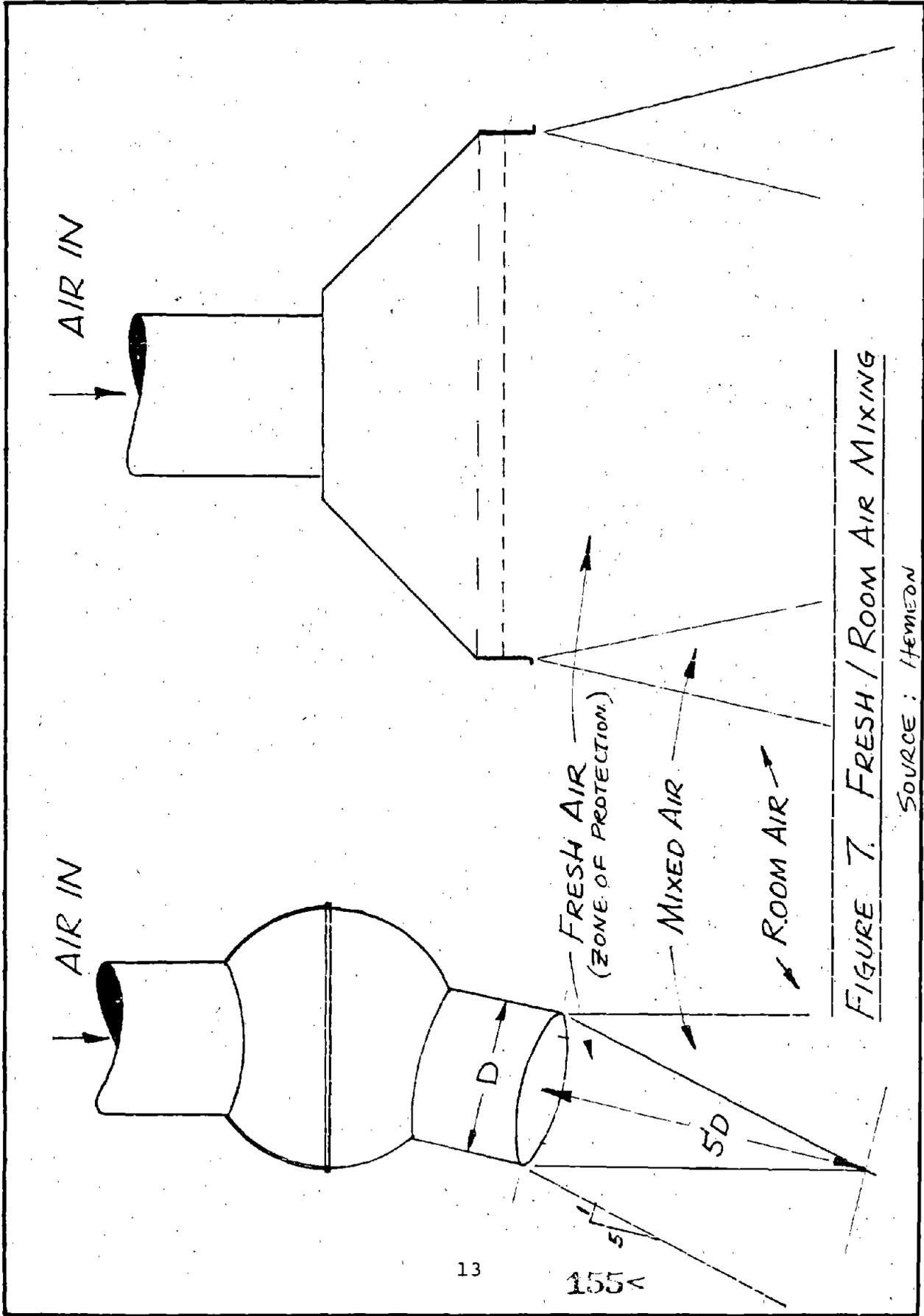


FIGURE 7. FRESH / ROOM AIR MIXING

SOURCE: HEMEDON

TABLE 2. ACCEPTABLE AIR MOTION AT THE WORKER

| <u>Continuous Exposure</u>  | <u>Air Velocity, fpm</u> |
|---|--------------------------|
| Air conditioned space   | 50-75                    |
| Fixed work station, general ventilation or<br>spot cooling: Sitting | 75-125                   |
| Standing  | 100-200                  |
| <u>Intermittent Exposure, Spot Cooling or Relief Stations</u>       |                          |
| Light heat loads and activity                                       | 1000-2000                |
| Moderate heat loads and activity                                    | 2000-3000                |
| High heat loads and activity  | 3000-4000                |

SOURCE: ACGIH VENTILATION MANUAL

### Heat Control

In addition to providing exposure protection, a supplied-air island can also be useful in providing cooling in hot, dry atmospheres. Figure 8 shows two graphs used to estimate the effective temperature of air flowing over men doing light physical work. Moving air provides cooling by enhancing sweat evaporation and convective cooling. The effective temperature does not take into account infrared heat sources (the "globe" temperature), but does account for temperature and humidity ("wet- and dry-bulb" temperatures.)

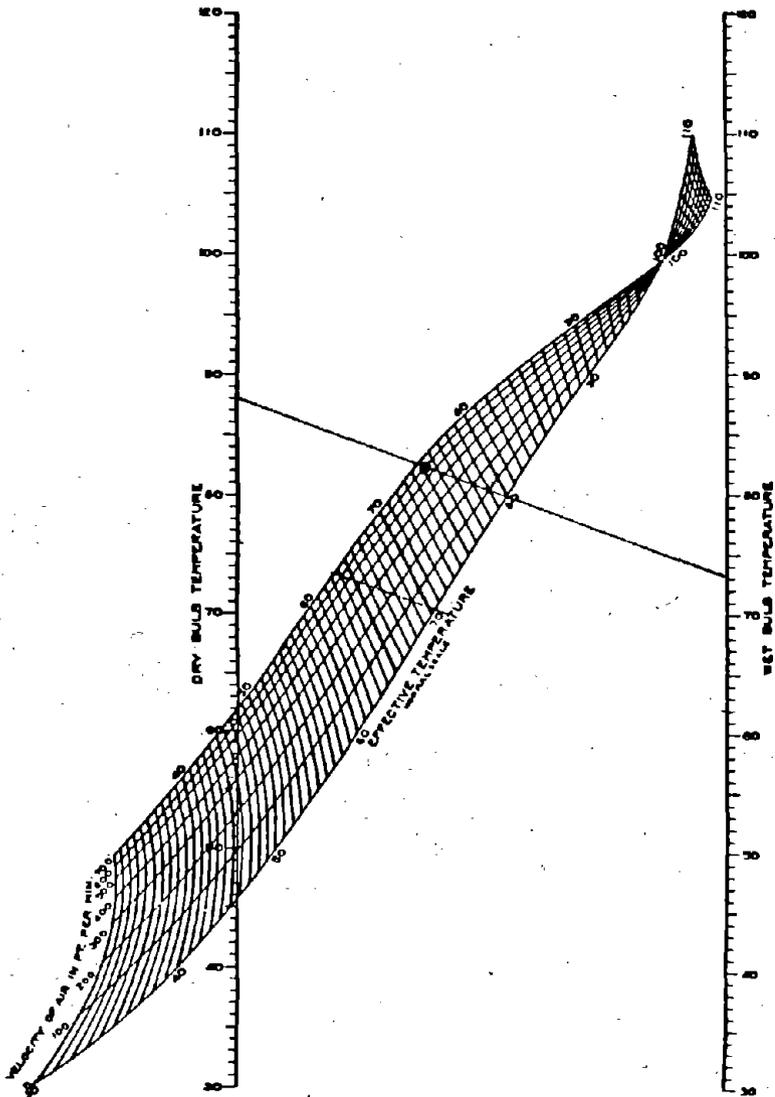
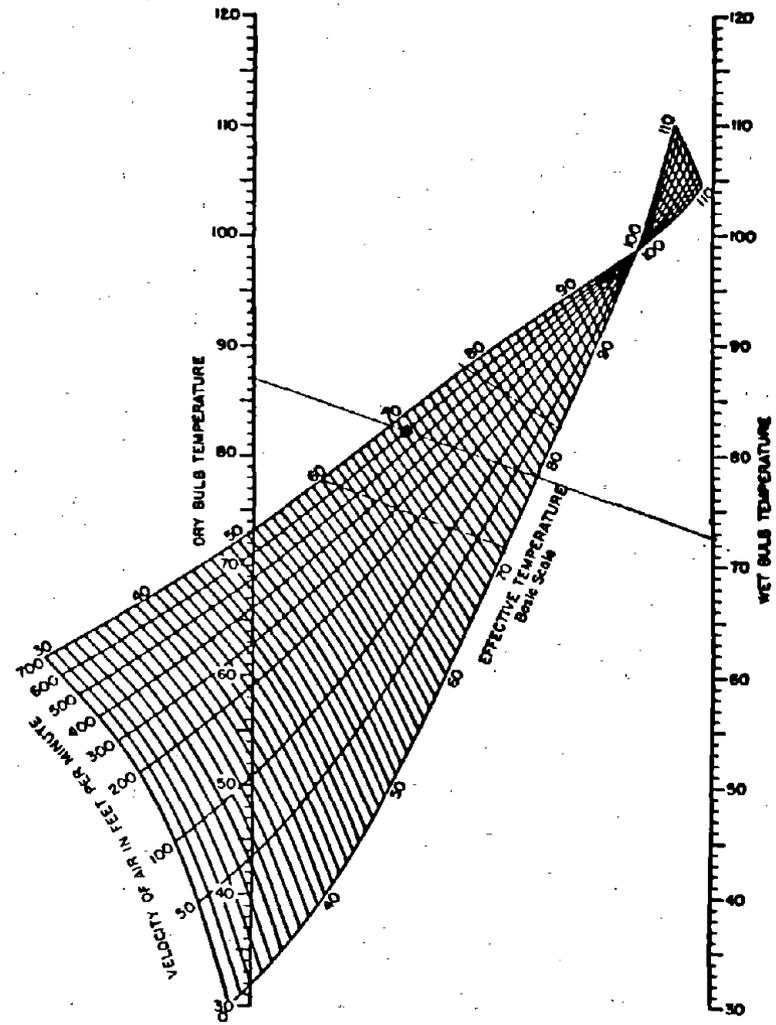


Chart showing normal scale of effective temperature (applicable to persons at rest and normally clothed).



At rest or doing light physical work in rooms heated by convection methods.

Basic scale of effective temperature applicable to men stripped to the waist.

Figure 8 Effective Temperature

Source: ACGIH

#### 4.0 DESCRIPTION OF THE GBC CASTING SKIMMER'S SUPPLIED-AIR ISLAND

##### 4.1 Design and Installation

Figure 9 shows side and front schematic views of the system as it was originally designed. Figure 10 shows details of the hood as originally specified. Figure 11 shows the placement of the island at the skimmer's work station, as it was originally designed. Original specifications are provided in Table 3. The system was intended to provide about 600 fpm face velocity in the island, at a volume flow rate (Q) of 5,000 acfm and a fan outlet static pressure (SP) of 1.7 inches w.g.

The system was installed very much as originally designed. However, support considerations required the island to be located about 9" right of the optimum location, placing the skimmer in the left half of the island most of the time. (Additional discussion of the effects of hood placement is found in Section 7) The island also encroached on a casting enclosure installed independently of the supplied-air island. Figure 12 shows the hood as installed.

Figure 13 shows the clear plastic sheets on two sides which are intended to extend and protect the zone of protection.

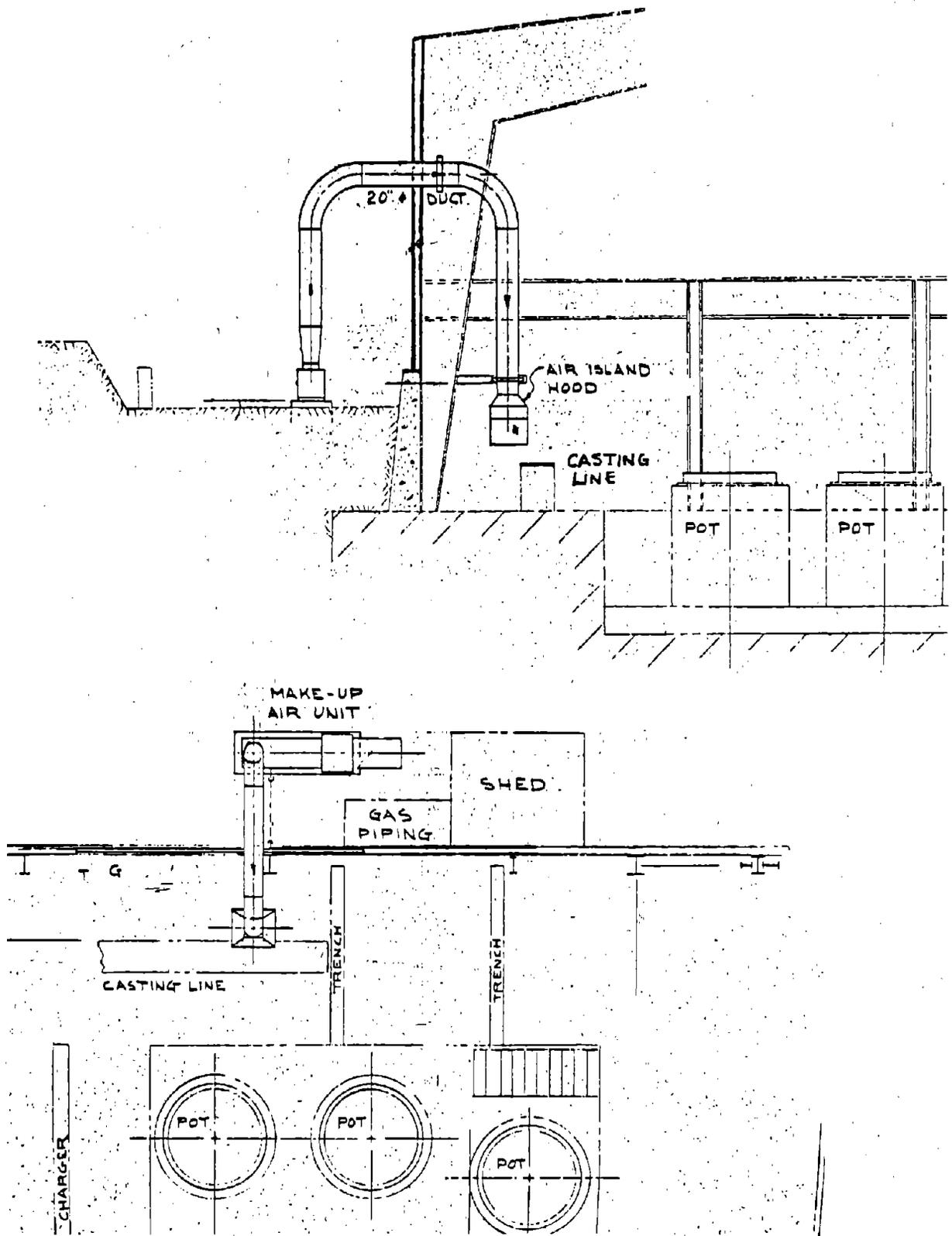


Figure 9. Side and Plan Views

BAFFLE : 2 SIDES -  
 3/8" THK ABRASION RESISTANT  
 LEXAN, # MR-4000, GENERAL  
 ELECTRIC CORP, PROVIDE  
 (3) 3" STL HINGES W/  
 REMOVABLE PINS, BOLT TO HOOD  
 & LEXAN, TYP EACH BAFFLE

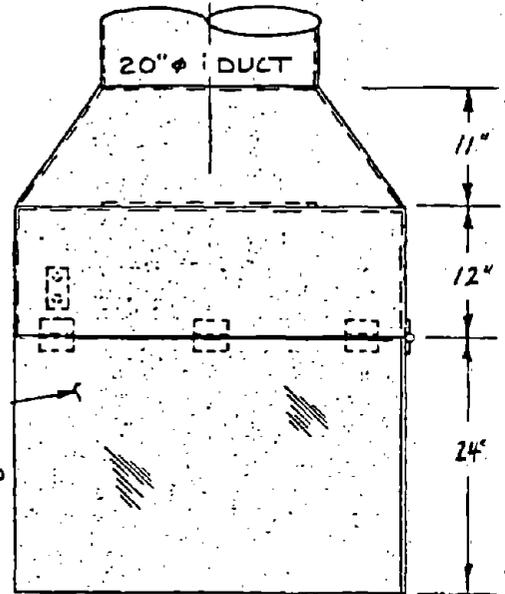
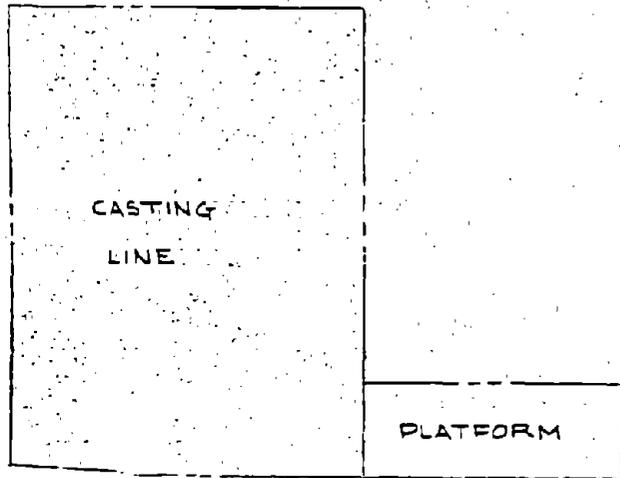
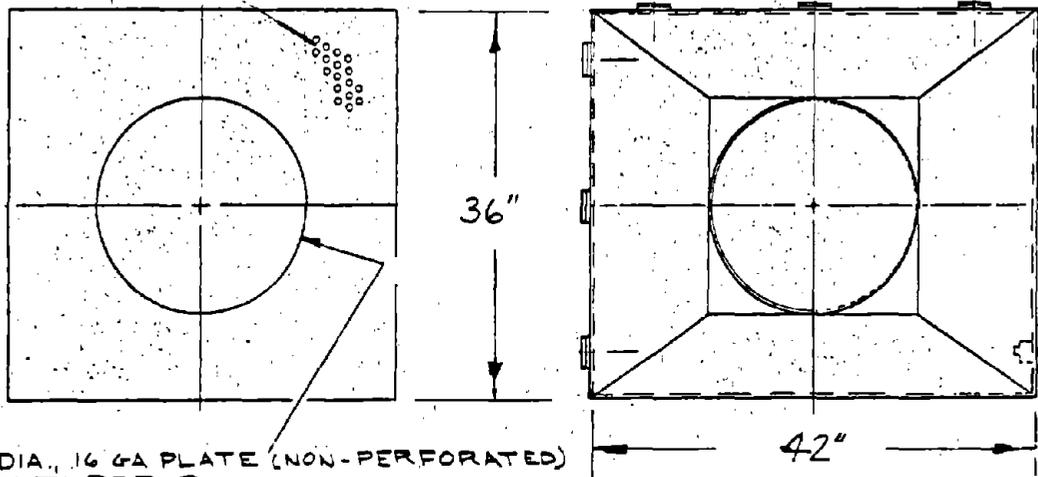


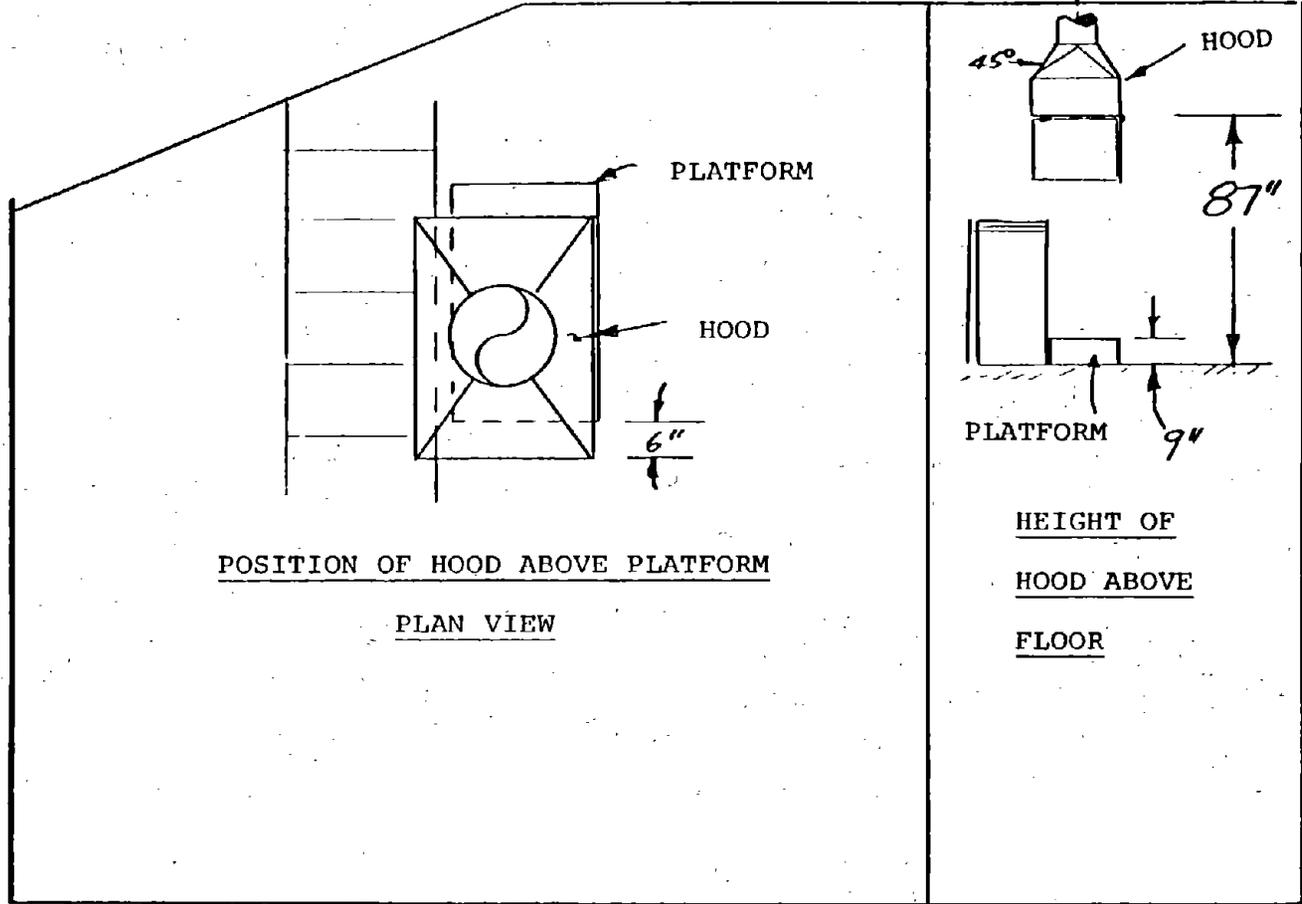
Figure 10. Hood Detail



PERFORATED PLATE : 10 GA,  
 3/8" DIA. HOLES ON 1/2" STAGGERED  
 CENTERS, 51% OPEN



20" DIA., 16 GA PLATE (NON-PERFORATED)  
 TACK TO PER. PL



POSITION OF HOOD ABOVE PLATFORM  
PLAN VIEW

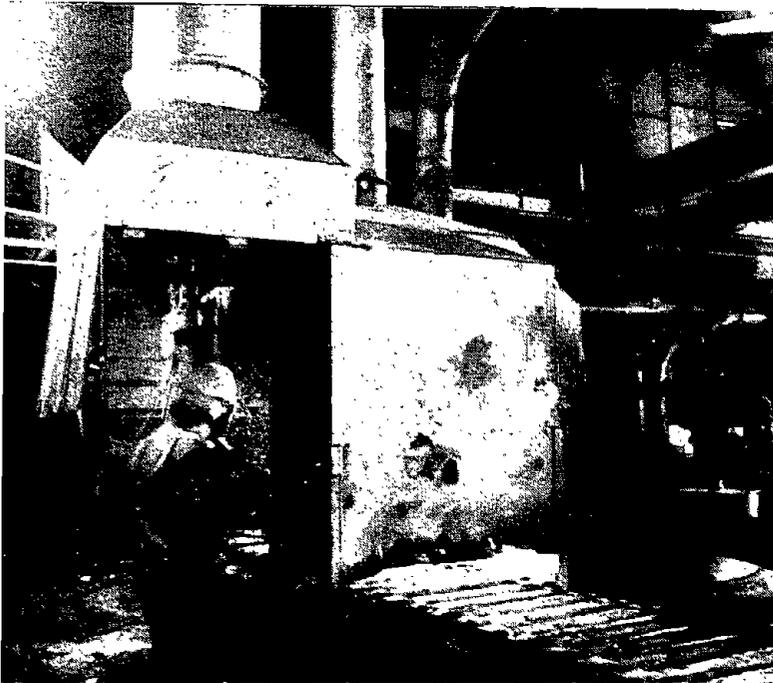
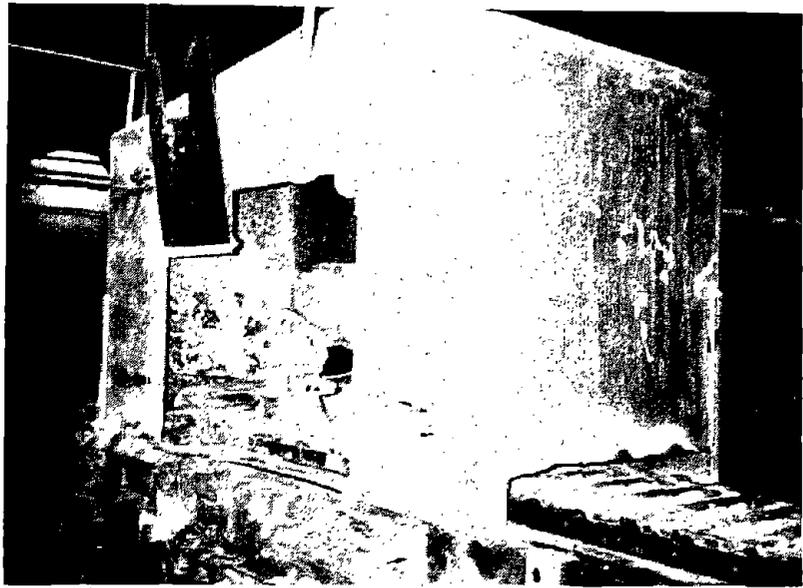
HEIGHT OF  
HOOD ABOVE  
FLOOR

Figure 11. Island Hood Placement

TABLE 3. GENERAL SPECIFICATIONS

|   |   |
|---|---|
| Ducts                                   | <p>Length, 55'</p> <p>Elbows, 2 at R=2</p> <p>Steel, Galvanized, 16-18 gauge</p> <p>Diameter, 20"</p> <p>@Q=5000 cfm, V=2300 fpm</p>  |
| Hood/Island                             | <p>Galvanized steel, 14 gauge;</p> <p>Plastic Sheets, 3/8", side-baffles</p>  |
| Static Pressure Requirements, inch w.g. | <p>1.7 inch w.g.</p> <p>(See Appendix for calculations)</p>   |
| Air-Supply Unit                         | <ul style="list-style-type: none"> <li>● Fan-5000 cfm @1.7" w.g.</li> <li>● Motor-5 HP</li> <li>● Heater-Gas-fired, direct, natural gas only, 500,000 BTU/HR;</li> <li>● Modulating Burner Control;</li> <li>● Variable Volume Damper, Motor Driven</li> <li>● Temperature Control and Thermostat at work station; Heavy Duty</li> <li>● If Direct-fired, Malfunction Feedback Device.</li> </ul> |

**Original Enclosure**



**Island Hood  
and Enclosure**

**Figure 12. ISLAND Placement and Casting Enclosure**



**Figure 13. Installed Hood**

Figure 14 shows the island and its placement near the casting line enclosure. Figure 15 shows the make-up air heating unit on the outside of the building. Figure 16 shows the temperature controls of the unit. Figure 17 shows results of face velocity measurements taken at three planes in the supplied-air island. (The horizontal velocity component of air entering the enclosure increased to 100-200 feet per minute.) The average velocity of the island at level A-A (at the edge of the sheet metal hood) was measured at 565 fpm, resulting in an estimated flow rate of 5,270 cfm, very close to original design specifications.

Figure 18 provides face velocity measurements at the intake of the make-up air unit. Measured flow rate was 5,170 cfm (as compared to an outlet measurement of 5,270 cfm, well within expected measurement error.)

#### 4.2 Operating Conditions During Testing

On the days of evaluation, June 14-16, 1983, both blast/reverb systems were operating. The refinery was at full operation and casting was performed during both days.

Skimming is performed most naturally with the left hand. However some skimmers used right and left hands alternately. Although five castings are in front of the skimmer, skimming tended to be performed on the casting closest to the

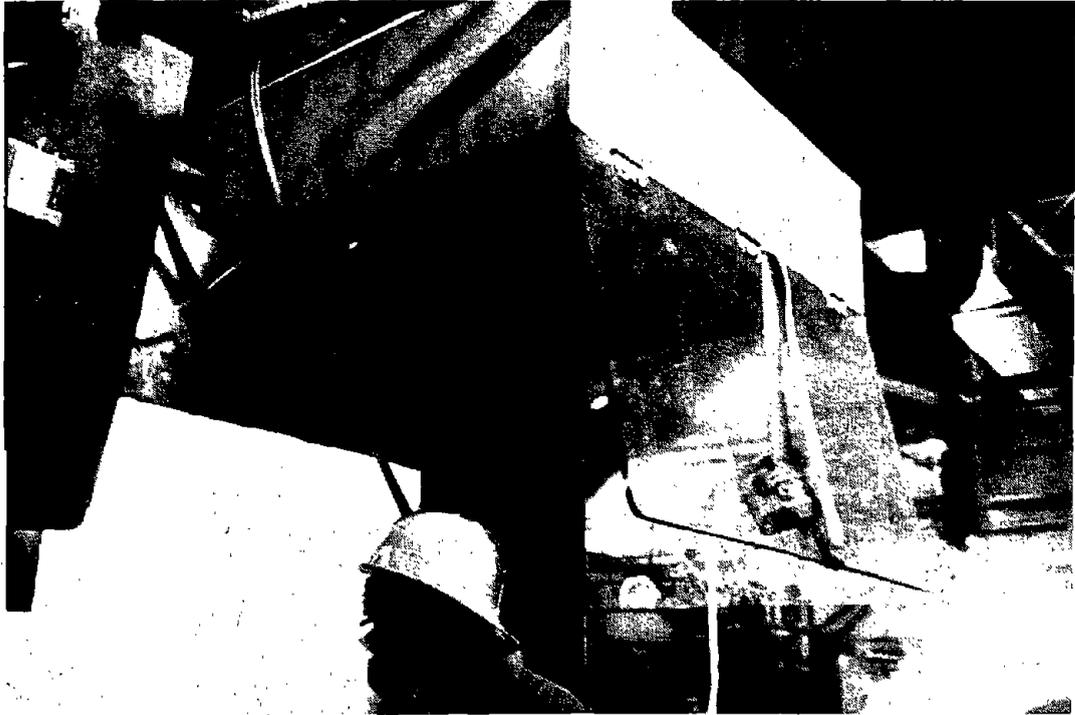
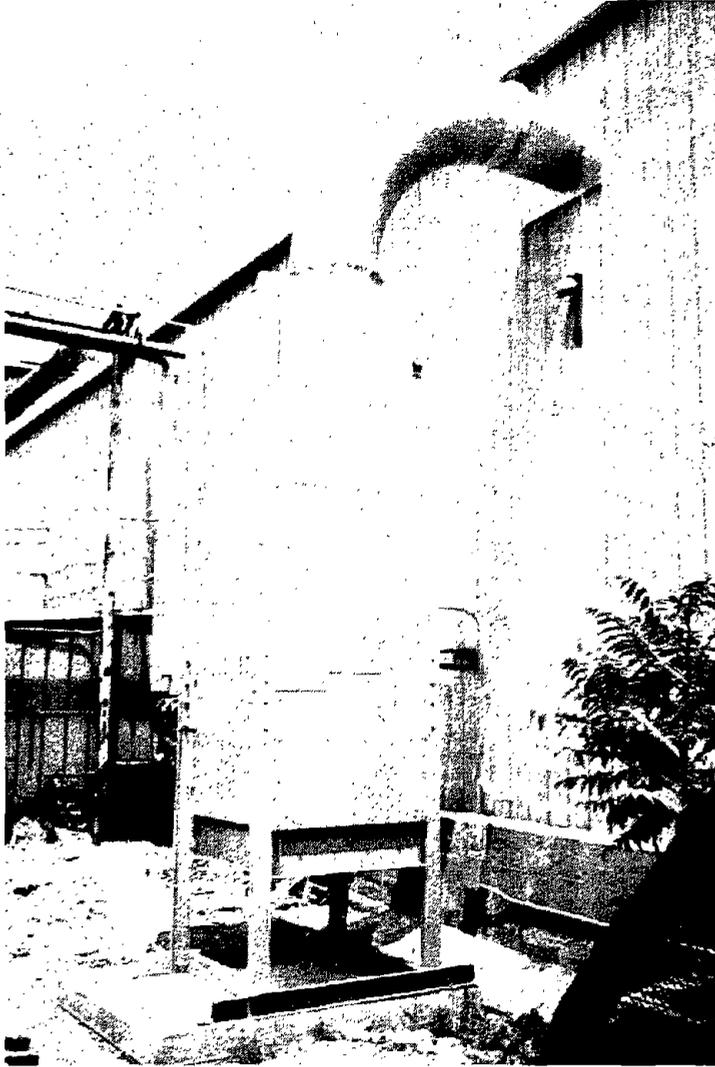
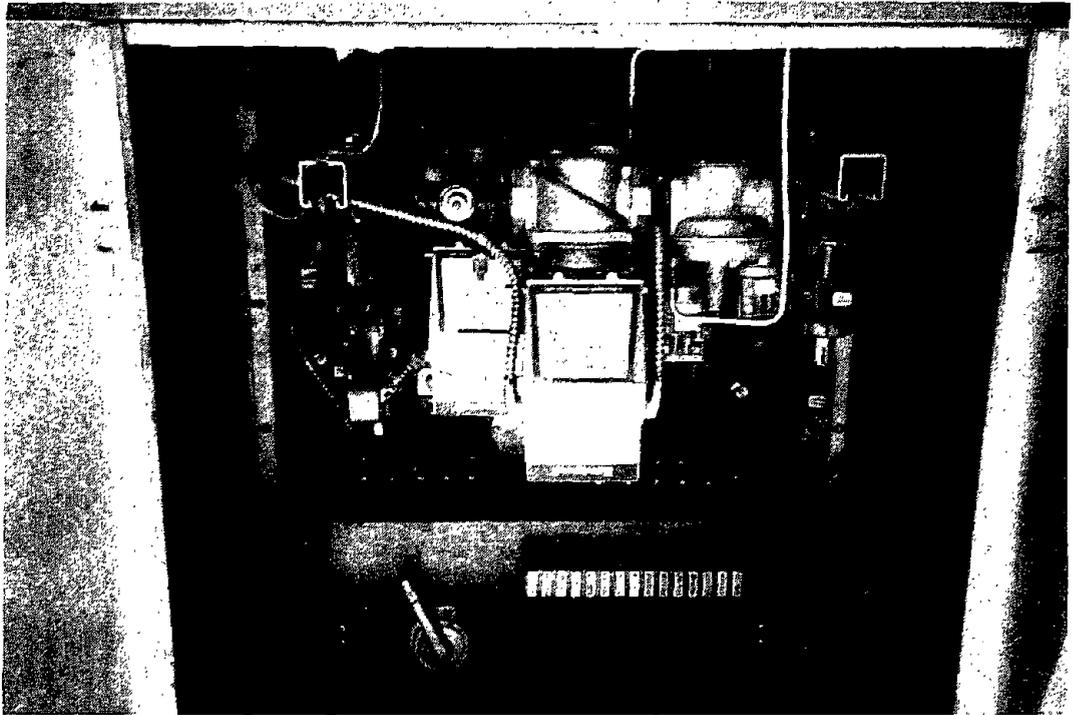


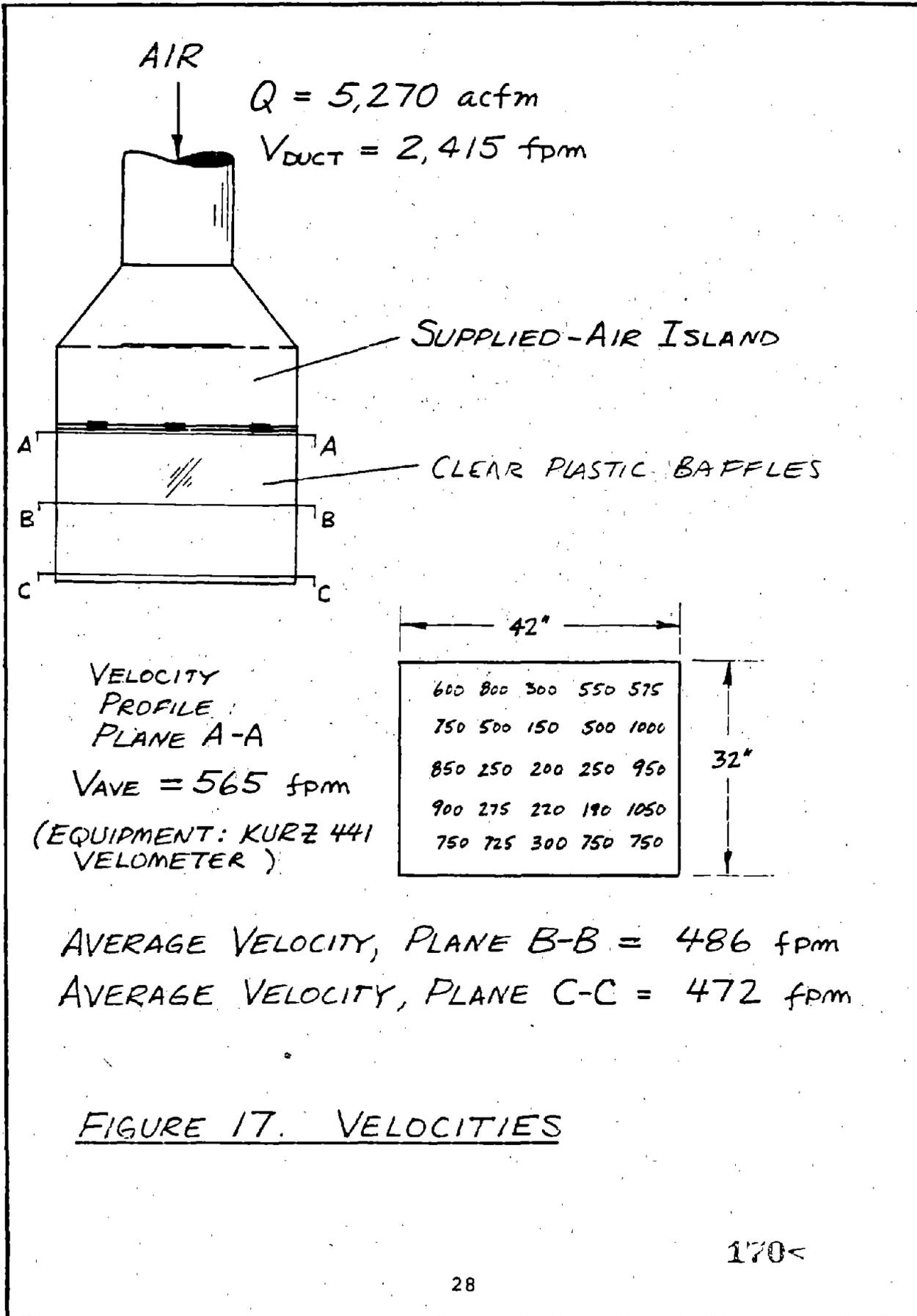
Figure 14. Supplied-air Island

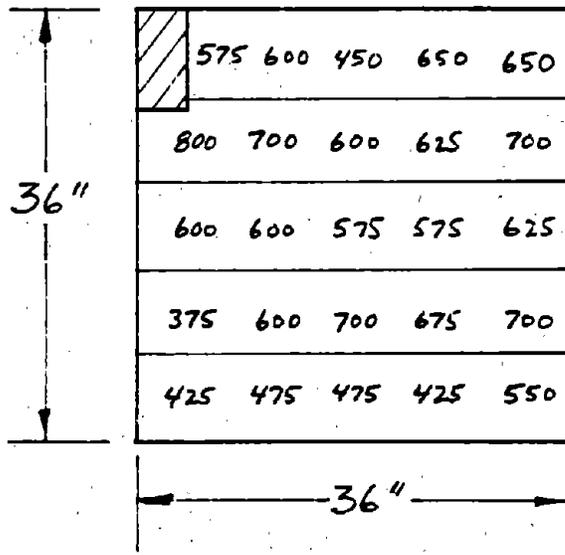
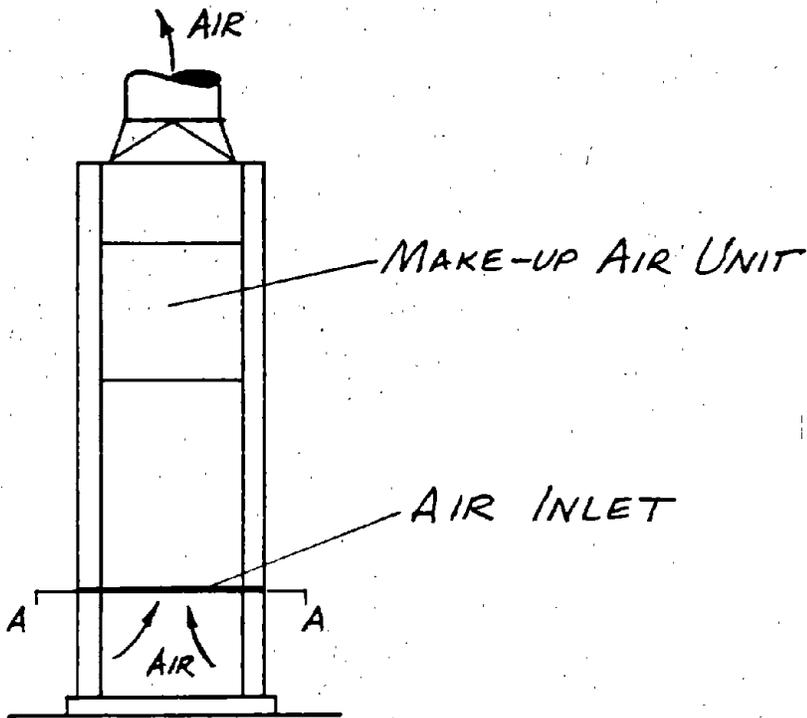


**Figure 15. Make-up Air Heating Unit**



**Figure 16. Motor/Burner Controls**





VELOCITY  
PROFILE  
PLANE A-A

$V_{AVE} = 589 \text{ fpm}$

$Q = 5,170 \text{ cfm}$

FIGURE 18. VELOCITIES AT INTAKE

star wheel. This resulted in the skimmer leaning into and towards the left-front edge of the supplied-air island, as shown in Figure 19.

According to casting line workers, work conditions were normal. The casting crew rotated between four jobs: the Skimmer, Stacker #1, Stacker #2, and Fork-lift operator. Each of the crew spent approximately 25% of the time at each job.



**Figure 19. Skimmer at Left Front Area of Island**

## 5.0 ENVIRONMENTAL CONSIDERATIONS

The environmental evaluation considered exposures to noise, heat and lead, each of which is discussed below.

### 5.1 Noise

Sound pressure levels measured on June 14, 1983 at 2:00 p.m. are summarized on Table 4. Noise levels in the supplied-air island were not significantly different from noise levels measured in the vicinity of the casting line.

### 5.2 Heat Stress

Temperature measurements obtained on June 15, 1983 at 11:30 a.m. are summarized on Table 5. The temperature inside the island was considerably below temperatures in the vicinity of the casting line. The effective temperature (see Figure 8) was estimated to be 70-75°, about 20° below the dry bulb temperature outside the island. No globe-thermometer measurements were obtained. As such, the influence of IR from hot castings (400-600°F) was not evaluated.

TABLE 4. NOISE MEASUREMENTS

|  |   |
|--|---|
| Equipment Description                                  | Quest Sound Level Meter<br>Model 211A/FS<br>ANSI S1.4 Type S2<br><br>Calibrator CA-12 |
| Calibration  | 110 dBA (okay)<br>Battery (okay)  |
| Date and Time  | June 14, 1983<br>2:00 - 2:30 P.M.   |
| Temperature  | 95°F (D.B.)   |
| Sound Levels<br>in various locations<br>near casting   | 89-91 dBA (slow)  |
| Sound Levels in<br>supplied air island<br>at ear level | 89-90 dBA (slow)  |

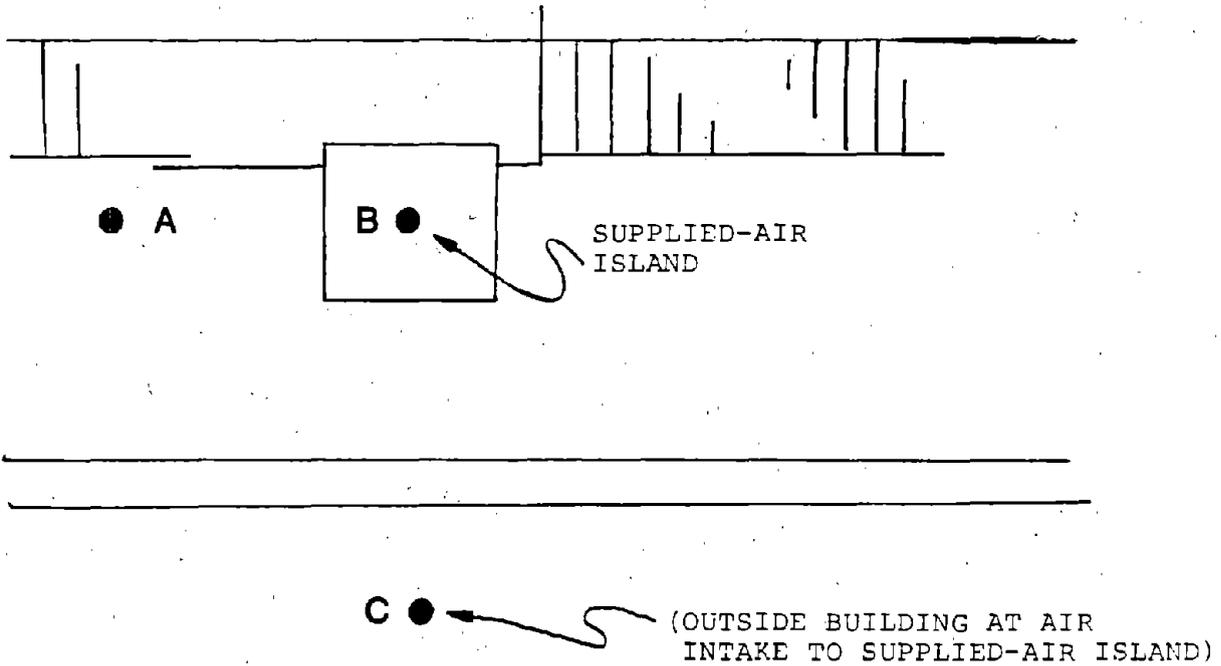
TABLE 5. TEMPERATURE MEASUREMENTS

EQUIPMENT DESCRIPTION BACHARACH SLING PSYCHOMETER

DATE AND TIME June 15, 1983  
11:30 a.m.

TEMPERATURE

|                 | TEMPERATURE, F |       |    |
|-----------------|----------------|-------|----|
|                 | A              | B     | C  |
| Dry Bulb        | 93             | 87    | 86 |
| Wet Bulb        | 76             | 73    | 73 |
| Effective Temp. | 82-83          | 70-75 | -- |



### 5.3 Lead Exposure

The major purpose for installing the supplied-air island was to reduce lead exposures to the casting line skimmer operator.

Contributors to the skimmer's exposure are complex and constantly varying. Emission sources include all of the operation's associated with the smelter building (See Figure 2) Providing emission control for all emissions is presently infeasible at the GBC smelter.

Exposure levels measured since 1978 are summarized in Table 6. Samples obtained during June 1983 are summarized on Figure 20.

Figure 21 shows the sampler at the inlet to the make-up air heater unit outside the building.

Figure 22 shows one of two samplers placed inside the hood: one was an area sampler, the other (shown) a breathing-zone, personal sampler.

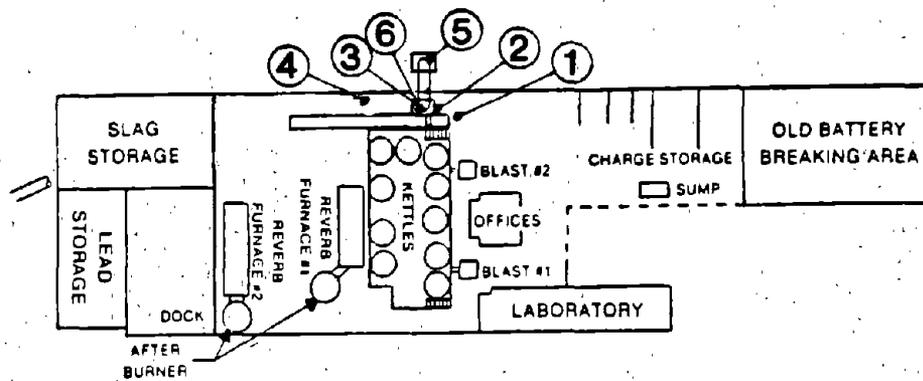
TABLE 6. LEAD LEVELS AT THE CASTING AREA, SUMMARY

| <u>Dates of Sampling</u> | <u>Type of Sampling</u> | <u>Number of Sampling</u> | <u>Source of Sampling</u> | <u>Results Low-High-Average ug/m3</u> |
|--------------------------|-------------------------|---------------------------|---------------------------|---------------------------------------|
| 1978                     | BZ/TWA                  | 6                         | GBC                       | 201 - 899 - 511                       |
| 1979-80                  | BZ                      | 13                        | GBC                       | 90 - 1598 - 621                       |
| 1981                     | BZ/TWA                  | 24                        | GBC                       | 54 - 1910 - 422                       |
| Dec, 1981                | BZ/TWA                  | 2                         | RADIAN                    | 342 - 649 - 495                       |
| Dec, 1981                | AREA                    | 6                         | RADIAN                    | 343 - 1130 - 515                      |
| 1982-83                  | BZ/TWA                  | 17                        | GBC                       | 76 - 332 - 175                        |
| June, 1983               | AREA                    | 9                         | RADIAN                    | 62 - 738 - 213                        |

\*BZ - Breathing Zone, Personal Samples

TWA - Time weighted Average

AREA - Area Samples (does not include any samples taken in the supplied-air island)



| SAMPLE LOCATION | DESCRIPTION OF LOCATION           | TYPE<br>A-AREA<br>P-PERSONAL | NUMBER<br>OF<br>SAMPLES | RANGE<br>ug/m <sup>3</sup> | AVERAGE<br>ug/m <sup>3</sup> |
|-----------------|-----------------------------------|------------------------------|-------------------------|----------------------------|------------------------------|
| 1               | Near holding kettle               | A                            | 3                       | 135-738                    | 380                          |
| 2               | Adjacent to supplied-air island   | A                            | 3                       | 140-210                    | 170                          |
| 3               | In supplied-air island            | A                            | 3                       | 5-10                       | 6                            |
| 4               | Middle of casting line            | A                            | 3                       | 65-118                     | 89                           |
| 5               | Outside Building at air intake    | A                            | 3                       | 7-15                       | 10                           |
| 6               | Breathing zone samples on skimmer | P                            | 3                       | 14-36                      | 24                           |

Figure 20. Summary of Sampling, June, 1983

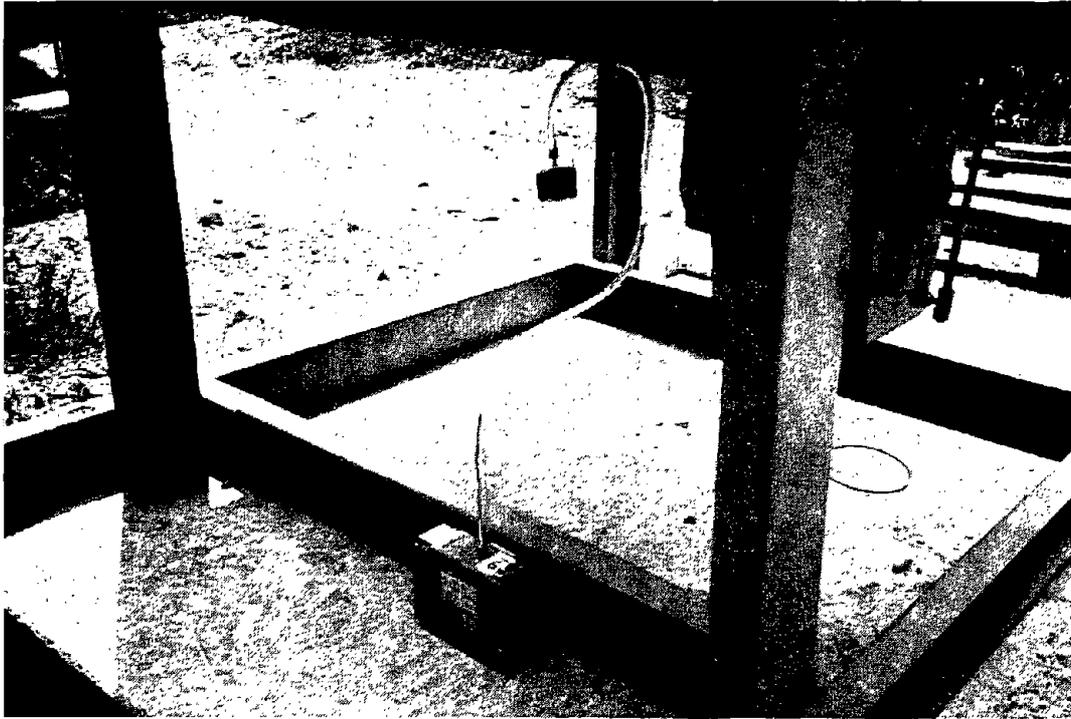


Figure 21. Sampler at Air Intake, Location No. 5

180<



**Figure 22. Breathing-Zone Sampler**

## Discussion

Average TWA exposure levels have been substantially reduced since 1979-1980. This may reflect other emission control efforts made by GBC in the smelter building.

During the evaluation of June, 1983, airborne lead levels within the island's zone of protection were reduced to less than 10% of lead levels measured directly outside the hood, (i.e., 170 ug/m<sup>3</sup> reduced to 10 ug/m<sup>3</sup>). Breathing zone exposures were reduced to less than 15% of average exposure levels measured during 1982-1983, (i.e., 175 ug/m<sup>3</sup> reduced to 24 ug/m<sup>3</sup>.) Breathing-zone exposures are higher than might be expected because skimmers tended to lean out of the primary zone of protection.

Since the casting crew rotated between jobs, each casting line worker spent about 25% of the work shift in the supplied-air island. Average expected exposures can be estimated by the following calculation:

$$\begin{aligned}\text{Expected Exposure} &= 175 (.75) + 24 (.25) \\ &= 137 \text{ ug/m}^3\end{aligned}$$

## 6.0 COSTS

Table 7 provides actual initial costs incurred in the design and construction of the supplied-air island.

Operating costs are estimated at \$2,400/yr., primarily to heat make-up air to the supplied-air island. Maintenance costs are estimated at 10% of capital costs, bringing annual O&M costs to \$3,900/year.

TABLE 7. COSTS

| Item                                    | <u>Cost, \$*</u> |
|---|------------------|
| Design                                  | 840              |
| Make-up Air Unit,<br>delivered          | 6,449            |
| Ducts, sheetmetal<br>work; installation | <u>7,600</u>     |
| Total                                   | \$14,889         |

\*Costs do not include design and evaluation costs associated with Radian's participation.

## 7.0 SUMMARY AND RECOMMENDATIONS

The supplied air island built by GBC at the casting skimmers work station was effective in reducing breathing-zone exposures to below 30 ug/m<sup>3</sup>. Persons working full-time at this work position would likely be in compliance with the OSHA PEL, 50 ug/m<sup>3</sup>.

Improvements in the system could include:

- Placement of the supplied-air island directly over the skimmer. (See Figure 19)
- Removal of the circular air deflector in the face of the supplied-air island: the deflector was placed at a location directly over the skimmer's head in an effort to reduce the air velocity over the skimmer's face. However, 600+ fpm face velocities were found to be acceptable to the skimmer when temperature controls were provided. The deflector created unwanted turbulence at the boundary of the supplied-air island, reducing the effective zone of protection.

Appendix

Calculation of Static Pressure Requirements.  
Original, Conceptual Design Specifications.

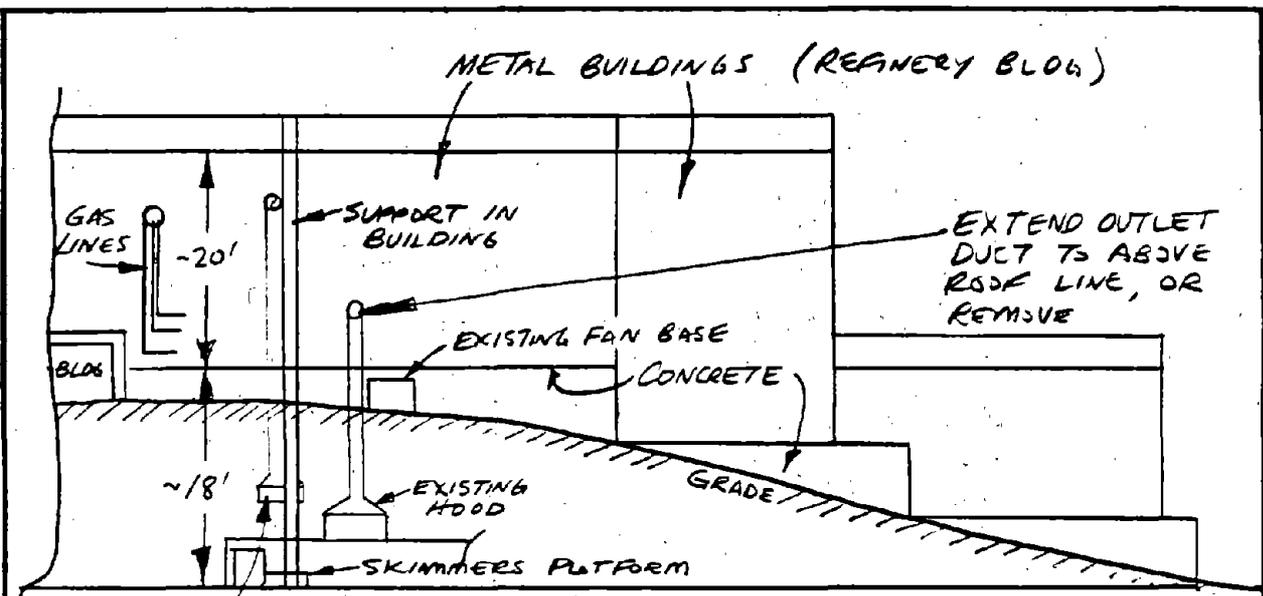
# Estimated Static Pressure Requirements

## Velocity Pressure Method

| ROW | ITEM                                 | SOURCE              | UNITS    |              |       |
|-----|--------------------------------------|---------------------|----------|--------------|-------|
| 1   | DUCT IDENTIFICATION                  | PLANS               | FROM-TO  | INLET/OUTLET |       |
| 2   | DESIGN Q                             | PLANS               | CFM      | 5000         |       |
|     | SLOTTED HOOD? (Yes-ROW 3; No-ROW 10) |                     |          |              |       |
| 3   | SLOT VELOCITY                        | PLANS               | FPM      | /            |       |
| 4   | SLOT AREA                            | ROWS 2 3            | SQ.FT.   |              |       |
| 5   | SLOT VF                              | FIG. 6-16           | IN.W.G.  |              |       |
| 6   | ENTRY LOSS FACTOR                    | (1.78)              | NONE     |              |       |
| 7   | ACCELERATION FACTOR                  | (1.0)               | NONE     |              |       |
| 8   | PLENUM LOSS FACTOR                   | ROWS 6+7            | NONE     |              |       |
| 9   | PLENUM SP                            | ROWS 5X8            | IN.W.G.  |              |       |
| 10  | DUCT DIAMETER                        | FIG. 6-15           | INCH     |              | 20"   |
| 11  | DUCT AREA                            | FIG. 6-18           | SQ.FT.   |              | 2.182 |
| 12  | DUCT VELOCITY                        | ROWS 2 11           | FPM      | 2290         |       |
| 13  | DUCT VF                              | FIG. 6-16           | IN.W.G.  | 0.33         |       |
| 14  | DUCT LENGTH                          | PLANS               | FEET     | 55           |       |
| 15  | FRICTION FACTOR                      | FIG. 6-17           | VP/100'  | 0.98         |       |
| 16  | ACTUAL FRICTION                      | ROWS 14x15/100      | NONE     | 0.54         |       |
| 17  | HOOD ENTRY LOSS                      | VS OF FIG 6-10      | NONE     | 0.25         |       |
| 18  | ACCELERATION                         | (1.0)               | NONE     | 1.0          |       |
| 19  | ELBOWS                               | FIG. 6-12           | NONE     | 0.54         |       |
| 20  | BRANCH ENTRY                         | FIG. 6-13           | NONE     | -            |       |
| 21  | OTHER                                | FAN INLET/OUTLET    | NONE     | 0.5          |       |
| 22  | OTHER                                | ORIFICE DIFFUSER    | NONE     | 1.78         |       |
| 23  | OTHER                                | ( )                 | NONE     |              |       |
| 24  | TOTAL LOSS FACTOR                    | SUM 16-23           | NONE     | 4.61         |       |
| 25  | DUCT SP LOSS                         | ROWS 13X24          | IN.W.G.  | 1.52         |       |
| 26  | OTHER EQUIP. LOSS                    | FILTER              | IN.W.G.  | 0.2          |       |
| 27  | OTHER EQUIP. LOSS                    | ( )                 | IN.W.G.  | 1.72         |       |
| 28  | PRECEDING JUNCTION                   | (at FROM)           | IN.W.G.  | -            |       |
| 29  | JUNCTION VP CHANGE                   | (at FROM)           | IN.W.G.  | -            |       |
| 30  | TOTAL SP LOSSES                      | SUM 25-29           | IN.W.G.  | 1.72"        |       |
| 31  | IS THIS GOV. SP?                     | PLANS               | (YES/NO) |              |       |
| 32  | GOV. SP                              | (at TO junction)    | IN.W.G.  |              |       |
| 33  | CORRECTED VOLUME FLOW RATE*          |                     | CFM      |              |       |
| 34  | SPh                                  | ROWS 9+(13X(17+18)) | IN.W.G.  |              |       |

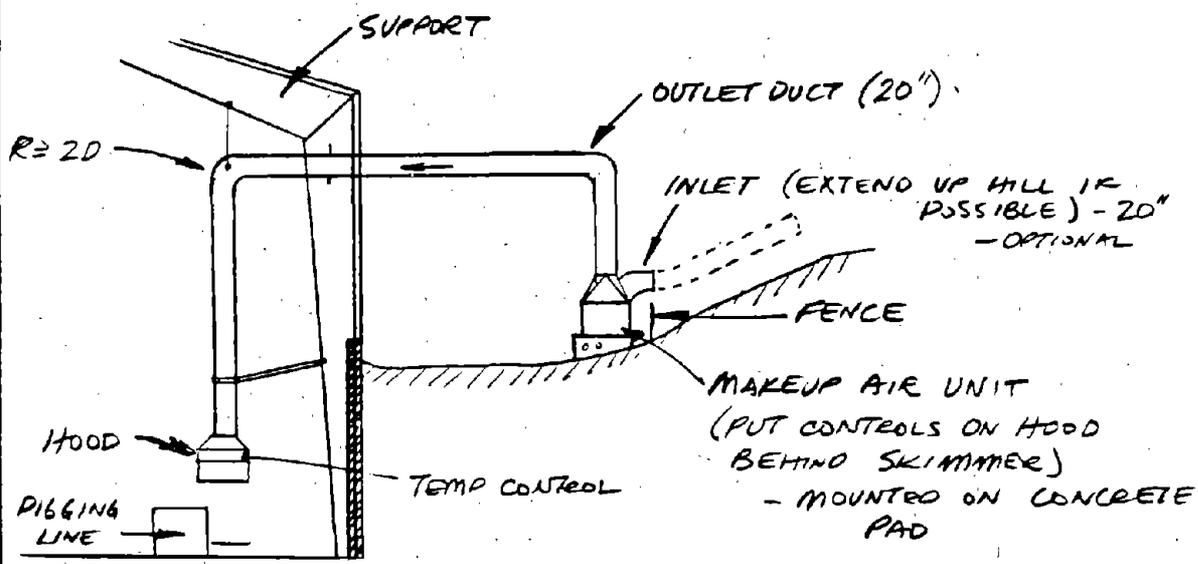
ADAPTED FROM THE ACCIH

$$* Q_{CORR} = Q_{ACT} \sqrt{\frac{SP_{GOV}}{SP_{CORR}}}$$



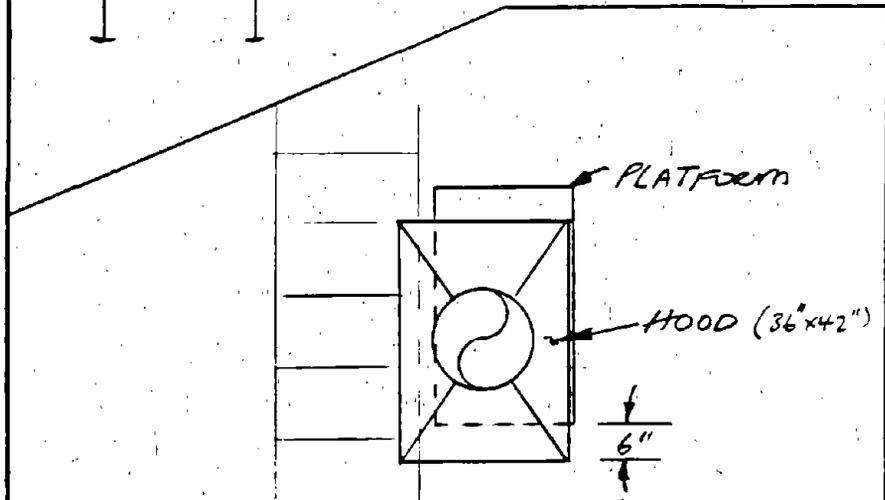
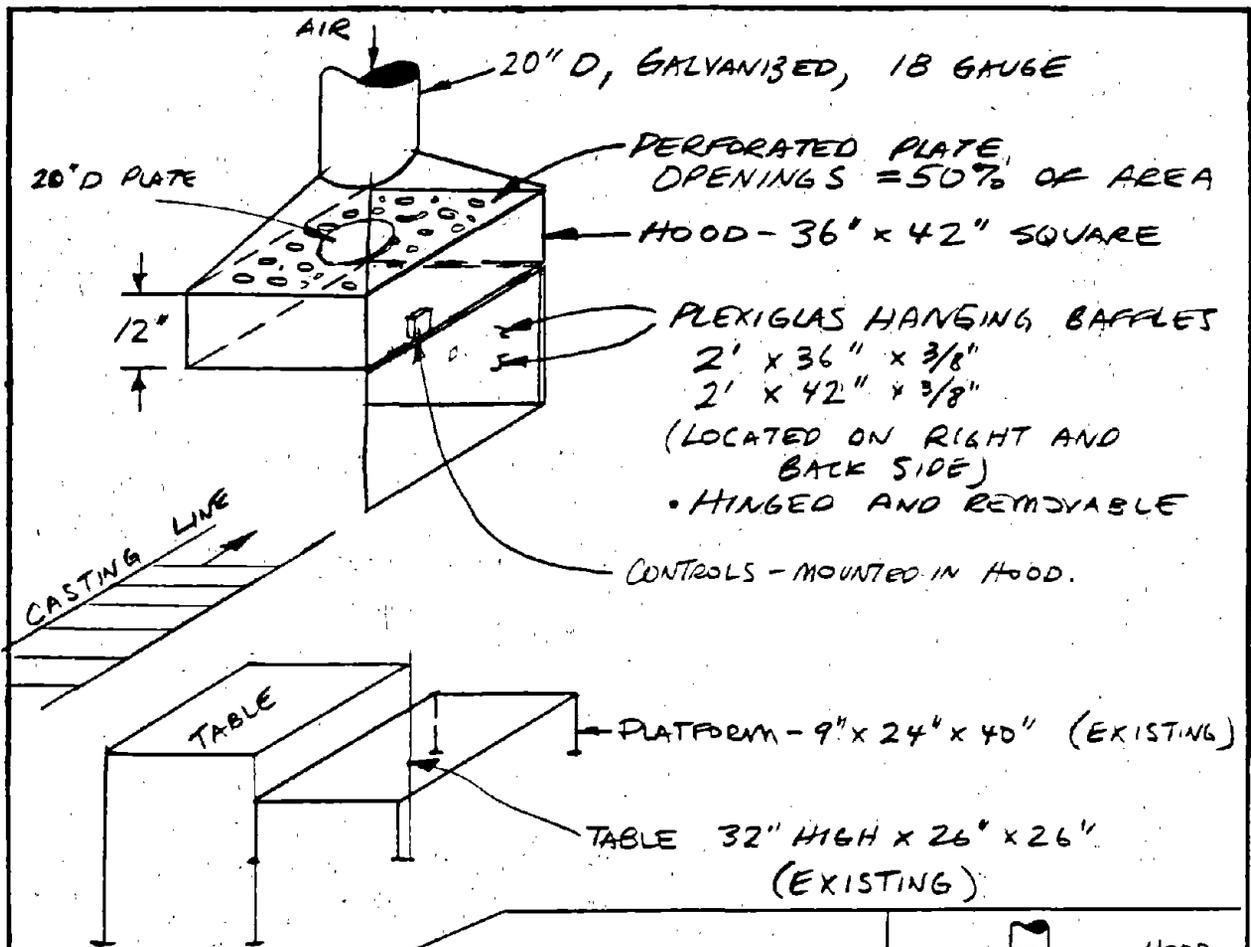
SUPPLIED-AIR ISLAND HOOD

VIEW FROM WEST (DOES NOT SHOW PROPOSED SUPPLIED-AIR ISLAND.)



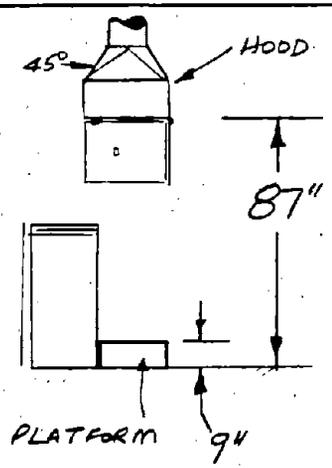
SIDE VIEW (PROPOSED SYSTEM)

188<



POSITION OF HOOD ABOVE PLATFORM  
(APPROX)

PLAN VIEW

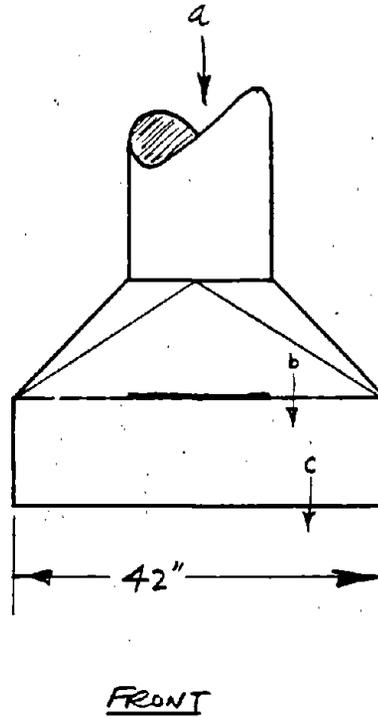
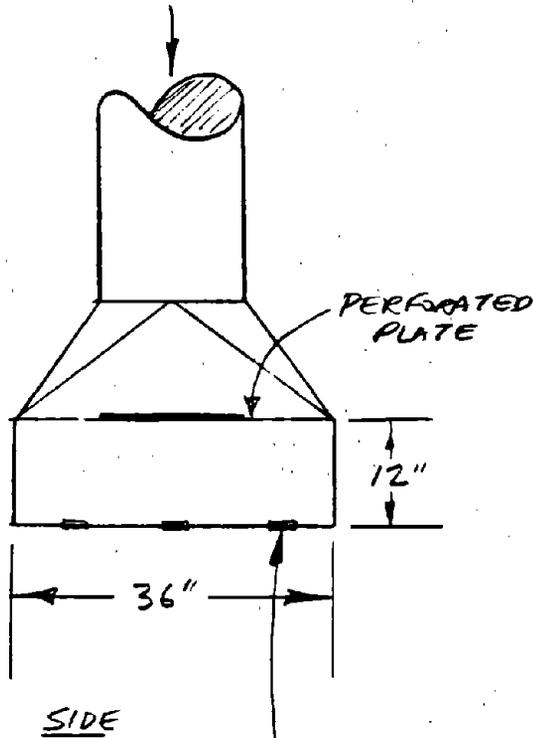


HEIGHT OF HOOD ABOVE FLOOR

183<

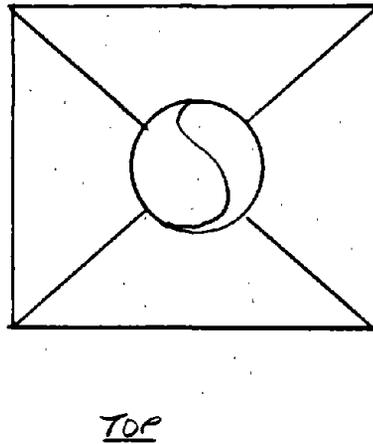
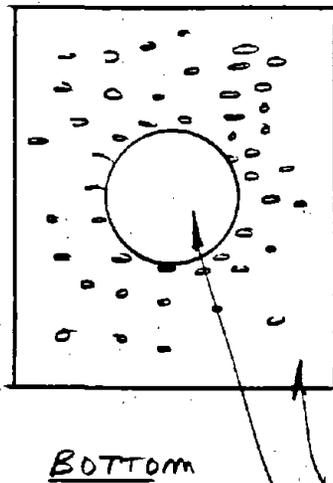
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**RADIAN**  
CORPORATION



VELOCITIES  
a. 2300 FPM  
b. 1200 FPM  
c. 600 FPM

HINGE ATTACHMENTS FOR PLEXIGLASS  
BAFFLES (2 SIDES ONLY)  
BACK - 42" x 24" x 3/8" ; RIGHT - 36" x 24" x 3/8"



PERFORATED PLATE. 50% OPEN.

20" D PLATE WITH NO PERFORATIONS  
DIRECTLY UNDER DUCT INLET.

DROSS EMISSION CONTROLS  
USING A SCREW  
DROSSING MACHINE

Final Technical Report  
Demonstration Project Number Five

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

NIOSH Contract No. 210-81-7106

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

June, 1982



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## 1.0 INTRODUCTION

In this report we describe the results of a study funded by the National Institute for Occupational Safety and Health (NIOSH). The study was conducted by the Occupational Safety and Health Division of Radian Corporation at a secondary lead smelter owned and operated by Tonolli North America in eastern Pennsylvania. This report presents an evaluation and characterization of a Tonolli-built screw dressing machine, which is used to reduce emissions and exposures during the removal of drosses from refining kettles.

Radian conducted on-site studies at Tonolli's Nesquehoning, Pa. plant during October and December, 1981. Most of the technical data were supplied by Tonolli. Measurements of airflows and exposure levels were obtained by Radian. Lead samples were analyzed in Radian's AIHA-certified laboratory in Austin, Texas.

### 1.1 PURPOSE AND OBJECTIVES

The purpose of this project is to investigate, evaluate, and characterize the operation of the Tonolli screw dressing machine.

The objectives of the report are to describe the findings of the study and to provide useful information to smelter operators, government agencies, engineers, etc. It is hoped that utilization of this information will result in reduced exposures to smelter workers, and more cost-effective expenditures of funds for exposure control.

## 2.0 DESCRIPTION OF TONOLLI OPERATIONS

In order for other plants to determine the applicability of a screw drosser to their operations, we include here a brief description of the Tonolli plant.

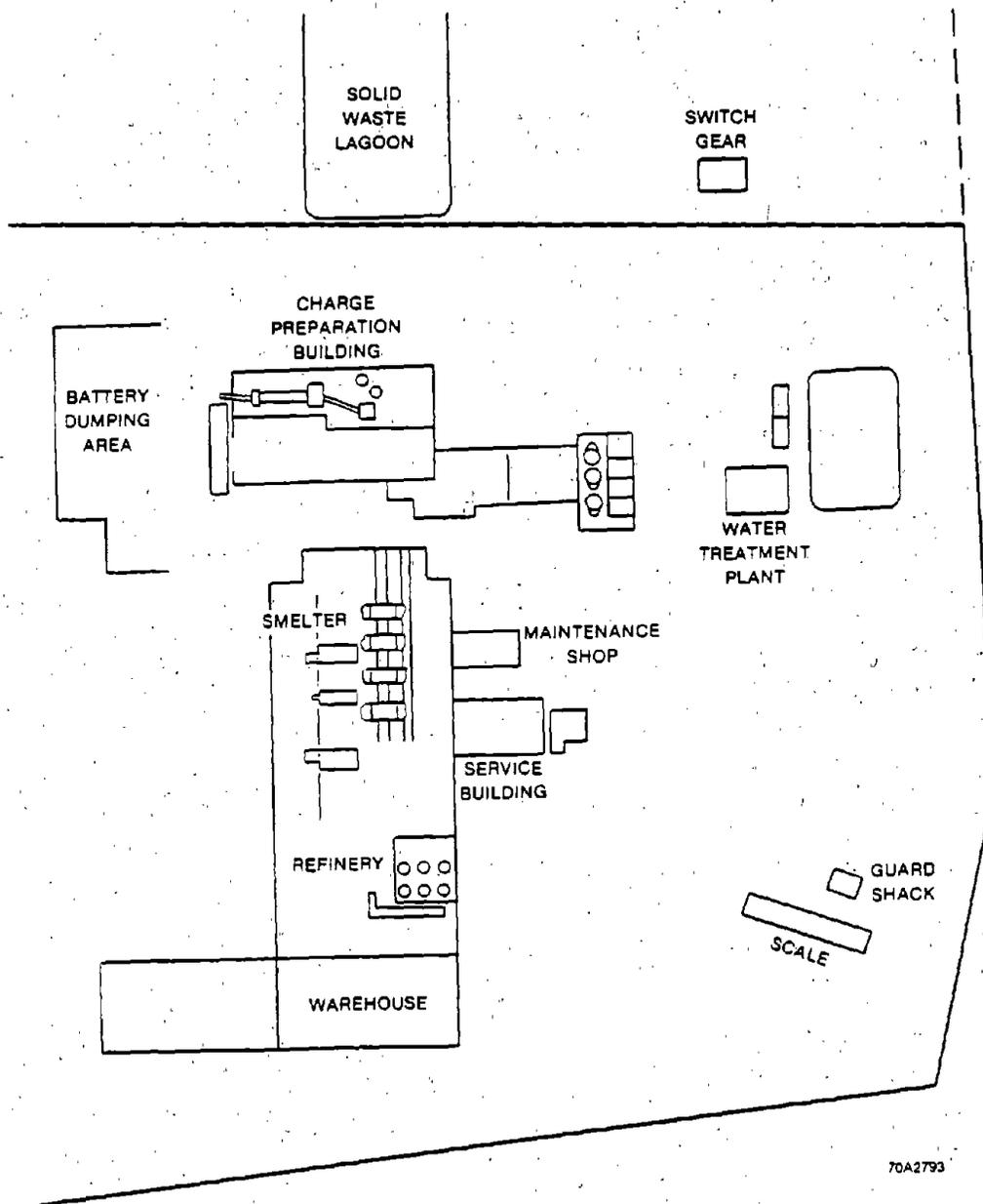
The Nesquehoning smelter processes lead acid batteries and other lead scrap materials. End products include hard and soft lead pigs and other shapes. The plant is capable of producing various forms of special lead alloys and lead-based solder. At full capacity, the smelter can produce 125 tons lead/day. The plant operates 24 hours/day, 7 days/week, 48 weeks/year, under normal conditions.

The smelter relies primarily on four rotary furnaces for smelting and six 100-ton kettles for refining. Auxiliary equipment includes a battery breaking and separating process, material handling equipment, casting machines, a flue dust agglomeration furnace, baghouses and scrubbers, and other support equipment. Figure 1 presents the basic plant layout.

### 2.1 RAW MATERIALS HANDLING

Raw material inputs are approximately 85% used batteries and 15% scrap and kettle drosses. Scrap batteries are brought in by truck, weighed, and driven to an outdoor, paved dumping area surrounded on three sides by a 10-foot concrete wall. In this large paved area battery acid is removed from scrap batteries and drains into a sump for neutralization.

Broken batteries are transferred to the hopper of a hammermill crusher. From the crusher the pieces are moved by a conveyor belt into a battery separation process. The battery separator processes 45-50 tons per hour of crushed batteries.



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FIGURE 1 PLANT LAYOUT (NOT TO SCALE)

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## 2.2 FURNACE CHARGE PREPARATION

There are generally two "recipes" charged to the rotary furnaces. The first, based on a dry lead oxide/lead sulfate paste mixture is charged about 70% of the time. For the remaining 30%, the plant charges metallic lead (grids and posts), which is about 97% lead alloys. The metallic lead could be charged directly to the refining kettles, but it is more convenient to charge it to the furnace.

Other constituents of the charge may include agglomerated flue dust, anthracite coal and cast iron borings (reducing agents), and soda ash to facilitate sulfur removal in the slag.

## 2.3 FURNACE OPERATION

The plant has four identical, refractory-lined, rotary furnaces, of which three are normally operated at any one time. Charge materials are introduced at the rear, and lead and slag are tapped from spouts in the center, side wall and front sections of the furnace.

### Charging

The charge is introduced through the rear door by one of two track-mounted charging machines. Tote boxes are lifted hydraulically or by crane and dumped into the charge machine hopper. The charge machine has a long scoop or chute with a hemispherical cross section. The furnace door is opened and the scoop is pushed into the furnace and inverted to deposit the charge.

### Tapping

Lead and slag are tapped in to five foot diameter by four foot

tall, cone-shaped crucibles, which are coated with lime to facilitate product removal. Tapping of lead is accomplished by rotating the furnace until the tap hole is at the level of an upper platform where the tap hole is unplugged. Then the furnace is rotated a quarter turn to position the hole at the bottom of the furnace, and lead runs out in to the crucible. A crust of lead sulfate matte is skimmed from the surface of the molten lead and returned to the furnace. After tapping, the lead is cooled, the crucible is pulled along a track, removed from the hooding/tunnel, and transferred by crane to the refining kettle area.

#### 2.4 REFINING, DROSSING, AND CASTING

The refining kettles are in the same building on a ten-foot platform next to the furnaces. There are six 100-ton kettles, with three used for refining, two for pouring and one for standby. About six 15,000-lb. crucibles are required to fill one 100-ton kettle. Sulfur for copper removal and sawdust for oxide removal are added during the refining operation. All the kettles are provided with hoods. Figures 2 and 3 show the kettle layout and ventilation system.

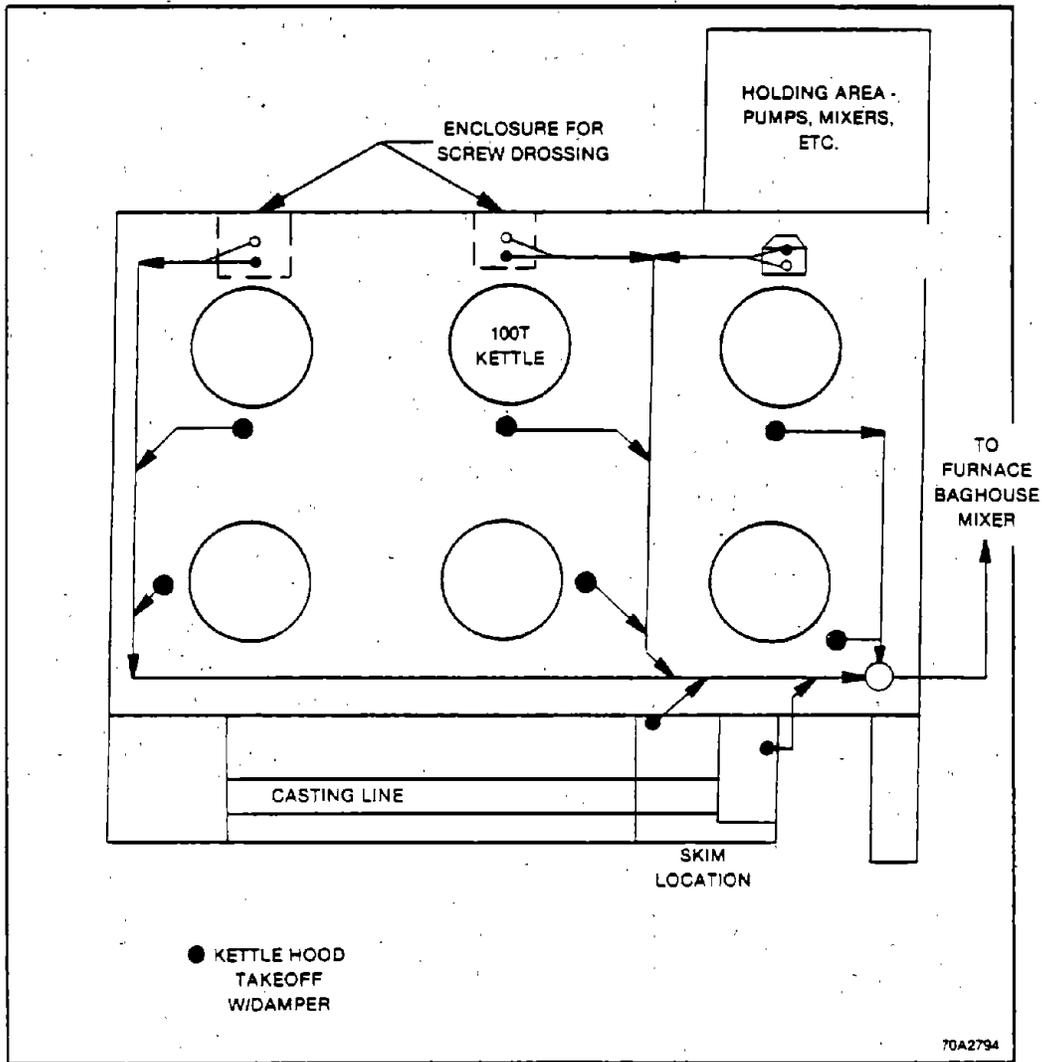
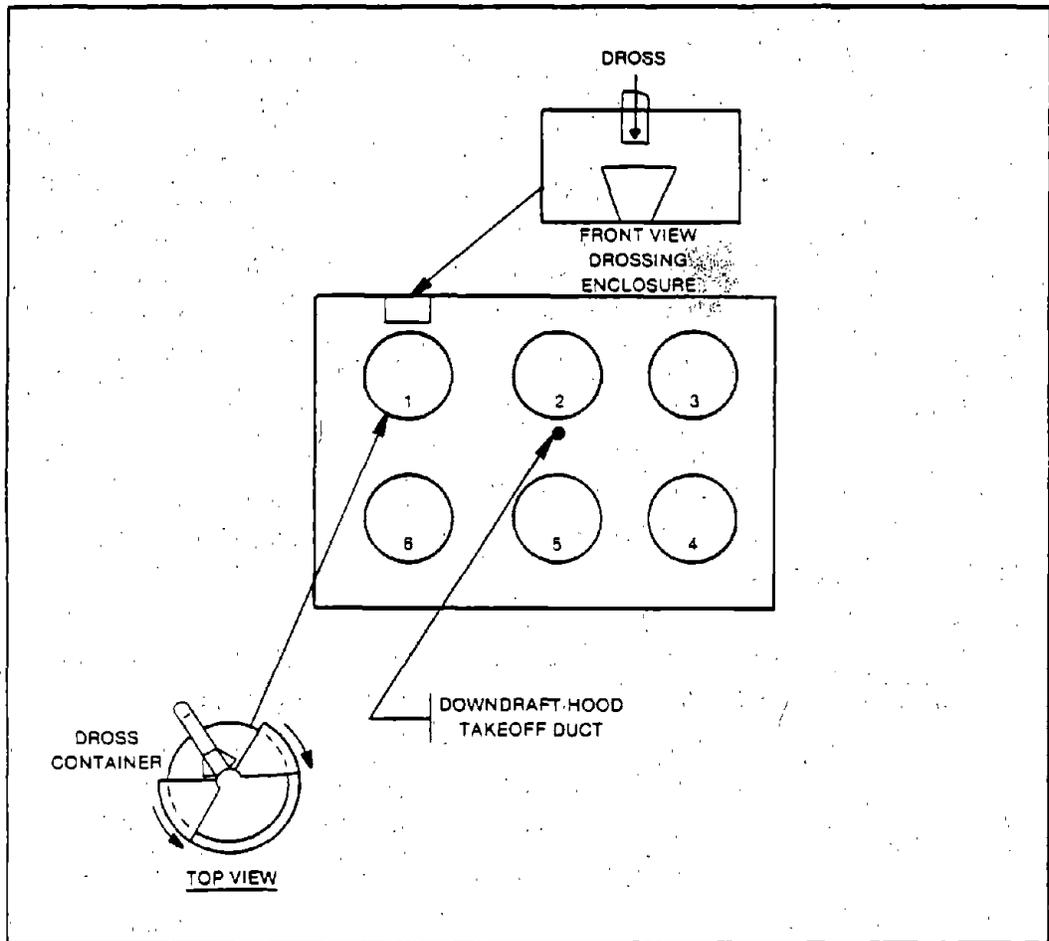


FIGURE 2 KETTLE REFINING VENTILATION SYSTEM



70A2795

FIGURE 3 KETTLE HOOD CHARACTERISTICS

### 3.0 DROSSING OPERATIONS

Refining of lead bullion produced in smelter furnaces (e.g. blast, reverberatory, rotary) is usually conducted in hemispherically-shaped kettles. Kettle sizes range from 3 to 12 feet in diameter.

Refining generally means removing impurities, or altering the composition of the bullion, so as to obtain a desired lead product. Drossing is usually the first step in the refining process, although the term "drossing" is often applied to all skimming of impurities from refining kettles. (The word "dross" refers to any of the solid scum floating on the lead bath, and typically consists of metal oxides of antimony, tin, zinc, copper, arsenic, bismuth, and metallic sulfides.) Dross is produced by a number of operations, e.g. heating, cooling, stirring, blowing of air or oxygen, adding sawdust, sulfur, zinc, calcium, magnesium, carbon, etc.

Dross has traditionally been skimmed by hand using a steel paddle or scoop. The skimmer dips the scoop into the lead bath and extracts a load of dross which he then dumps into a container. Non-antimonial dross is usually very dry and dusty, creating high emissions (and high exposures) during handling. Spilled dross becomes a major secondary source of lead emission and contributes to background levels of lead in the area.

In the past, Tonolli, like all other smelters, has performed skimming of dross by hand. No specific emission data are available but it is commonly assumed that hand drossing contributes a significant portion of a refinery worker's total lead exposure during the shift. Dross materials are typically hot, dry, and dusty. Emissions occur in every operation associated with skimming and dross handling.

Additionally, the process of hand skimming is miserably hot and time consuming--typically the worst job in the refinery worker's daily routine.

Several solutions to the problem have been suggested: vacuum drossing, clam shell drossing, and screw drossing.

Vacuum drossing uses high-velocity air flow to entrain and transport dross to a closed container. Its major advantages are that it controls emissions, contains dross in air tight containers, and frees the operator from working over a hot kettle. Vacuum drossing has been attempted but written reports of its use are unavailable. It is reported by smelter operators that the major problem with past attempts was plugging and fouling of vacuum lines.

The clam shell has been tried with limited success. Its advantage is that it uses a scoop for positive pickup control. Its drawback is that it is nothing more than mechanized hand skimming. Emissions continue to be a major problem. Dross spillage and dross container handling continue to be major sources of lead emissions.

Screw drossing has also been tried at various plants, but with mixed success to date. No written reports are available. Verbal reports indicate that plugging of the conveyor and equipment reliability have been major problems.

This report presents the results of a study of a new approach to screw drossing developed by Tonolli. It is unique in that it incorporates the best features of all other drossing methods, i.e. screw conveying, scoop pickup, air flow control of emissions, and enclosed storage and handling of dross.

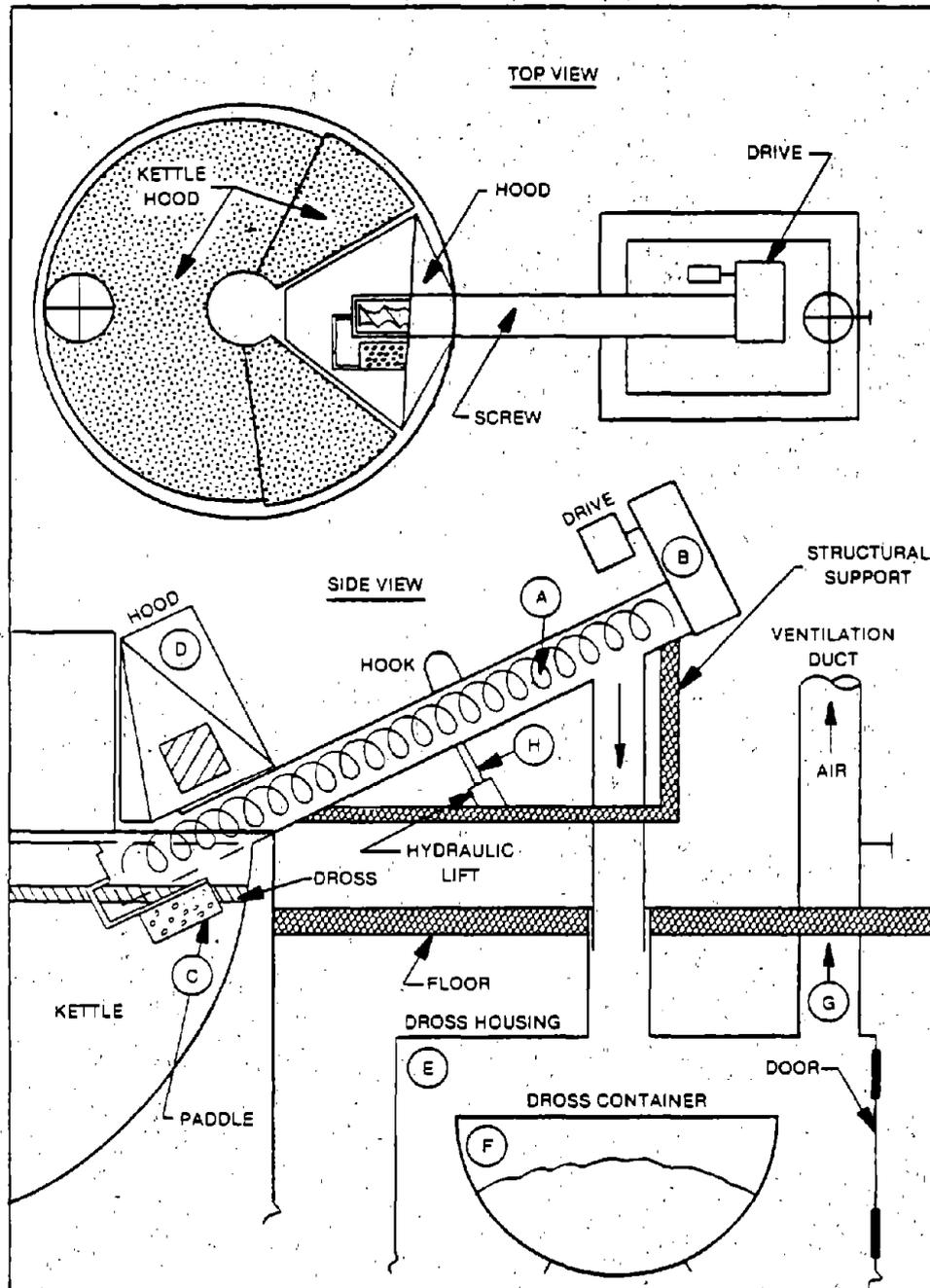
### 3.1 TONOLLI SCREW DROSSING MACHINE

Figure 4 presents two schematic diagrams of the equipment.

Basic operating components of the system include:

- A. A screw conveyor which moves dross up to a drop chute.
- B. A drive mechanism to turn the screw and the paddle.
- C. A paddle which lifts the dross from the surface of the bath and deposits it in the screw conveyor.
- D. A hood which encloses the open area of the kettle hood.
- E. An enclosed housing which contains the dross container.
- F. A removable dross container, with lid.
- G. A negative pressure exhaust system which keeps all parts of the screw conveying system under negative pressure. Air is drawn in at the hood, up the screw conveyor, and out at point G. All openings in the system are under negative pressure, thus eliminating fugitive emissions.
- H. A hydraulic lift to position screw.

Figure 5 shows the unit being moved into place. Figure 6 shows a closeup of the flexible coupling and the hydraulic lift device which is used to position the screw over the bath. As the dross is removed, the screw may be repositioned to provide optimum capture of dross. Note also "burn marks" on conveyor body. Gas



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FIGURE 4 SCREW DROSSING

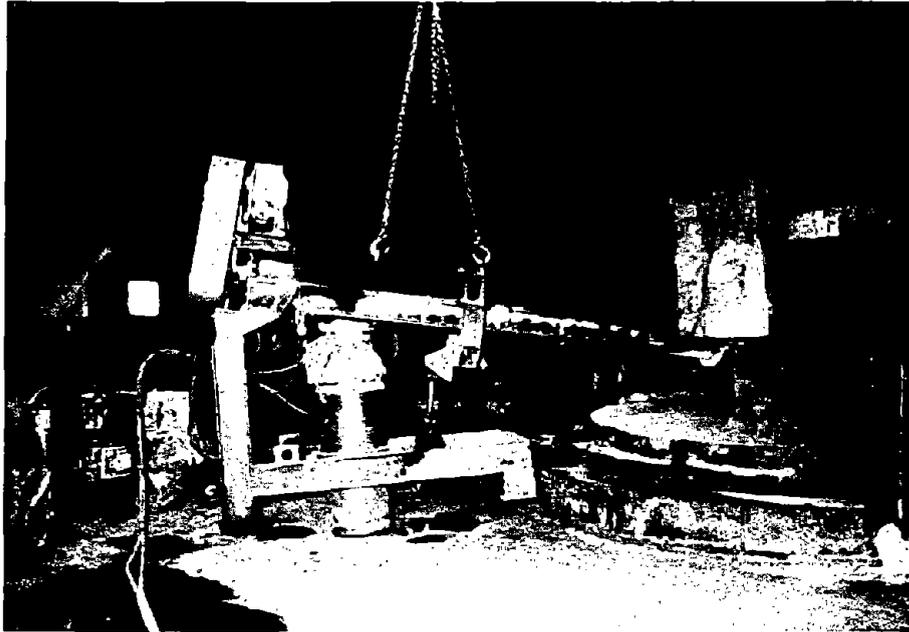


FIGURE 5 POSITIONING DROSSER

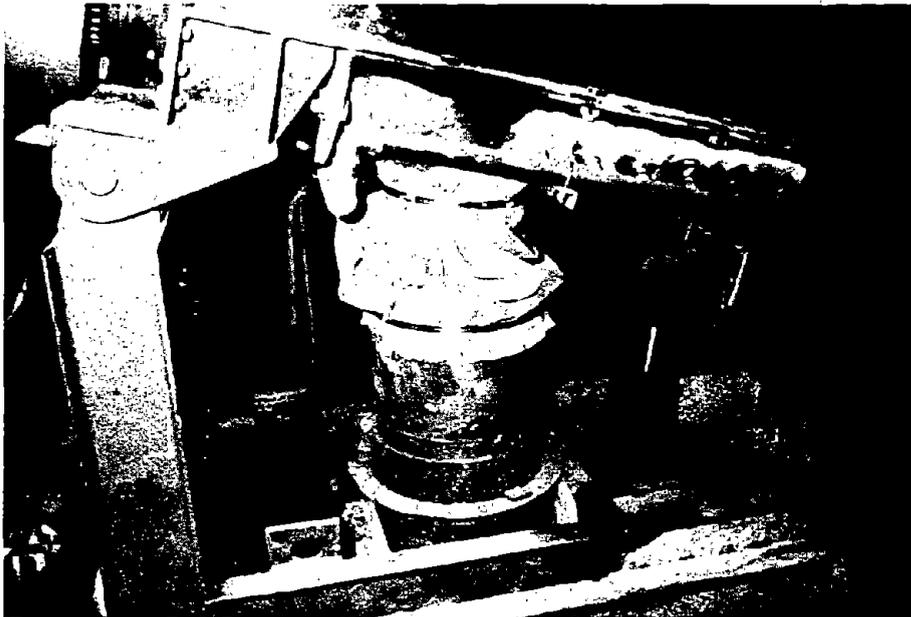


FIGURE 6 CLOSE-UP OF DOWN SPOUT AND HYDRAULIC LEVELER

burners are used to keep lead metal from adhering to the inside of the screw housing.

Figures 7 and 8 show side views of the dross machine in place.

Figure 9 shows a close-up of the paddle used to lift and deposit dross into the screw conveyor. Figure 10 demonstrates the usefulness of access holes in the hood. The holes are used for viewing and pushing dross. The exhaust systems of the hood and the screw drosser maintain a hefty inflow of air at all times.

Figures 11 through 14 show the enclosed dross container housing, removal of the dross container, and housekeeping. Note on Figure 11 the hydraulically-operated blast gate. After drossing is finished, the gate is closed and the dross container is removed for recycle.

### 3.2 PHYSICAL AND OPERATING PARAMETERS

This section describes the physical layout and operation of the equipment, as observed by Radian in December, 1981.

#### 3.2.1 Physical Description

Tonolli operates six 100-ton, 8-ft. diameter kettles. The refinery processes about 200,000 lbs per day. About 20% of input materials are skimmed and recycled.

Figure 15 shows the basic components of the Tonolli screw drossing machine, e.g. a screw conveyor, a drive mechanism, an hydraulic leveler, a flexible coupling to the down spout, a dross container, a container housing, a hood at the kettle, and an exhaust duct to maintain a negative pressure in the system (See also Section 3.1).

The screw is constructed of mild steel. The screw is 12" in

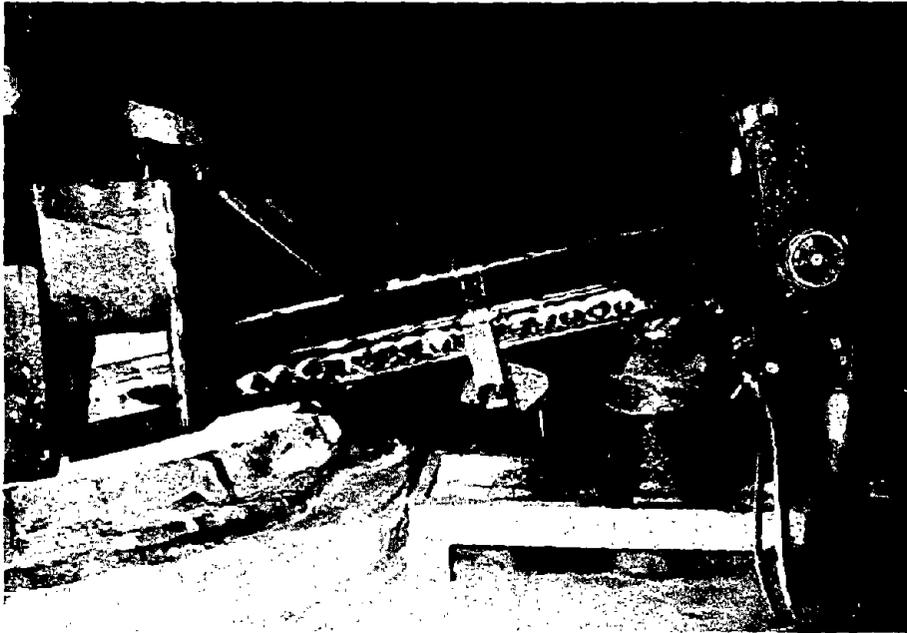


FIGURE 7 LEFT VIEW

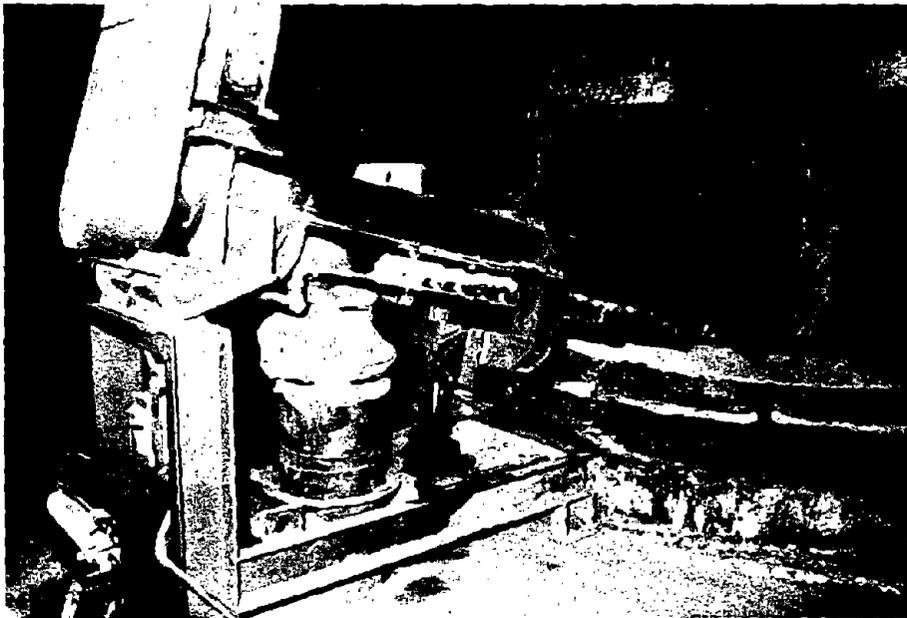


FIGURE 8 RIGHT VIEW

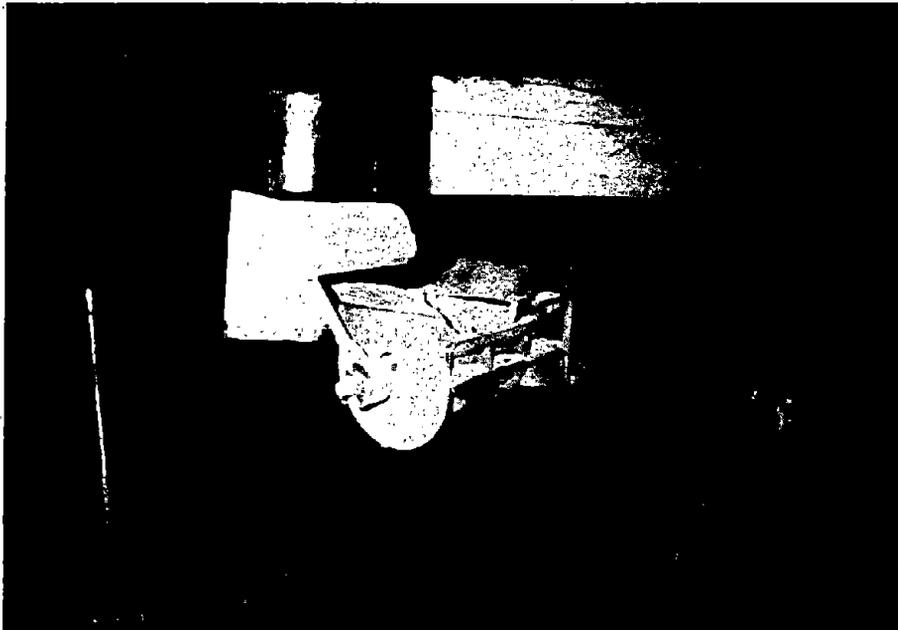


FIGURE 9 PADDLE



FIGURE 10 ACCESS HOLES

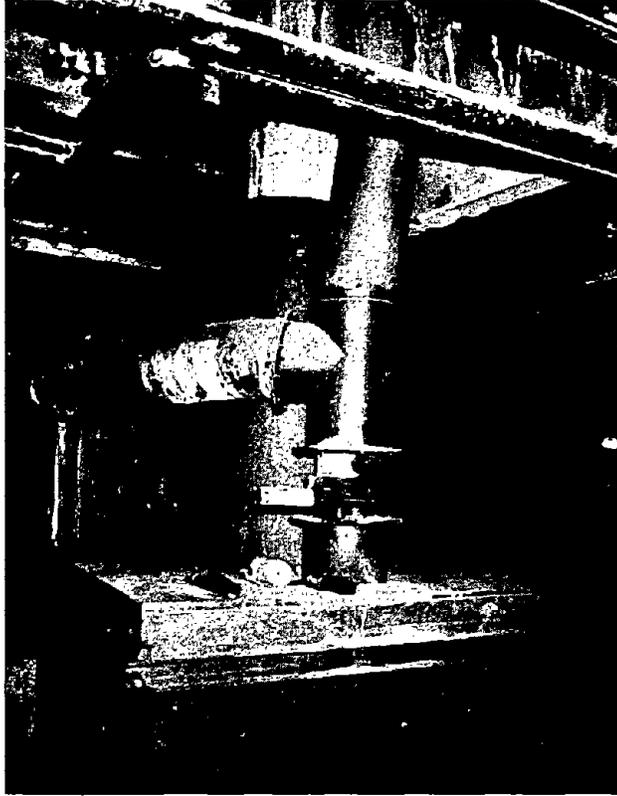


FIGURE 11  
DROSS  
CONTAINER  
HOUSING

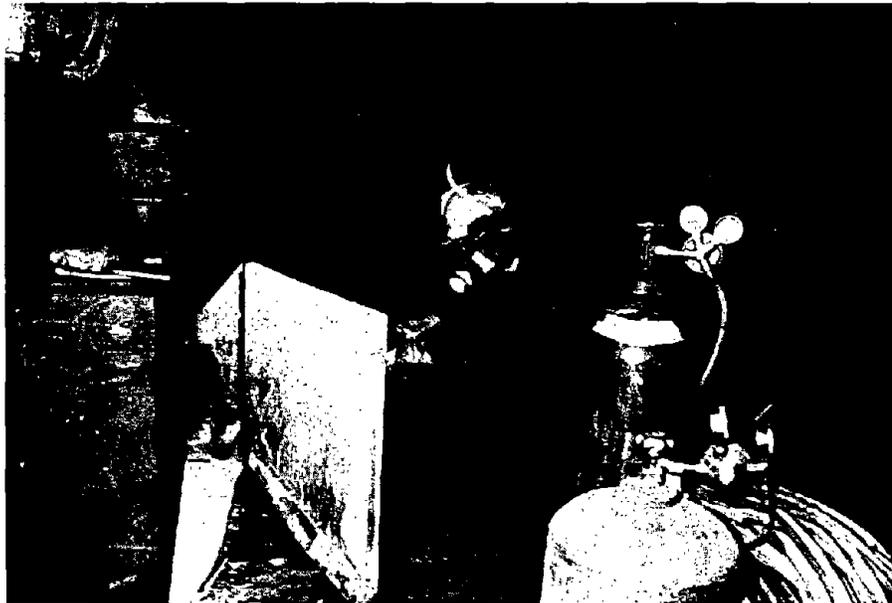


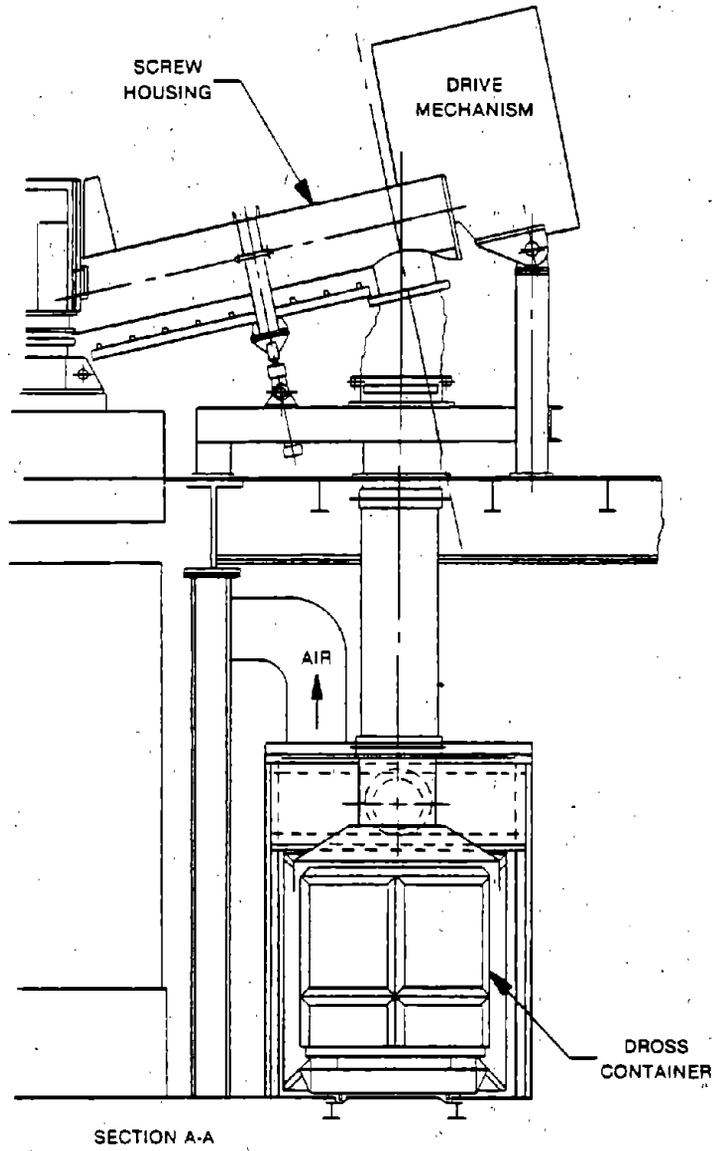
FIGURE 12    OPENING THE HOUSING AFTER DROSSING  
IS COMPLETE



FIGURE 13 REMOVING CONTAINER



FIGURE 14 CLEANING HOUSING



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FIGURE 15 SIDE VIEW OF DROSSING SYSTEM

diameter and fits tightly against the housing. In order to preclude freeze-up in the screw mechanism, a gas-fired heating mechanism has been installed along the side of the screw housing. In the event that liquid metal gets into the housing, the heater allows the lead to remain fluid and flow back into the kettle.

### 3.2.2 Operation

The refinery is operated 24 hours per day. Two men work each of three 8-hour shifts. Drossing (or skimming of dross) consumes 2-4 hours per shift. Typically, two kettles are skimmed per shift.

No special skills are required to operate the Tonolli drossing machine. One person must occasionally push the dross around in the kettle to assist pick-up. During our observations, an employee stood at the kettle for about 30 minutes per drossing cycle.

The speed of the screw is important to the efficient operation of the equipment. If the screw turns at a too-high rate, lead is drawn into the screw housing. If the screw turns at a too-low rate, the screw tends to clog with dross. We observed the screw turning at 15 RPM, with no problems of clogging.

### 3.2.3 Maintenance/Housekeeping

It is anticipated that daily, but minor, maintenance of the scoop, the motor, the gear box, and the screw will be required. Tonolli anticipates replacing the scoop quarterly and the motor and screw annually.

Housekeeping requirements are considerably less than during hand drossing. However, vacuuming of spills is still required. Cleaning of the dross container housing is also required.

Housekeeping required about 20 minutes/kettle during our observations.

#### 3.2.4 Labor

Tonolli estimates that as much as 2 man-days per operating day could be saved using the screw dressing machine. However, it is company policy to maintain a two-man crew for safety reasons.

#### 4.0 ENVIRONMENTAL ASPECTS

This section describes Radian's observations and measurements of conditions affecting emissions, employee exposure, and safety.

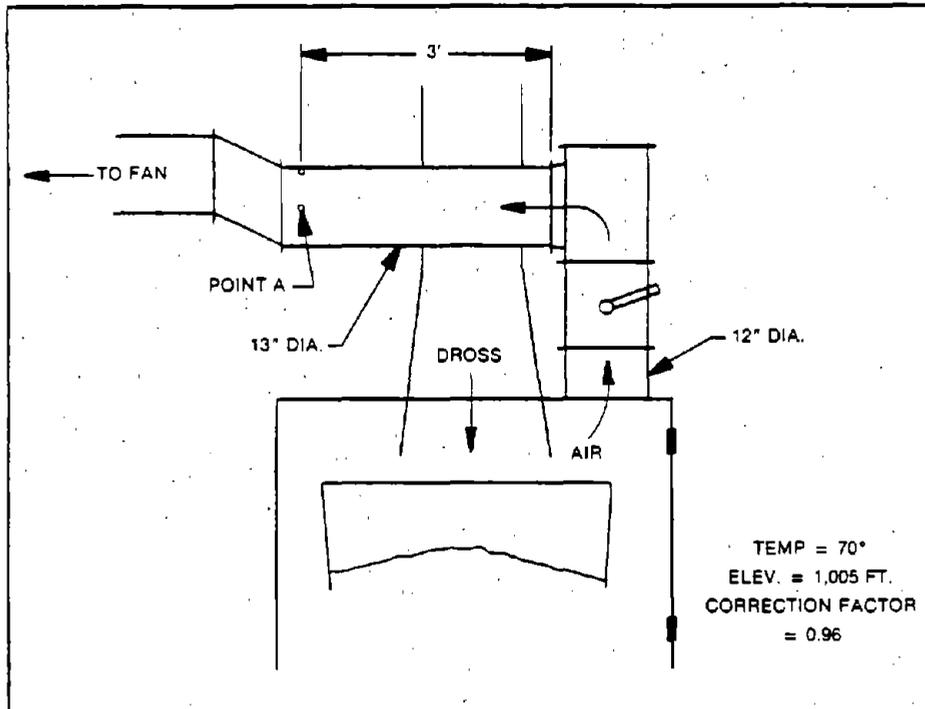
#### 4.1 EMISSION SOURCES AND EMISSION CONTROL

Emissions during drossing occur at the following locations or during the following operations:

- o The kettle surface
- o Removal of dross from kettle
- o Dumping of dross into a container
- o Handling of container
- o Paddle or skimming device
- o Spills

All of the emission sources are effectively controlled by the Tonolli screw drosser. (Occasional spills still occur and must be cleaned up with the central vacuum system.)

Emissions from the kettle are controlled by the kettle hood and the drossing hood. Emissions during the removal, dumping, and handling of dross are controlled by the negative pressure maintained in the entire system. Figure 16 shows the location of ventilation measurements made on December 3 during a dross removal operation. Hood static pressure and a sixteen-point velocity pressure traverse were taken at point A. Results are shown on Figure 16. Measurements were obtained using a Dwyer No. 1227 Dual Range Manometer and Dwyer Pitot Tube, No. 60-18. The system was moving 4800 SCFM at 5,000 FPM in the exhaust duct. The hood static pressure was measured to be -1.85 inch H<sub>2</sub>O.



| POINT | INCHES<br>DIST.<br>FROM EDGE | VP IN INCH H <sub>2</sub> O |                 | VELOCITY IN FT/MIN |                |
|-------|------------------------------|-----------------------------|-----------------|--------------------|----------------|
|       |                              | VERT.<br>TRAV.              | HORIZ.<br>TRAV. | VERT.<br>VEL.      | HORIZ.<br>VEL. |
| 1     | 7/16"                        | 1.0"                        | 1.6             | 4005               | 5066           |
| 2     | 1 3/8                        | 1.8                         | 1.7             | 5374               | 5222           |
| 3     | 2 9/16                       | 1.7                         | 1.7             | 5222               | 5222           |
| 4     | 4 7/8                        | 1.5                         | 1.8             | 5066               | 5374           |
| 5     | 8 1/8                        | 1.5                         | 1.8             | 4905               | 5374           |
| 6     | 10 7/16                      | 1.5                         | 1.7             | 4905               | 5222           |
| 7     | 11 5/8                       | 1.4                         | 1.7             | 4739               | 5222           |
| 8     | 12 9/16                      | 1.2                         | 1.6             | 4386               | 5066           |

AT  
POINT A

$V_{AVE} = 5,000$  FPM     $Q = 4,800$  SCFM (CORRECTED)  
 $SP_h = -1.85$  INCH H<sub>2</sub>O     $h_p = 0.87$

FIGURE 16 AIR FLOW MEASUREMENTS

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Measurements of capture velocities in and around the kettle and drossing machine were made with an MSA smoke generator and an Alnor 6000P velometer. Smoke tests were all positive, with strong capture velocities observed at all openings to the kettle and the drossing machine. Figure 17 presents velocity measurements at three major open areas at the hood/kettle interface. Based upon the measurements of emission control ventilation, Radian would conclude that little if any fugitive or process emission was reaching the atmosphere of refinery employees.

#### 4.2 WORKPLACE LEAD-IN-AIR LEVELS

##### 4.2.1 Procedures

In order to test the hypothesis that the Tonolli screw drossing machine is able to control lead emissions during the skimming operation, Radian conducted area sampling for lead.

Area samples were taken at locations near the kettle being skimmed. Separate samples were taken during drossing and during the periods when the drossing machine was not operating. Sample locations and results are shown on Figure 18. Figures 19 and 20 show the typical placement of samplers.

Samples were taken with Bendix Pumps and 0.8  $\mu$  pore size, 37 mm diameter cellulose ester membrane filters, in closed face cassettes. Calibration of flow was conducted immediately before sampling using an inverted 1000 ml buret and soap bubble solution. Flow rates were checked during sampling using a precision rotameter. Samples were analyzed in Radian's AIHA-certified laboratory using the NIOSH method S-341 for analysis, i.e. digestion in  $\text{HNO}_3$  followed by atomic absorption spectrophotometry analysis.

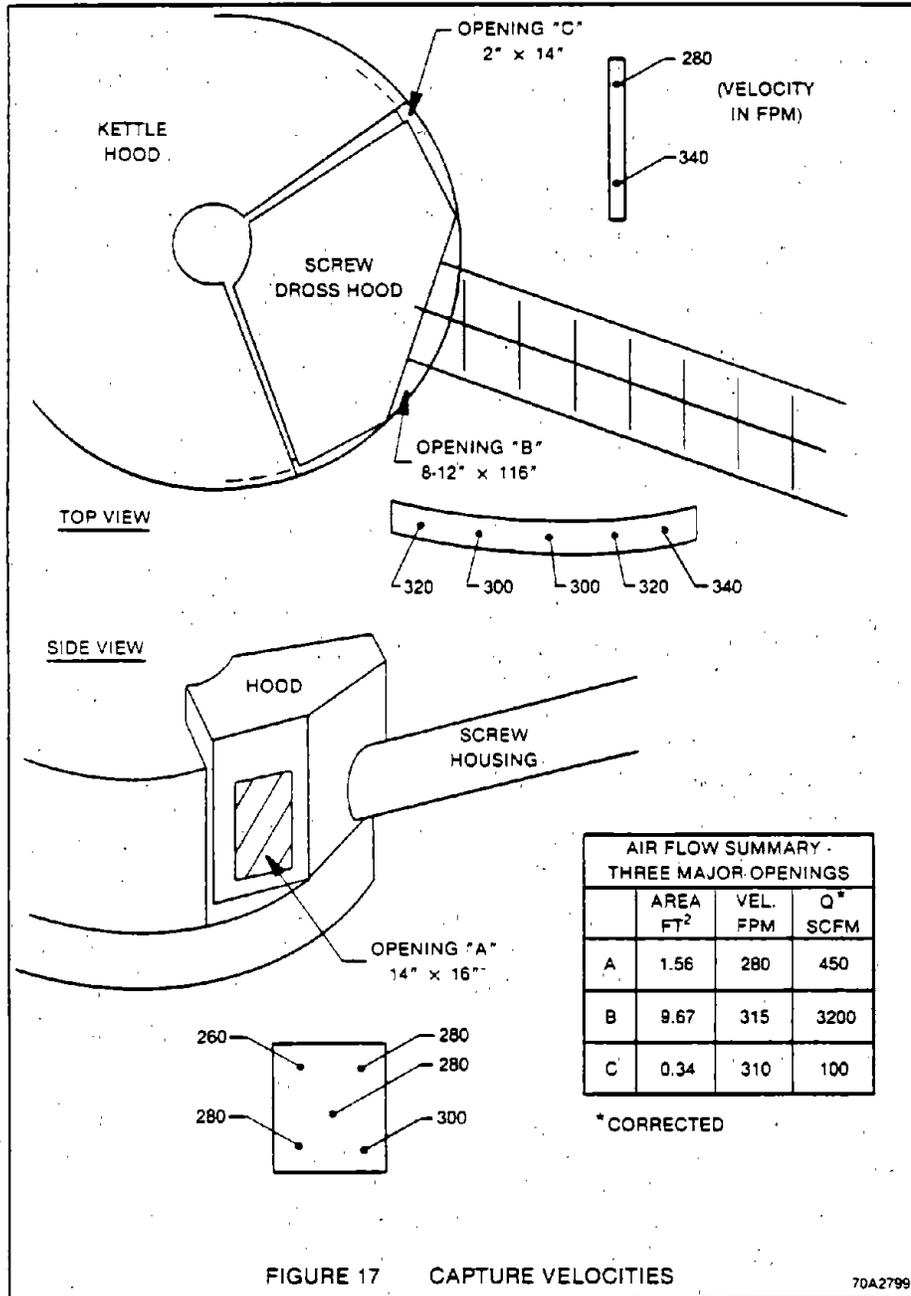
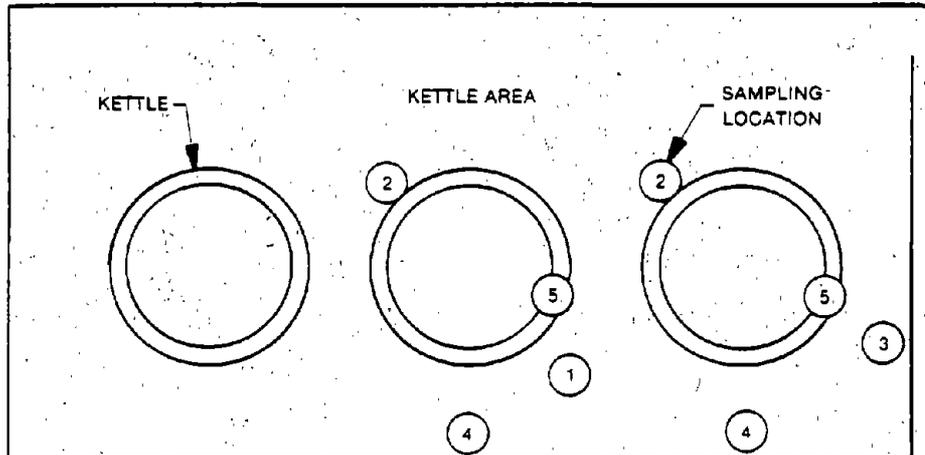


FIGURE 17 CAPTURE VELOCITIES

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AVERAGE LEAD-IN-AIR MEASUREMENTS.  $\mu\text{g}/\text{m}^3$  \*

| SAMPLE LOCATION | DROSSING | NOT DROSSING | HEIGHT, FEET |
|-----------------|----------|--------------|--------------|
| 1               | 210      | N.A.         | 2            |
| 2               | 120      | 190          | 4 1/2        |
| 3               | 120      | 290          | 4            |
| 4               | 140      | 160          | 4            |
| 5               | 200      | 240          | 7            |
| AVERAGE         | 160      | 220          |              |

\* AVERAGE OF MEASUREMENTS DURING THREE DROSSING CYCLES, OVER TWO DAYS OF OPERATION

FIGURE 18 AREA SAMPLING RESULTS

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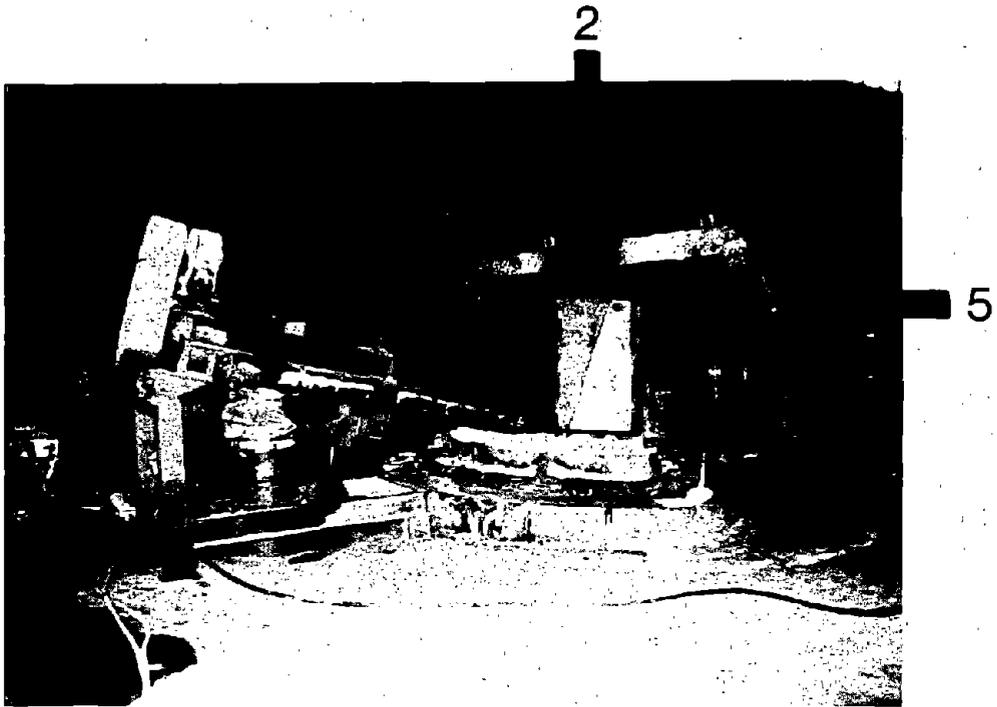


FIGURE 19 AREA SAMPLING LOCATIONS

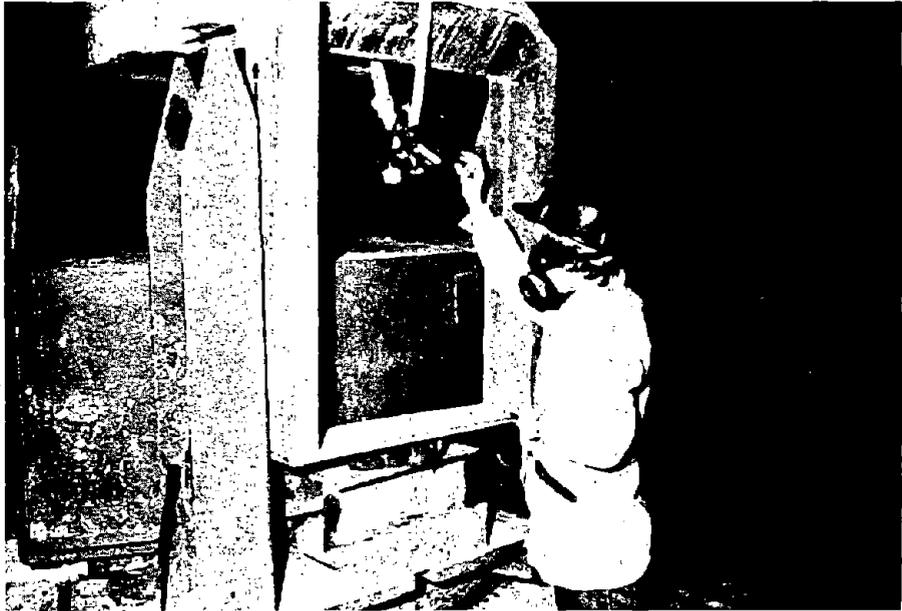


FIGURE 20 PLACEMENT OF AREA SAMPLER AT LOCATION (5)

#### 4.2.2 Discussion of Sampling Results

Sample results indicate that lead-in-air levels adjacent to the kettles were considerably less during drossing operations, i.e., a reduction from 220  $\mu\text{g}/\text{m}^3$  to 160  $\mu\text{g}/\text{m}^3$ . Based on measurements of emission controls it was hypothesized that lead-in-air levels would not be greater during drossing as compared to non-drossing times. However we did not anticipate seeing a 25% reduction in lead levels. The reduction might be explained by one or more of the following reasons:

- (1) The random and systematic errors associated with sampling and analysis might be large enough to explain the difference, i.e., there is actually no difference between results, statistically.
- (2) The increased air flow (4,800 CFM) into the kettle and drosser due to the ventilation attached to the drossing machine might have diluted background levels of lead. This is possible because air moving into the ventilation system would have been replaced largely by air coming from the shipping and receiving area, an area of relatively low lead levels.

Personal sampling was not conducted for two reasons:

- (1) Hand-drossing exposure data were not available, i.e., no before/after comparison was possible, and
- (2) Other emission sources in the smelter building presently contribute substantially to the refinery workers exposure.

## 5.0 COSTS

Tonolli estimates the total costs of design, procurement, construction, installation, testing, and modification to be about \$20,000 (1981 dollars) for the first dressing machine. Two machines obtained at the same time would run about \$15,000 each.

Annual operating and maintenance costs are estimated at \$4,000-5,000 per year, which include power, replacement parts, and maintenance. Overall refining costs may be less because of potentially reduced labor costs.

Time of implementation is estimated at six months. This time estimate runs from decision-to-purchase to fully-operational.

## 6.0 DISCUSSION

Based upon our observations, we conclude that the Tonolli Screw Drossing Machine represents a significant advance in control technology for drossing operations. In the following paragraphs we explore limitations and problems, possible applications, and potential improvements.

### 6.1 LIMITATIONS AND PROBLEMS

Gas-Fired Heater. The heating of the surface of the screw conveyor will vaporize any lead contamination of the surface. This problem can be minimized by inspecting and cleaning the surface of the screw conveyor prior to operation.

Openings between hoods. Unless the drossing hood is well-positioned, large openings between the dross hood and the kettle hood are created, increasing the chances for fugitive emissions. This problem can be minimized by good design of the hood and operator training.

Size. The equipment works better on larger kettles. Tonolli considers a 100-ton kettle as the smallest size kettle for which the drossing machine would be economical to operate. (Technically, the equipment could be adopted for any size kettle.)

Dross composition. The Tonolli drossing machine is best suited for dry, dusty drosses. Antimonial drosses which are typically wet and sticky may not be compatible. Large chunks of dross, such as lead sulfate mattes, will be difficult to handle without design modifications. Of course, any steel hooks or cables must be removed from the bath before drossing begins.

Physical Layout. In order for the drossing machine to operate, space must be available. The machine is about 3 feet wide, 7 feet high, and 10 feet long. Ideally, the dross container housing should be below the level of the kettle. Refineries built at ground level will require modifications to the collection and storage system, e.g. screw conveying to a ground-level container.

## 6.2 APPLICABILITY TO OTHER OPERATIONS

The Tonolli Screw Drossing Machine can be applied to any dry drossing operation, in any size kettle (but see economic limitation comments in Section 6.1). The equipment is also compatible with any kettle temperature, e.g. crystal dross at 400°C or tin dross at 540°C.

## 6.3 POTENTIAL IMPROVEMENTS

We noted several conditions which might be improved.

Spillage. We noticed that refinery workers "pushing" dross around on the bath tended to remove the scoop from the kettle hood, spilling dross on the refinery floor. This source of lead contamination could be reduced by stricter work-practice procedures and by installing a hood inside the kettle hood so that the scoop need not be removed from the kettle environment.

Non-Crane Operation. Ideally, the drossing machine should be positioned permanently near the kettle, e.g. on a swing-away mount. This would eliminate the need for a crane and the time consumed in transporting the drossing machine from one place to another.

Dross loss. The configuration of the existing dross container housing is poor in that a considerable amount of dross is entrained in exhaust air and is removed to the baghouse. This problem could be alleviated by the use of a larger housing, a more enclosed container, or a re-positioning of the take-off duct. Contamination in the housing is evidence of a significant amount of mixing turbulence within the housing. This might be corrected by a tapered takeoff on the exhaust duct, a larger housing, and baffling at the inlet of the dross down-comer.

Container handling. The use and handling of dross containers presents the opportunity for upsets and fugitive emissions. The problem could be eliminated by the use of a vacuum system to convey dross directly to a silo or baghouse from the dross container. (Vacuum transport from the container would eliminate the clogging problems encountered in vacuum drossing at the kettle surface.)

