Cairo Air Improvement Project

Lead Pollution Abatement Component

Technical and Economic Study for Small and Medium Lead Smelters

Chemonics International, Inc.

USAID/Egypt, Office of Environment

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Acronyms and Abbreviations

Acfm	Actual cubic feet per minute
C	Centigrade
$CaCo_3$	Calcium carbonate
EEAA	Egyptian Environmental Affairs Agency
FOB	Free on board (freight)
ft	Foot, feet
GOE	Government of Egypt
HAPs	Hazardous air pollutants
kg	Kilograms
L/D	Length to diameter
LEAP	Lead Exposure Abatement Plan
LPG	Liquefied petroleum gas
LSAP	Lead Smelter Action Plan
m, m^2, m^3	meter, square meter, cubic meter
mg/dscm	milligrams per dry standard cubic meters
MT/Y	Metric ton per year
$NaCo_3$	Soda ash
NEMA	National Electrical Manufacturers Association
Pb	Lead
PM	Particulate matter
scfm	Standard cubic feet per minute
SO_2	Sulfur dioxide
SWSI	Single width/single inlet
US	United States (of America)
USAID	United States Agency for International Development

Executive Summary

The report presents a technical and economic study that defines a capital cost estimate for a modern small- to medium-sized secondary lead smelter producing 1,000–1,200 metric tons per year (MT/Y). The study aims to support stakeholders' decisions to relocate their lead smelters to a new site outside the populated areas of Greater Cairo, as part of the solution to the high pollution levels in Cairo's air.

The scope of the report focuses on two different estimates of costs, based on a conceptual design for small and medium secondary lead smelters constructed by the American engineering firm of Stone & Webster. The first estimate is compiled from offers presented by US suppliers, while the second estimate uses costs from local Egyptian suppliers and manufacturers. The design uses modern technology applied in secondary lead smelters for the production process and pollution control system to comply with Law 4/Year 1994, the Egyptian Environmental Law.

All required items are specified. The first estimate (from US suppliers) is $1,660,000; the second (using locally manufactured equipment) is £E2,169,840.

In order to reduce costs as well as to ensure sustainability and maximum technology transfer to local experts, it is recommended to manufacture most of the smelter equipment locally using US designs and materials.

1. Introduction

1.1 Background

The Government of Egypt (GOE) has developed a comprehensive plan for the Lead Abatement in Cairo, the Lead Exposure Abatement Plan (LEAP).[1] The main target of the plan is to reduce emissions of lead from all sources. The lead smelter industry was identified as one element of the LEAP, and the Lead Smelter Action Plan (LSAP) was developed. Law 4 of Year 1994, known as the Egyptian Environmental Law, identified limits for lead emissions from all sources, and set standards for lead in ambient air and in the workplace.

The secondary lead smelting industry produces lead and lead alloys by reclaiming lead, mainly from used batteries. This industry, although a source of lead pollution, should be recognized for its overall environmental benefit. Most of the lead used in batteries and other products these days is secondary (recovered) lead as opposed to primary (mined) lead. Recycling eliminates the need to dispose of large quantities of lead, which is classified as hazardous waste, and would pollute the environment if disposed of improperly. Battery recycling, besides being a proper disposal means of potentially hazardous materials containing heavy metals, including lead and arsenic, is also an economically viable venture. Therefore, regulatory focus should be on using the proper technology in secondary lead smelters to minimize lead pollution.

Secondary lead smelters, the subject of this report, produce and emit harmful levels of lead inside the workplace and to the surrounding community. The purpose of this report is to provide technical and economic information to the Egyptian Environmental Affairs Agency (EEAA), the United States Agency for International Development (USAID), and the owners of small- and medium-sized smelters in Egypt about how lead smelters can comply with the environmental law. If the smelters are relocated to a remote site, they should be built and equipped with state-of-the-art equipment and air pollution control systems that will virtually eliminate environmental pollution.

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[11] Egyptian Environmental Affairs Agency, *Lead Smelter Action Plan*, Cairo, 1997.

1.2 Characteristics of Smelters in Cairo

There are 11 lead smelters in the Greater Cairo Area that produce lead ingots. Five additional smelters produce lead products from lead ingots.[2] Total production capacity ranges from 40,000 metric tons per year (MT/Y) to 58,000 MT/Y, depending on demand and on the availability of used batteries in the market. The smelters are distributed as shown in the map in Figure 1.

1.2.1 Large Smelters

Two major companies own the four large lead smelters in Greater Cairo. Awadallah, a private company, and General Metals, a public company, own the major smelters that are responsible for about 82 percent of the total production of lead ingots. The remaining seven smelters are medium and small ones and are privately owned. The Awadallah family owns and operates several smelters, which are responsible for nearly 68 percent of total lead ingot production in Egypt. They have three smelters located in Shoubra el-Kheima, a high-density residential area. The company has expressed willingness to consolidate operations and relocate and upgrade to improve efficiency and reduce emissions in order to comply with Law 4/1994.

The public sector company, General Metals, is the second largest producer of lead ingots in Egypt. General Metals is responsible for about 14 percent of the total production of lead, with average production of approximately 7,800 MT/Y. Previous studies indicated that the General Metals smelting facility produces lead ingots from used batteries and buys primary lead to produce lead oxide.[3] General Metals is located in El-Tebbin in Helwan.

The company intends to relocate and upgrade, but must receive permission to import used batteries, an activity that is forbidden under the terms of the Basel Convention and the regulations of Law 4/1994. If and when EEAA grants permission to resume importing used batteries, General Metals will build a new smelter in a non-residential area, and CAIP will undertake design of a remediation action plan for their old site. At this time, General Metals is producing lead ingots in their existing facility.

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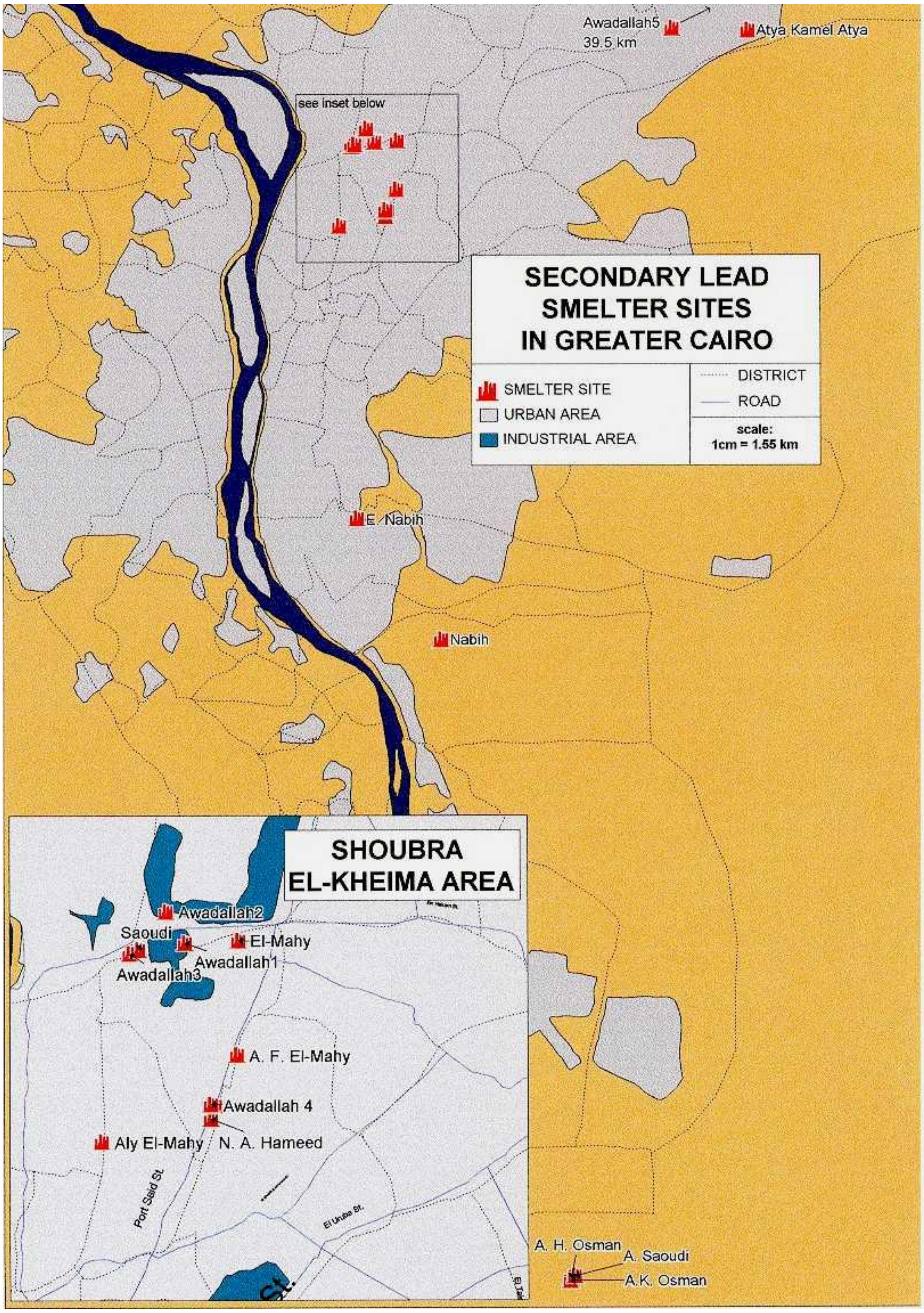
[2] Cairo Air Improvement Project, Air Quality Monitoring Component, "Emission Test Report on Saoudi Secondary Lead Smelter," Cairo, 1998.

[3] Ibid.

1.2.2 Small and Medium Lead Smelters

There are presently seven small- and medium-sized secondary lead smelters in the Greater Cairo Area producing lead ingots. Five others fabricate products from lead. The annual production capacity of small and medium smelters ranges between 7,500–11,000 MT/Y.

Figure 1
Secondary Lead Smelter Sites in Greater Cairo


Awadallah5
39.5 km
Atya Kamel Atya
see inset below
SECONDARY LEAD
SMELTER SITES
IN GREATER CAIRO
SMELTER SITE
URBAN AREA
INDUSTRIAL AREA
DISTRICT
ROAD
scale:
1cm = 1.55 km
E. Nabih
Nabih
SHOUBRA
EL-KHEIMA AREA
Awadallah2
Saoudi
El-Mahy
Awadallah1
Awadallah3
A. F. El-Mahy
Awadallah 4
Aly El-Mahy
N. A. Hameed
Port Said St.
A. H. Osman
A. Saoudi
A.K. Osman

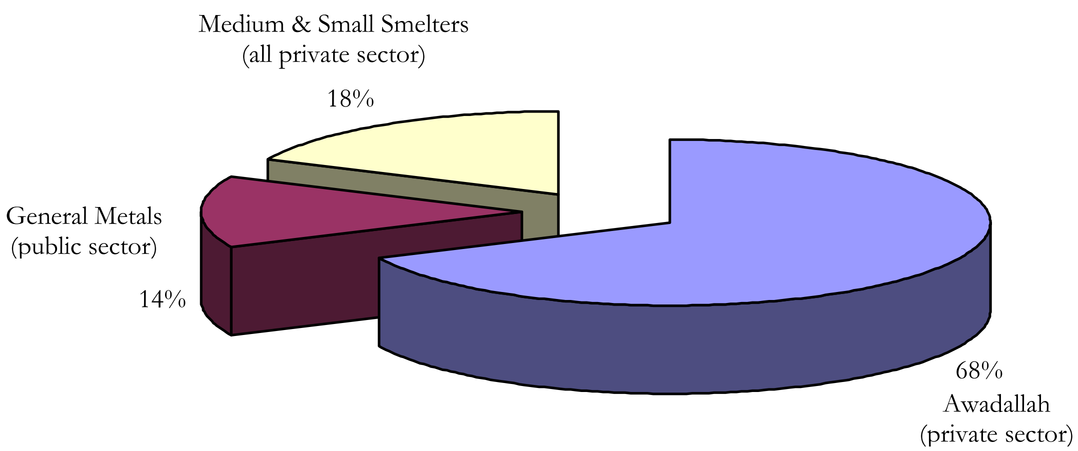
Relative lead production capacity is illustrated in Figure 2. This production capacity represents about 18 percent of Egypt's total production. All small and medium smelters are owned and operated by the private sector and about 67 percent of them are located in densely populated areas.

Although their production capacity is only a small percentage of that of the large smelters, their emissions are influencing the quality of Cairo's air.

This report concentrates on small- and medium-sized smelters, which are using outdated technology. Most of the processes are performed manually, emissions control techniques, if they exist, are very primitive and inefficient, and workers are exposed to high levels of harmful emissions. The pollutants in emissions from these smelters are much higher than the limits defined by Law 4/1994.[4]

This report describes existing conditions in the small and medium smelters of Greater Cairo in detail, and compares those conditions with an ideal smelting process. Proposed short- and long-term solutions are presented along with capital cost estimates for relocating smelters to industrial areas far from residential neighborhoods. The capital cost estimate was compiled following two approaches: the first uses costs from foreign suppliers, while the second uses cost figures from local manufacturers and suppliers.

Figure 2
Relative Lead Production Capacity



[4] Cairo Air Improvement Project Air Monitoring Component, "Emission Test Report on Awadallah Secondary Lead Smelter," Cairo, 1998.

2. Objectives

The objective of this report is to provide technical and economic information to decision-makers, EEAA, USAID, and to the owners of these small and medium smelters. This information covers aspects related to the costs involved in relocating smelters away from heavily populated areas and installing equipment that allows operation in compliance with Law 4/1994.

This will be achieved through:

- Presenting a conceptual design for facilities for small- and medium-sized secondary lead smelters using modern technology for both production and pollution control systems.
- Providing a list of equipment needed to implement the conceptual design.
- Providing a price list for the required equipment from international and local suppliers.
- Estimating the total cost of a facility using the two pricing options.

3. Process Description, Emissions, and Emission Control

The secondary lead smelting industry produces elemental lead and lead alloys by reclaiming lead, mainly from used batteries. The smelting operation is carried out at temperatures ranging between 1,200–1,300°C. Secondary lead may be refined at temperatures between 327–400°C to produce soft, pure lead or other alloying elements may be added to produce hard lead alloys.

Lead-acid batteries represent about 90 percent of the raw materials at a typical secondary lead smelter. The other 10 percent consists of dross, lead pipe scrap, and cable sheathing solder. A small, dry automotive lead-acid battery weighs about 11 kg. It contains about 9 kg of lead and 2 kg of plastic material, while a large, dry automotive battery weighs about 15 kg and contains about 12 kg of lead. Sixty percent of the lead in a lead-acid battery is in the form of lead oxide and lead sulfide paste. The balance, or 40 percent, is in the form of lead metal grids and posts.

Some secondary smelters offer a "tolling service," where a customer delivers scrap lead to the smelter and receives the recovered lead, paying only for the service of having the lead processed and cast into ingots. This is common among the small smelters.

3.1 Process Description

The basic secondary lead smelting process consists of:

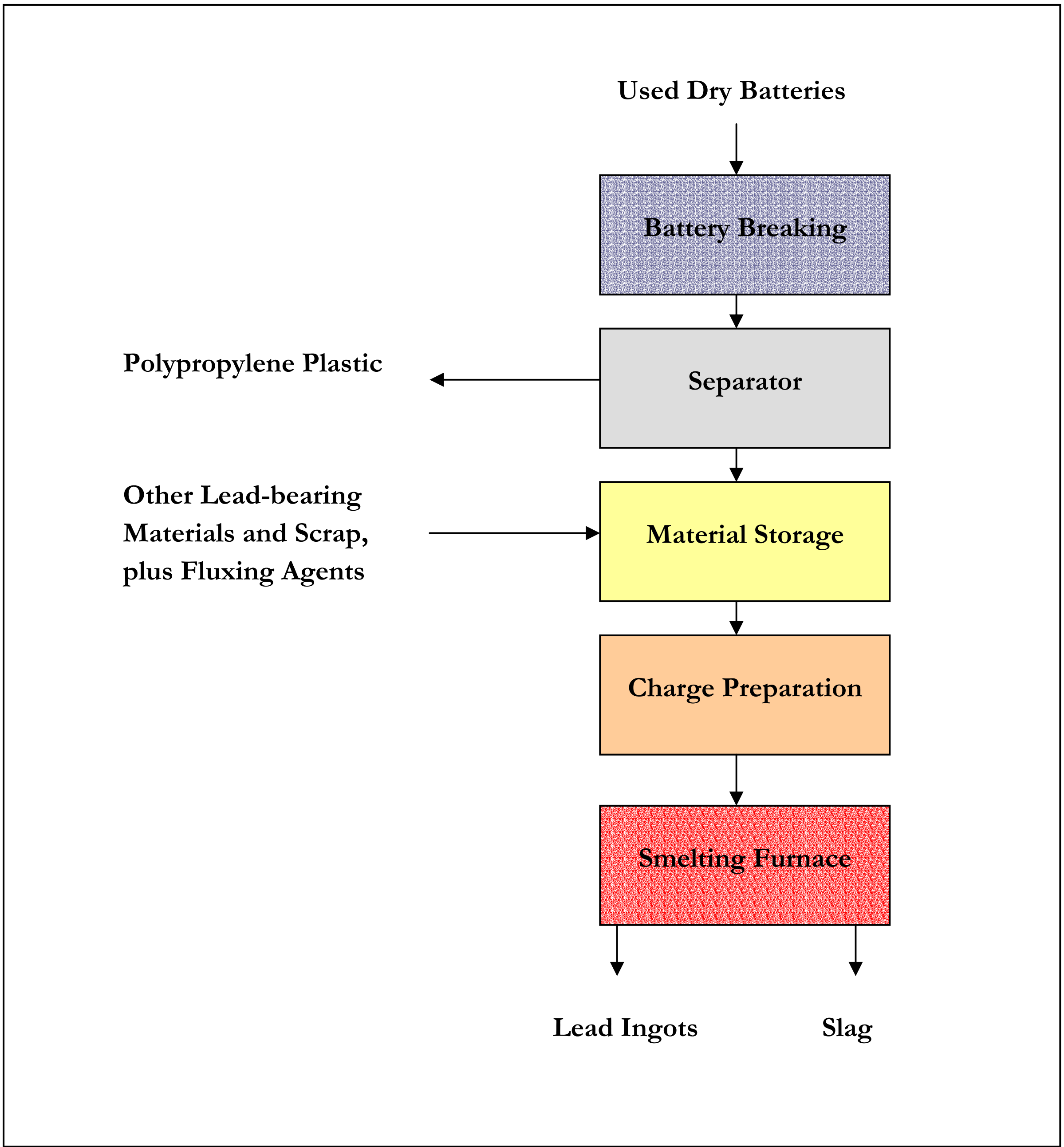
1. Breaking the batteries and separating the materials.
2. Preparing the furnace charge with fluxing agents.
3. Smelting.
4. Tapping the lead bouillon in unfired kettle to pour into ingots.

The process flow for secondary smelters is shown in the diagram in Figure 3.

3.1.1 Battery Breaking and Material Separation

Used batteries are broken using hammer-mills, saws, shears, or some combination of the above equipment. The batteries may be punctured to allow the acid to drain before they are broken.

Figure 3
Process Flow Diagram for Secondary Lead Smelting



The broken batteries are usually conveyed to a separator, which separates the battery plates from the cases. Following the battery breaking, it is recommended to have a paste de-sulfurization unit to reduce the need for fluxing agents in the smelting process to minimize SO_2 emission from the furnace. The plates are then sent to raw materials storage and the cases are sent for crushing to reduce the size.

3.1.2 Furnace Charge Preparation and Fluxing Agents

Furnace charge materials consist of lead-bearing raw materials, lead-bearing slag, flue dust, dross, fluxing agents, and coke. Fluxing agents consist of iron, silica sand, and limestone (calcium carbonate [$CaCo_3$] or soda ash [$NaCo_3$]). Fluxing agents are added to the furnace to promote the conversion of lead compounds to lead metal and to remove impurities through slag formation. The charge materials vary depending on the furnace type and on the particular practices of the plant operators. A balanced charge is shown in Table 1. This charge content has a typical recovery rate of 64 percent, and will decrease the percentage of lead in the slag to less than 2 percent.

Table 1
Balanced Charge for Secondary Smelters

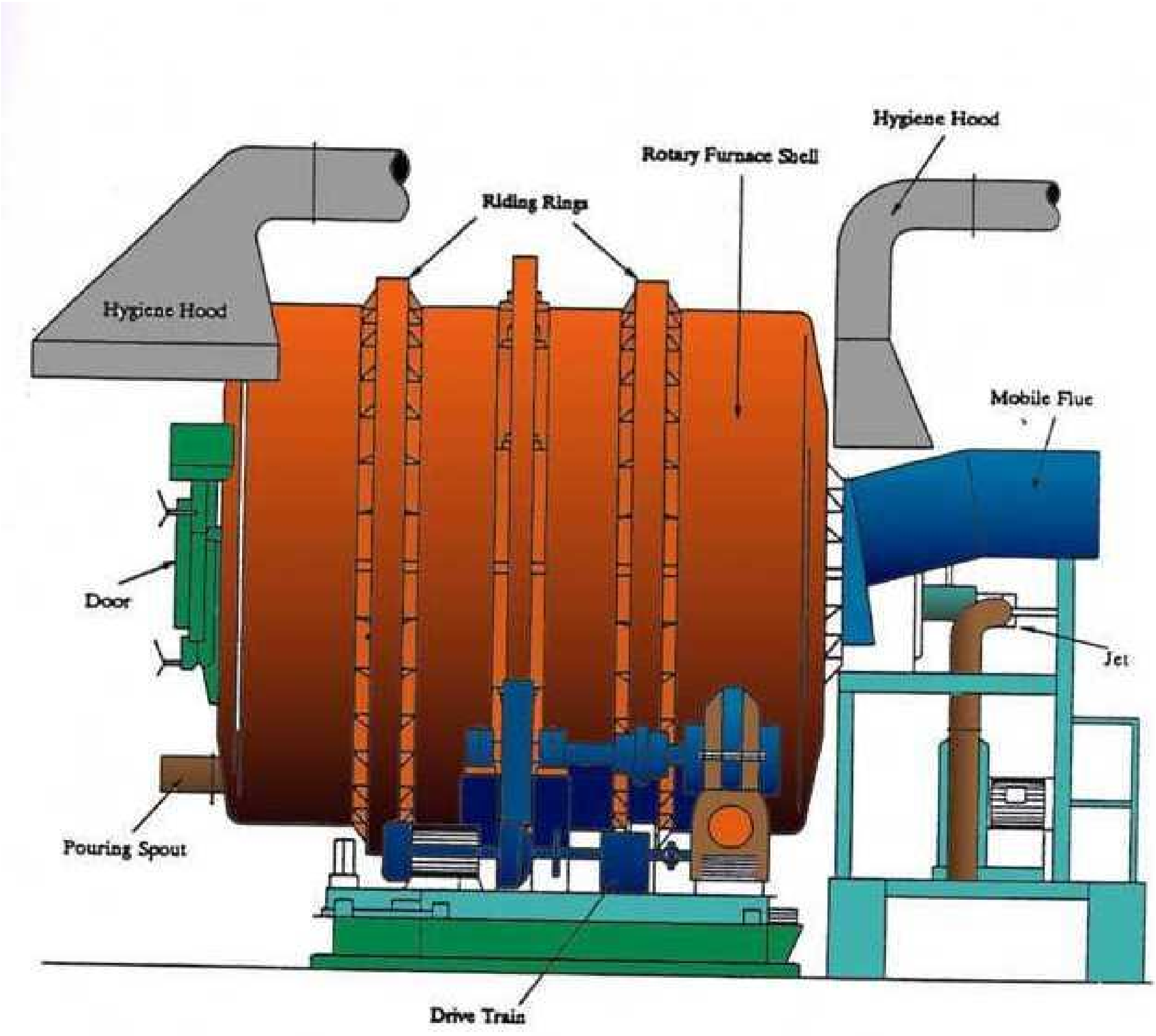
Contents of Balanced Charge	Metric Ton
Battery Scrap	6
Soda Ash ($NaCo_3$)	0.4
Coke	0.3
Iron	0.3

3.1.3 Smelting Process

The smelting process is usually performed in blast, rotary, reverberatory, or electric furnaces. The rotary furnace is currently the most common type of smelting furnace in Egypt. It has three advantages over other furnaces. First, it is easier to adjust the relative amount of fluxing agent because the furnace is operated on a batch rather than a continuous basis. This method suits the Egyptian smelting industry. Second, it achieves better mixing of the charge contents. Finally, the furnace has high exhaust temperatures—up to 1,300°C. This temperature is high enough to burn all organic hazardous air pollutant.

The rotary furnace as shown in Figure 4 consists of a steel drum of 1.8–4.5 meters diameter, and 2.5–6 meters in length. A short furnace, where the length to diameter ratio is approximately 1:6, provides better smelting conditions. The furnace is refractory-lined and mounted on rollers. Variable speed motors are used to rotate the drum. An oxygen enriched single or duel fuel burner at one end of the furnace heats the charged material and the refractory lining of the drum. The connection to the fuel is mounted at the same end of the burner. A sliding door at the end of the furnace opposite from the burner allows charging of material to the furnace. Charged materials are typically placed in the furnace using a conveyor or a loader with charge bucket. Rotary furnaces are operated at a slight negative pressure. Using the predetermined fluxing

Figure 4
Typical Rotary Furnace



agents with the charge, the furnace produces slag that is relatively free of lead, less than 2 percent.[5]

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[5] United States Environmental Protection Agency, "Secondary Lead Smelting Background Information Document for Proposed Standards," NESHAP, Volume 1. Washington, DC, 1994.

3.1.4 Tapping and Casting Ingots

At the end of the smelting cycle, the rotation of the furnace is halted, lead and slag are tapped from the furnace into crucibles from a single tap hole located at the edge of the furnace shell. Both charge loading and lead tapping positions are hooded and vented to a pollution control system. Rotary furnaces produce a semi-soft lead.

3.2 Emissions

The smelters have two main types of emission: those emitted from the furnace's main exhaust, and fugitive dust emissions, which comes from the battery breaking area, the furnace, and blowing dust.

3.2.1 Process Exhaust Emissions

Smelting furnaces are sources of metal hazardous air pollutants (HAPs) and particulates (PM). Metal HAPs are predominately compounds of lead, antimony, and arsenic, with smaller amounts of other metals compounds. HAP and PM emissions are independent of smelting furnace type and configuration. Metal HAPs are about 40 percent by weight of controlled PM emissions.[6] Lead compounds constitute about 70 percent by weight of total metal HAP emissions. The remaining 60 percent are believed to be primarily mineral compounds and soot. The quantities of organic HAPs, THC, and CO emissions are dependent on the furnace type. Rotary furnaces produces low values of these compounds, especially when combustion is complete. HCL, CL_2 and SO_2 emissions are controlled in the furnace by adding the fluxing agents.

3.2.2 Fugitive Emissions

The main sources of process fugitive emissions are furnace charging, slag, tapping, agglomerating furnace operations, and battery breaking. Fugitive dust emissions contain metal HAPs and PM, which are dependent on the size of the facility and the dust controls and work practices in place in the facility.

[6] United States Environmental Protection Agency, "Secondary Lead Smelting Background Information Document for Proposed Standards," NESHAP, Volume 1. Washington, DC, 1994.

3.3 Emission Control Techniques

Smelting operations have different types of emissions (gases and metals HAPs). Applicable controls for each emission should be used.

3.3.1 Baghouses

Baghouses are a well-known technology to control metal HAP process emissions from smelting furnaces. Wet scrubbers for acid gas control may follow the baghouse; however, no significant additional removal of metal HAPs is achieved.

Many designs and operating parameters affect baghouse efficiency, such as bag material, pressure drop, air-to-cloth ratio, type of cleaning, and operating temperature. The average working temperature in the baghouse ranges between 120–180°C, depending on the sulfur content of the exhaust gases. Therefore, in most applications the exhaust gases should be cooled to that temperature before entering the baghouse. Different cooling systems may be installed after the furnace to accommodate the temperature requirements. Further cooling, below the sulfuric acid dew point, may cause corrosion of the baghouse metal frame and ductworks. Figure 5 shows main details of and airflow inside the baghouse.

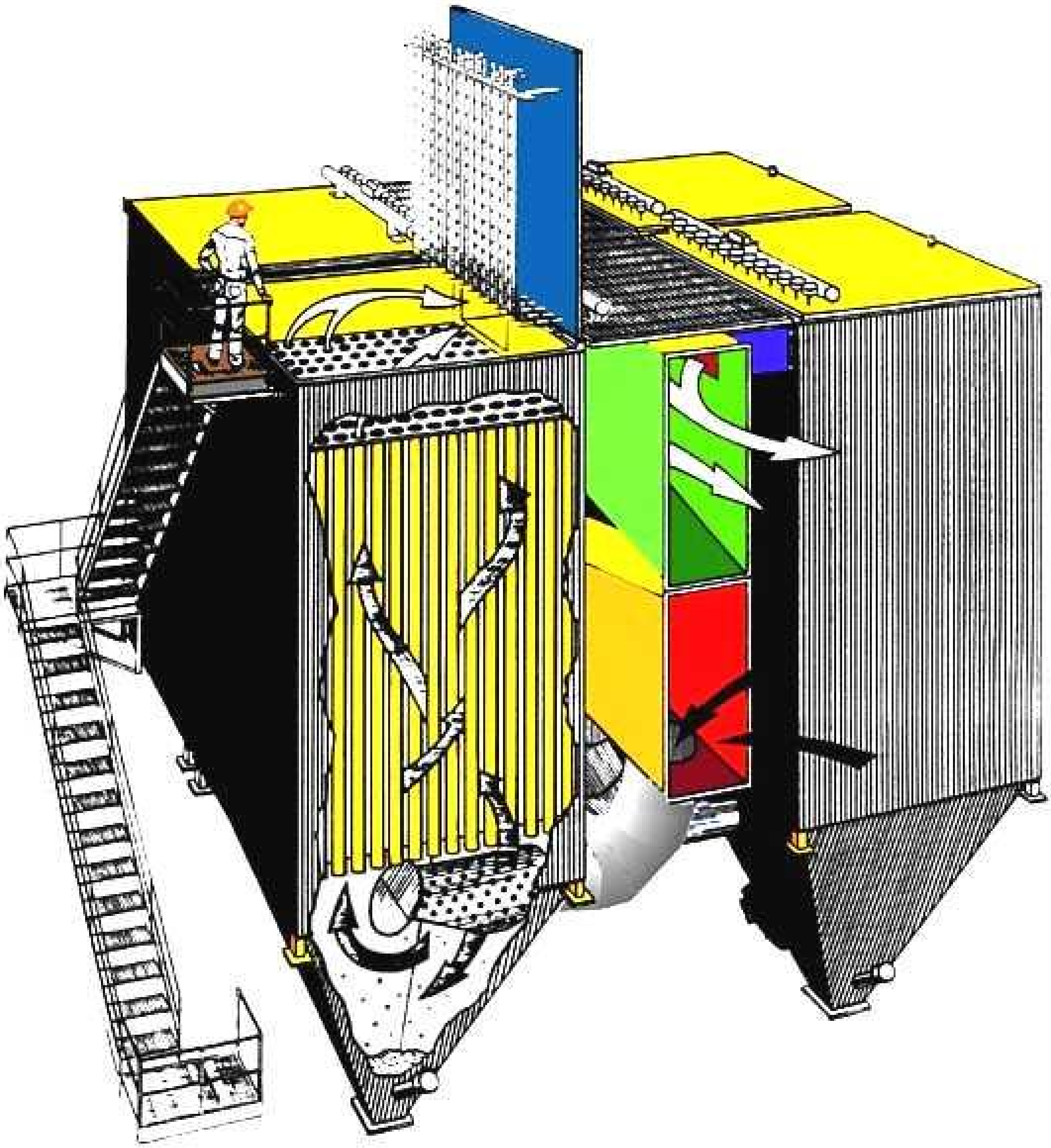
3.3.2 Wet Scrubbers

Wet scrubbers are capable of controlling HCL, CL_2, and SO_2 emissions. Important parameters that affect the scrubber's performance are scrubber type media and liquid-to-gas ratio.

3.3.3 Hoods

Hoods are used to control the fugitive dust from battery breaking, furnace charging, tapping, slag tapping, and agglomerating furnace operations. Dust is controlled by enclosing the source in a hood and ventilating the hood to a baghouse. The two most important factors in determining the efficiency of a hood in capturing fugitive emissions are the degree of enclosure and the air speed at the hood opening. The recommended air speed at the hood opening is 75–150 meters/ minute. Minimal opening hoods are the most effective in capturing the flow.

Figure 5
Baghouse Operation and Air Flow



4. Present Conditions

4.1 Description of Existing Conditions in Small and Medium Smelters

The following descriptions are mainly based on site visits to operating smelters of various sizes and rates of production.[7] Practices described are common to all small and medium smelters.

Plants operations are based on experience, with few controls over operating parameters. Smelting time is the same regardless of the material charged to the furnace. Almost all process steps are performed manually, and there is no mechanical equipment at the plants to help reduce the physical effort involved in the operations. The workers appear to have limited mechanical and electrical skills.

Space is severely restricted at these plants and much of the operating area is not paved. Dried lead paste from battery scrap, lead dross spills, and metal from furnace tapping, refining, and pouring operations can easily contaminate the ground. Worker exposure to lead is very high.

Emission measurements were made at an existing smelter, with results indicating that the PM emission concentrations were 13,141 and 11,108 mg/dscm before and after the wet scrubber, respectively.[8] Pb emissions were 10,358 and 8,413 mg/dscm at the same locations, which indicates that the efficiency of the existing pollution control device is about 20 percent. Concentrations of Pb in exhaust gases are more than 400 times the maximum limit of lead as specified in Law 4/1994, which is 20 mg/m^3.

Detailed descriptions of existing smelter conditions follow.

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[7] Weiss, M. G., "Report Based on Site Visit to Secondary Lead Smelters in Egypt," Cairo Air Improvement Project, Cairo, 1998, and Licht, C., "Small Smelter Upgrade," Cairo Air Improvement Project, Cairo, 1998.

[8] Cairo Air Improvement Project Air Quality Monitoring Component, "Emission Test Report on Awadallah Secondary Lead Smelter," Cairo, 1998.

4.1.1 Battery Wrecking

Batteries are usually broken manually at small- and medium-sized smelters, by workers using an axe or similar device. This practice provides a high potential for injuries, but more important, because plastic cases are not easy to chop or cut manually, the amount of polypropylene separated for potential recycling is reduced. Generally, in such plants whole batteries are charged to the furnaces. This results in air pollution problems caused by using the entire battery in the smelting process, without removing the plastic component—particularly PVC and other chlorine-bearing plastics. In addition, metal recovery is reduced since more non-metallic materials are charged to the furnace. It is reported that lead yield is currently 50 percent from battery scrap; a low recovery rate for batteries with a lead content of approximately 72 percent.

4.1.2 Furnaces

Rotary furnaces are used, as shown in Figure 6. Capacity of existing furnaces appears to be more than 1 MT/hour. Charge weights are estimated based on volume of material. Furnaces are configured with a L/D ratio of around 2. Although current furnaces have large capacities, a shorter furnace would reduce the contact between the burner flame and furnace charge. The greater diameter reduces the surface area in contact with furnace gases, decreasing dust, and a deeper bath would allow better separation of metal and slag.

Burners in many of the smelters use fuel inefficiently and have a crude design, which cause poor combustion characteristics, low heat recovery, and generation of excessive soot. The fuel used in most cases is mazot, which costs £E160/ton. Neither the fuel nor the air supplied to the burner is controlled. At maximum fire, the ratio of fuel to air is determined by the capacities of the fuel oil pump and the air blower, leading to inefficient combustion.

The furnace usually operates for 4 hours after the material is charged. This time does not change regardless of the size of the charge. After the furnace is fed, the burner is set on low fire. For the first hour, the furnace is rotated one-quarter turn every 15 minutes, and the burner air and fuel supplies are gradually increased. On initial burning the stack gas is black as the scrap plastic cases burn, with little energy value recovered. This is to be expected since the ignition point of polypropylene is low. The smoke gradually changes to white, stretching from the stack. Even after furnace tapping and burner shut off, the stack continues to smoke.

When the lead is removed from the furnace, it drains into a holding pot in the ground. Dross is skimmed from the surface of the lead and eventually fed back to the furnace.

4.1.3 Emission Control Devices

Emission control devices are nonexistent at worst and inadequate at best. Some existing facilities have installed wet scrubbers to capture dust. The scrubbers are effective in partially cooling the

Figure 6
Typical Egyptian Rotary Furnace

furnace gases, but they do not remove the fine dust generated in the smelting process. Scrubbers do little to remove dust for two reasons: they are too small to reduce air velocity and allow time for dust to be wetted through contact with water; and installed systems are incapable of capturing very small dust particles. Most of the PM emitted by lead smelters are fine particles. Baghouses and fabric system filters, which are the most efficient method for capturing fine dust particles, are not currently installed at any of the smelters.

5. Proposed Solutions

As secondary lead smelters of all sizes are situated in populated areas of Greater Cairo. They are all characterized by being undeveloped and the use of primitive production methods. Furthermore, proper pollution control equipment is virtually nonexistent.

Two solutions are suggested to solve the current problems: one short-term, to upgrade existing facilities, and one long-term, to relocate smelters to a remote area outside populated areas. Both proposals include using advanced technologies for both production processes and pollution control systems to comply with the regulations of Law 4/1994.

5.1 Short-term Solution

Passage of the environmental law created tremendous pressure on the owners of small and medium smelters. The first article of the law requires existing smelters to bring their operations into compliance with the requirements of the law's executive regulations within 3 years from the time they were issued. The Environmental Minister and the Cabinet can extend the grace period by an additional 2 years if serious efforts are already being made to bring the smelters into compliance. Smelter owners who were threatened by being shut down sought a sustainable solution to the impasse. They argued that relocating the smelters to a remote site would take too long, and sought support for upgrading their facilities, to continue operating until they could relocate.

Some smelter owners made the following changes to upgrade their facilities:

- Changing the fuel from mazot to solar.
- Using proper burners and enhancing combustion characteristics to improve furnace efficiency.
- Installing pollution control equipment to decrease emissions from the plants.
- Training staff and workers to operate and maintain new equipment and to use good housekeeping practices.

All the above procedures resulted in reduction of emissions from the plants, but still the lead and particulate matter emitted from the stacks were above he limits as specified in Law 4/1994. To minimize the emissions, a baghouse could be designed and installed to collect a large percentage of the dust emitted from the furnace and other operations. For easy operation and maintenance, the baghouse should be of the mechanical shaker type, where dampers and shakers can be designed and fabricated for manual actuation.[9] Since all smelters use the batch process, manual shaking of the bags can be done without disturbing the operating cycle. To keep costs low, the baghouse can be fabricated locally. The fabric to be used in the filter bags would need to be purchased abroad. The cost estimate for purchasing a locally fabricated baghouse and accessories exceeded US$100,000.

This short-term solution may not be practical for small smelters, which suffer from space restrictions. They may find it impossible to install extra equipment in the existing facilities, or to meet the high cost of this equipment.

5.2 Long-term Solution

The proper approach to emission reduction is to relocate the smelters to a site outside of Cairo. Relocated/rebuilt smelters should comply with the environmental law, with HAPs within the values defined by the executive regulations of Law 4/1994. Worker exposure to lead inside the smelters should also comply with the law.

In order to accomplish this, new facilities need to be equipped with modern air pollution control systems, to protect both the environment and the workplace. Worker exposure to HAPs should be virtually eliminated.

Relocation of the facilities would involve significant investments in plant and equipment. However, relocation to a new site seems to be a better solution, especially now that there is an allocation of land for this purpose in Qalioubiya Governorate.

In order to estimate the capital cost of this move, a conceptual design for a minimum configured small- and medium-sized lead smelter was generated and submitted by Stone & Webster. New technologies for both production processes and pollution control equipment to meet the requirements of Law 4/1994 are used. A capital cost estimate was developed based on this design. Two main approaches were used to compile the capital cost of the smelter. The first used prices provided by US and Canadian suppliers, as presented by Stone & Webster. The second used prices from local Egyptian manufacturers and suppliers. The second approach was used to reduce costs and ensure spare parts for continued future operation and sustainability.

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[9] Weiss, M. G., "Report Based on Site Visits to Secondary Lead Smelters in Egypt." Cairo Air Improvement Project, Cairo, 1998.

6. Development of Capital Cost Estimates

The capital cost estimate is based on the conceptual design submitted by Stone & Webster for the small- and medium-sized smelters.[10] Required equipment is defined according to this design, and two different options—imported and locally supplied and

manufactured equipment—are presented for equipment procurement.

6.1 Conceptual Design for Small- and Medium-sized Smelters

The purpose of the secondary lead smelter conceptual design is to provide a facility that replaces an existing one, while reducing the emissions of lead and lead compounds to the surrounding environment. Development of the conceptual design is based on construction of a totally new facility at a clean site. Product type and production rates of the new facility are comparable to existing facilities. The facility conceptual design drawings as presented by Stone & Webster are shown in Figure 7.

6.1.1 General Environmental Constraints

The smelter design complies with the regulations of Law 4/1994. Areas of particular constraints included regulations governing limitations on gas and fume emissions from industrial sources and worker exposure to harmful materials. As a result of a recent determination by the Lead Abatement Team at CAIP that furnace slag is not hazardous, no solid waste treatment facilities for slag are included.[11]

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[10] Stone & Webster Engineering Corporation, "Small and Medium Sized Smelters Conceptual Design to Support Development of a Capital Cost Estimate and Explanation of Cost Estimate Entries." Boston, 1998.

[11] Osborn, S. K., "Review and Waste Determination of Slag Produced by Awadallah's Lead Smelting Operations," report for the Cairo Air Improvement Project. CAIP, Cairo, 1998.

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6.1.2 General Facility Description

6.1.2.1 Product Description

The facility produces unrefined (crude) lead from recycled lead wastes. Raw lead waste materials for the facility are mainly used dry (drained) batteries, as well as miscellaneous lead materials, such as lead scrap, pipes, sheets, etc. The smelter has no capabilities to refine crude lead. The final crude lead product is formed into ingots.

6.1.2.2 Production Rate

Annual production rate of crude lead ingots is in the range of 1,000 to 1,200 MT/year. The facility is designed around a single rotary furnace with a crude lead production capacity of 2 MT/shift. Assuming an operating schedule of 8 hours/shift, 2 shifts/day, 6 working days/ week, and 46 working weeks/year, this furnace is capable of producing a nominal 1,100 MT/year of crude lead bullion.

6.1.2.3 Process and Facility Description

The facility reflects manual processes, as preferred by most small- and medium-sized smelter owners, in order to reduce costs as much as possible. The process, as shown in Figure 8, consists of:

Battery Wrecking and Scrap Pretreatment

The process begins with receipt of used, whole, dry automotive batteries and miscellaneous lead scrap. Batteries are delivered by truck and are manually unloaded to a stockpile on an uncovered concrete slab. One station is provided for the manual disassembly of the whole batteries. The disassembly process consists of one band saw to separate the battery top from the main casing. The battery lugs are removed from the top manually, by hammering or similar means. The lead plates are also removed manually. A casing and top clean-out station is provided to wash off the lead oxide paste. The disassembled battery materials are stored inside the building. The casings and top materials are sent offsite to be recycled.

Smelting Area—Rotary Furnace

Loading, or charging, of the rotary furnace with lead bearing materials and fluxing agents is performed manually by a fork lift equipped with a rotating half pipe. The rotary furnace is a short body design, as shown in Figure 9, refractory lined, with the burner and flue gas discharge at one end, and the charging door at the opposite end. This design provides improved efficiencies compared to the design presently being used. Diesel fuel fires the single burner. Smelting temperatures

Figure 8

Lead Smelting Flow Chart

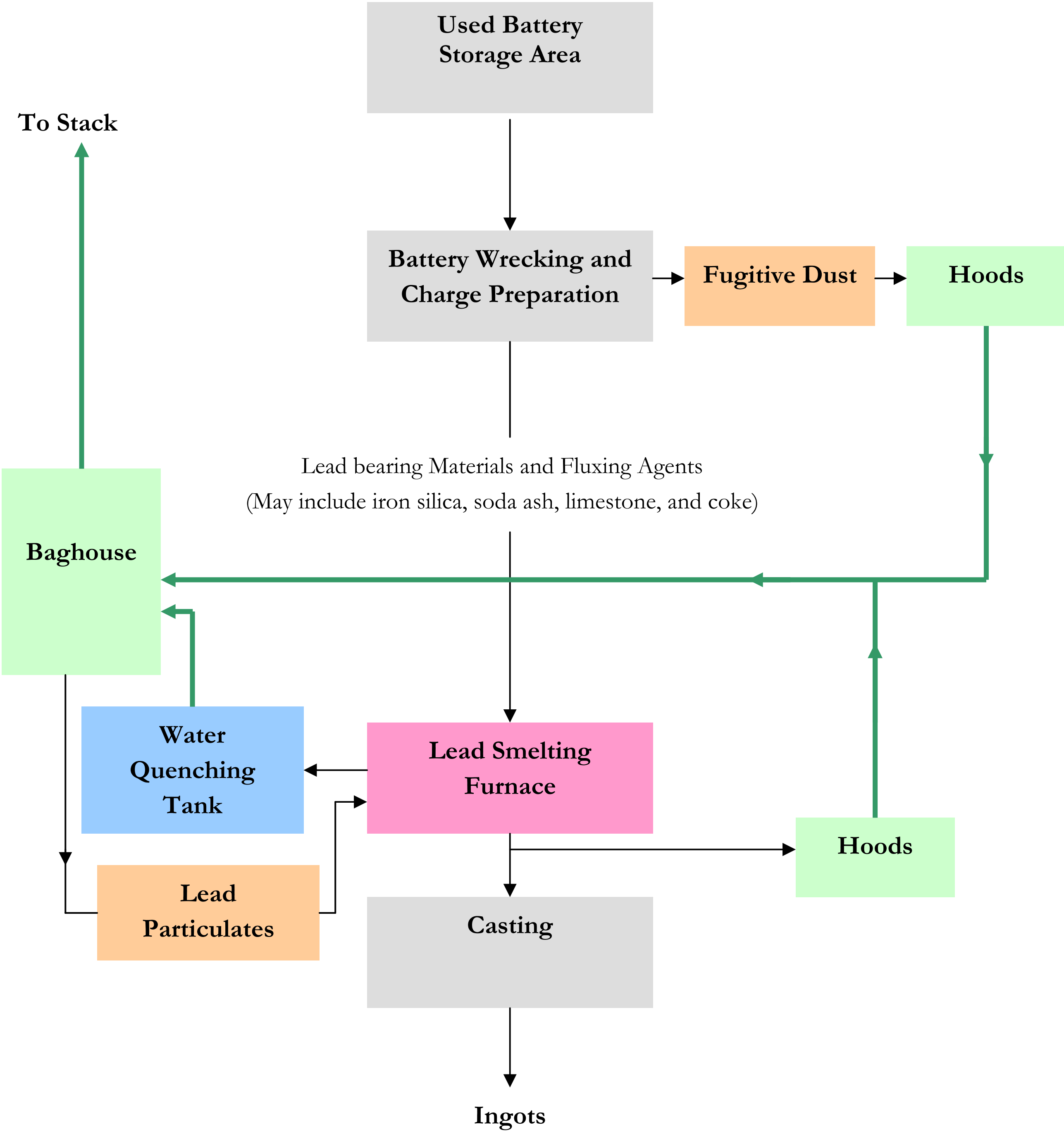

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Figure not available

reach about 1,200–1,300°C. The crude lead from the rotary furnace is tapped to a temporary, unfired holding kettle from which it is pumped through a manually controlled pipe for casting into ingots in stationary molds. Each mold has a 25-kg capacity. Sufficient ingot molds are included to allow casting the entire quantity of crude lead at the end of each shift. The molten ingots will cool enough to allow manual removal from the molds before the end of the next shift, when the molds will be needed again for casting. Ingots are hand loaded to temporary storage at the facility or directly into trucks.

Hoods for Fugitive Dust Collection

Adequate fugitive dust capture hooding is designed around the battery disassembly area, rotary furnace, and ingot mold cooling area. The collected gases and fugitive dust are conveyed to the baghouse through ductwork, which is also used to cool the rotary furnace exhaust gases before they enter the baghouse.

Pollution Control System—Baghouse

Baghouses are currently the only technology used to control metal HAPs process emissions from smelting furnaces since most particles are small. The main design and operating parameters that affect baghouse performance are type of cleaning mechanism, bag material, pressure drop, air to cloth ratio, and temperature.

One of the most important of these is baghouse temperature. Several metal HAPs found in smelting furnace emissions, including lead smelting, have detectable vapor pressures at typical flue gas temperatures. Therefore, the gas stream must be cooled in order to promote condensation of these metals for removal in the baghouse. However, cooling the flow below the acid dew point of sulfur can cause bag blinding and corrosion of the baghouse ductwork. Consequently, baghouses are operated at temperatures above the acid dew point, which depends on the sulfur content in the fuel. To achieve a proper operating temperature, exhaust gases are cooled prior to entering the baghouse. A quench chamber with compressed air atomized water spray is included to initially reduce the exit temperature of furnace exhaust gases. The quenched combustion gas is then mixed with the fugitive flow collected by the hoods for final cooling prior to entering a single pulse/jet style fabric filter (baghouse) for particulate removal. All collected dust is recycled to the rotary furnace and combined with the recycled lead materials.

The only waste stream existing in the facility is the solid waste slag from the furnace. Handling the fine dust collected by the baghouse must be done cautiously, as there are no systems to control this dust as it is collected for recharging into the furnace.

Service Area

A service area is provided for personnel to clean themselves before meal breaks and before leaving the facility at the end of the shift.

A hydro-pneumatic potable water tank is included for sanitary water use, and one sewerage lift station with duplex pumps is included to direct all sanitary wastes to a pre-treatment plant for removal of lead contamination prior to discharge to local municipal sewers. The floor of the facility will be poured concrete, and will be kept wet to reduce fugitive dust in the facility. A floor trench system with one submersible sump pump is provided. Fire protection will be through wall mounted hand-held fire extinguishers. No fire detection devices are included.

A system to receive and forward diesel oil is included. Potable water is supplied to the facility by truck delivery or direct connection to the municipal water source, and is stored in an on-site tank. There is no process water storage tank.

6.2 List of Items

The following list includes all items required for the new facility. Each item is specified to meet the conceptual design requirement.

6.2.1 Battery Processing System

The system includes the following items, followed by applicable technical specifications:

Industrial-duty Band Saw

- Variable speed drive
- Cutting depth in excess of 10 inches
- 26-inch throat

Washout Station

- Drum mounted washout sink

6.2.2 Rotary Furnace

The conceptual design for the furnace is shown in Figure 9.

- Short body type L/D = 1:6
- Charging door at one end and the single fuel (diesel) burner and flue gas exhaust at the opposite end
- Furnace diameter = 2.4 m (8 feet)

- Furnace length = 3.9 m (12.75 feet)
- Production rate up to 6 MT/day of crude lead bullion
- Production per shift = 2 MT/8-hour shift
- Total production per year = 1,100 MT of crude lead bullion
- Diesel fuel oil burner with complete flame safety system and fuel train
- One motorized door
- Provided with tracks, trolleys, and gear motor
- Refractory lined to sustain temperature up to 1,300°C.

6.2.3 Rotary Furnace Quench Tank with Atomized Water System

- Temperature drop through the tank from 1,300 to 535°C
- Injected water rate 1.1 gpm
- Quench chamber diameter of 1.5 × 5.0 feet in length, with refractory lining
- Duct outer diameter of 26 inches
- Provided with all necessary controls and interlocks.

6.2.4 Hood, Ductwork, Dampers, and Stack

- 3 collection hoods including all connecting ductwork, dampers, and supports for the gas path
- Stack of standard height.

6.2.5 Air Pollution Control System

The system consists mainly of a single pulse/jet baghouse and accessories. Other manual shaking systems could be applicable for Egyptian smelters.

- 8000 acfm air flow rate
- 177°C (350°F) flow temperature
- Top bag removal
- Factory welded
- Total filter area 3,560 $feet^2$ (387.76 m^2)
- 4 modules with a footprint 7 × 7 feet × 22 feet in length
- 81 bags per module
- 324 total bags
- Air-to-cloth ratio: 2:99 acfm/ft
- Each module has one hopper of 60° slope wall
- Material: mild steel

- All electrical items to be according to NEMA 4 (code), and designed for continuous operation.
- All structural steel from top of foundation should be provided
- All controls, devices, valves, timers, and other instrumentation, ladders, inlet and outlet manifolds, and air locks should be provided
- Draft fan and motor to satisfy the flow and pressure drop requirements: the fan is single width/single inlet (SWSI) type, complete with motor coupling, motor, manual radial inlet damper, flanged door, casing drain, coupling, and shaft guard
- Dust handling and storage system
- One 6-inch screw conveyor 10 feet in length, with motor
- One 9-inch inclined screw conveyor 24 feet in length, with motor
- One 4-foot diameter slide gate and load out chute.

6.2.6 Piping Systems

- The installed piping systems are for fuel oil, potable water, and process water
- All systems consist of 2-inch bore and under pipes.

6.2.7 Electrical Distribution System

- Motor control center
- Lighting
- Public announcement or paging system
- Distribution panels
- Cables
- Raceways.

6.2.8 Compressed Air System

The air compressor system is sized to meet the requirements of the baghouse (not needed if here is a manual shaking system), the air atomized water spray quench system, and for miscellaneous service air stations in the facility. The system delivers 56 scfm at a pressure of 100 psig. The system includes the following items:

- A single rotary sewer air compressor package
- High efficiency induction motor with motor starter
- Microprocessor control system
- 120 gallon receiver tank
- Coolant/lubrication system
- Vibration isolation

- Refrigerated dryer system
- Coalescing type air filter.

6.2.9 Fire Protection System

- 8 wall-mounted, hand-held fire extinguishers (30A/20BC)

6.2.10 Mobile Equipment

- 3,000 pound capacity LPG-fueled fork lift truck: Caterpillar model GC 15 vehicle, with 79-inch operator's overhead.

6.2.11 Miscellaneous Equipment and Systems

- 1 sewerage lift station
- 100 ingot molds with 25 kg capacity
- 1 unfired kettle to hold the tapped bullion
- 1 pump to pump the lead from the kettle into the molds.

6.3 Buildings and Building Facilities

6.3.1 Main Building

The main smelter building is conceptually sized at 40 × 30 m in plan. The building is an open structural steel framed enclosure with uninstalled steel walls. The floor is concrete slab on grade.

6.3.2 Utility Systems

The facility design includes a wastewater pre-treatment system to remove lead contamination from all water prior to discharging this water from the site. The treatment system is sized for a process flow rate of 15–25 gpm, and consists of:

- Water clarification
- Chemical feed
- Lead removal
- Retention tanks
- One 300-gallon hydropneumatic tank with accessories, to store potable water is included.
- Piping, valves, and fittings for the fuel oil system

- One 1,000-gallon horizontal cylindrical elevated tank with a diameter of 5 feet, 4 inches and a length of 6 feet is provided to store diesel fuel of 7-gauge mild carbon steel to UL142 requirements and painted with primer. Truck connection is included

6.4 Price List

The conceptual capital cost estimate shown in Table 2 was based on two main approaches. Stone & Webster used design, fabrication, construction, and pricing experience typical for grassroots facilities in the United States in developing the first approach. This approach reflects the environmental controls and levels of protection for workers typically required. The second approach used local manufacturers and suppliers for the majority of the required items specified in the conceptual designs, and also meets environmental requirements. Some of these items would be fabricated locally using imported materials and US designs and standards. Accordingly the capital cost estimates include two figures, one from manufacturers and suppliers from the US and Canada, and the other from local manufacturers and suppliers.

The description of the cost estimate are organized in the following table by serial numbers, the description of each item, total imported item cost in US dollars, and total locally manufactured or supplied item cost in local currency. The cost of imported equipment and materials is shown in US dollars to minimize confusion that might be caused by any fluctuation in the US dollar versus Egyptian pound exchange rate. The total imported item cost is subdivided to "Materials Only," which reflects the cost of the equipment FOB point of manufacture, or "Total Installed Cost," which includes construction and installation for particular items. A construction/ installation allowance is calculated for those items where costs are provided as "Materials Only."

The following items are not included in the estimate in Table 2:

One. Land cost

Two. Engineering design and project services (planning and scheduling)

Three. Vendor technical support (installation and start-up supervision)

Four. Handling, packing, freight, and insurance from point of manufacture to Egypt is not included for imported equipment

Five. Spare parts and start-up consumables

Six. Taxes and royalties

Table 2
Conceptual Engineering Capital Cost Estimate

Item Number	Description	Quantity	Units	Total Item	Imported Cost in US$	Local Cost in LE	Remarks
				Materials Only	Total Installed	Total Installed	
1	**Battery Processing System**					5,000 2,000	
	Industrial band saw	1		7,526			
	Wash out station	1		1,030			
2	**Rotary Furnace**						
	Complete with all accessories and lining	1		153,600		120,000	
3	**Rotary Furnace Quench Tank**	1		77,000		100,000	
4	**Hoods, Ductworks and Stack**	1			30,000	30,000	
5	**Air Pollution Control System**	1			178,000	300,000	
	Induced draft	1					
	Fabric filter	1					
	Dust handling system	1					
6	**Piping system (piping fittings and valves)**	1			5,000	5,000	
	Submersible sump pumps	1					
	Miscellaneous horizontal pumps (2 for potable water and for fuel oil)	4					

Item Number	Description	Quantity	Units	Total Item	Imported Cost in US$	Local Cost in LE	Remarks
				Materials Only	Total Installed	Total Installed	
7	**Electrical Distribution System**				25,400	25,000	
	Motor control system	1					
	Lighting and distribution panels	1					
	Public address and lighting systems	1					
	Race ways	1					
	Cables	1					
8	**Compressed Air System**				9,000	10,000	
	Single stage rotary screw air compressor						
	Induction motor						
	Microprocessor control system						
	120 gallon tanks and accessories						
9	**Fire Protection System**	8		160		500	
	30A/20Bc fire extinguishers						
10	**Mobile Equipment**	1			13,660	30,000	
	3,000 lb. Capacity forklift truck						
11	**Miscellaneous Equipment and Systems**						
	Sewerage lift station	1			1,000	1,500	
	Lead ingot molds	100			14,000	5,000	
	Unfired steel kettle	1			7,600	8,000	
	Lead transfer pump	1			6,000	5,000	

Item Number	Description	Quantity	Units	Total Item	Imported Cost in US$	Local Cost in LE	Remarks
				Materials Only	Total Installed	Total Installed	
12	**Buildings and Building Facilities, including Foundation and Steel Structure** 120 × 90 ft. smelter buildings and building facilities	1	1	350,000		800,000	
13	**Utility Systems** Wastewater treatment 12,000-gallon potable water storage tank, 12-ft. diameter, 15-ft. height 300-gallon hydropneumatic tanks 1,000-gallon fuel oil storage, horizontal, above ground	 1 1 1 1		 150,000 21,000 800 1,625		 120,000 20,000 1,000 2,000	
14	**Painting**	1		5,000		5,000	
15	**Site Preparation**	1				200,000	
16	**Exterior Slab on Grade** 60 × 30 feet × 6 inches	1		3,700		13,200	
	Construction and Installation (for materials only that require installation)			223,000		____	
	Subtotal			**1,328,000**		**1,808,200**	
	Allowance (calculated at 25% by Stone & Webster, and 20% for local suppliers)			332,000		**361,640**	

Item Number	Description	Quantity	Units	Total Item	Imported Cost in US$	Local Cost in LE	Remarks
				Materials Only	Total Installed	Total Installed	
	Total Project Cost			**1,660,000**		**2,169,840**	

7. Conclusions and Recommendations

The secondary lead smelting industry is important and beneficial. It eliminates the need to dispose of large quantities of hazardous materials. Therefore, concerned agencies should focus on ways to minimize the effects of lead pollution resulting from this industry, both inside and outside the smelters. Existing smelters in the Greater Cairo Area, situated in densely populated areas, are using old-fashioned technologies in their processes and are not using emission control systems. Consequently, the emission rates from these smelters are exceeding by far the rates imposed by the Law 4/1994. Upgrading the existing facilities would be a short-term solution; however, many small- and medium-sized smelters find it uneconomic to spend a considerable amount of money to consolidate their existing facilities. Relocation to a new site seems to be a more practical solution for most smelters. This solution is based on building new smelters using modern technologies that will enable them to comply with Law 4/1994 in both their production processes and their emissions to the surrounding areas. Costs for these modern smelters have been computed using offers from US and Canadian suppliers (costs totaling $1,660,000) as well as local manufacturers and suppliers (total cost of £E2,169,840—or equivalent to $638,188 at current exchange rates).

The Lead Abatement Team concludes that most of the smelter equipment can be manufactured in Egypt using US designs and technology. This will reduce the cost of the new smelters if the decision is taken to relocate them to new areas, ensure sustainability, and provide technology transfer to local experts.

Attachment 1

Consultant Report on Existing Conditions in Small and Medium Smelters

Date: October 9, 1998

To: Thomas F. Schwaller - CAIP
David Fratt - Chemonics International

Copy: Stasys Rastonis - CAIP
Thomas J. Horst - Stone & Webster

From: Michael G. Weiss

Subject: Trip Report - Cairo September 15-28, 1998

General

I had two major goals for the trip: 1) to get informed of Lead Pollution Abatement Group activity for the first year of the Cairo Air Project (CAIP) and plans for the second year, and 2) to learn about the operations of small and medium secondary lead smelters in Cairo.

The former was accomplished through discussions with CAIP Lead Group personnel and the Second Annual Work Planning Workshop. The Workshop also provided the opportunity to meet some Egyptian Environmental Affairs Agency (EEAA) and other government of Egypt (GOE) organization personnel concerned with reducing lead pollution.

To learn about the smelter operations, I reviewed background reports and visited two smelters - the Soudi smelter and the Awadallah number 3 smelter.

Planning Workshop

(The attached 9/27/98 memorandum on major program points for 2nd year covers the Planning Meeting and other discussions.)

The Lead Pollution Abatement Group discussions were quite active with good participation by Egyptian attendees, especially Dr. Mohamed Fawzy of the EEAA, Prof. Adel Nofat, president of the Central Metallurgical Research and Development Institute, and Eng. Adel Mahrous Ahmed, general manger for mechanical design at the IMC (Executive Organization for Industrial and Mining Projects).

General agreement was reached on several items. Activities which were ranked highest by the group included the need to identify Egyptian sources for design and manufacture of equipment and the need to inform or educate all potentially affected groups regarding the lead issue, i.e. the local populace, local government officials and their advisors and staffs, the news media, smelter owners.

- Egyptian sources for key parts and equipment will reduce capital cost for a new installation and provide easy to obtain spare parts to ensure continued future operations in an environmentally acceptable manner.

- Education of affected groups will be designed to explain reasons for new smelters to replace existing operations in order to gain support for and reduce opposition to the new plants.

Upgrade Existing Smelter Operations

An activity where I might assist the Lead Pollution Abatement Group activities for next year will be the upgrading of existing plants. Since any new site may be 2 to 3 years in the future (or more), major decreases in ambient air leads can be achieved by reducing the emissions at existing facilities.

If the two plants I visited are typical of small to medium and large smelters, emission control devices are nonexistent at worst and inadequate at best. Attempts have been made to capture dusts with scrubbers, but this is not an effective approach for the fine dusts generated in the smelting process. Even if a scrubber were suitable, the devices presently installed have design problems.

Two factors which must be considered in working with the existing plants are severe space restrictions and lack of maintenance skills in the workforce. The Soudi smelter occupies a site roughly 75 feet x 75 feet. While larger, the Awadallah plant also has very limited space. In both cases, dust collectors will have to be elevated to save floor space.

All of the processing steps that I observed are performed manually. Although I expected to find little manufactured mechanical equipment at the plants, I was surprised by the lack of homemade devices to help reduce the physical effort involved in the work. This indicates to me a lack of mechanical aptitude or knowledge. New equipment must be simple to operate and maintain so individuals with little mechanical background can easily learn proper operating, trouble shooting and maintenance procedures.

I believe a baghouse collector can be designed and installed at these smelters to collect a large portion of the dust emitted from the furnaces or other operations. To keep things simple and reliable, the baghouse should be of the mechanical shaker design. Dampers and shakers can be designed and fabricated for manual actuation. The principal mechanical device required will be a blower. If screw conveyors are desired to move the dust, then they will require drives. Since furnace operation is a batch process, manual shaking of the bags can be done without disturbing the operating cycle.

The major item that may require foreign supply is the cloth to be used for the filter elements (bags) themselves. Availability of industrial filter fabrics produced in Egypt has to be determined.

Assuming we can have a collector designed and fabricated locally, and the filter material can be obtained at a reasonable price, there are still three major questions that must be answered regarding the reduction in emissions from current smelters.

- First, what level of emission control will be required by the EEAA and local environmental authorities? It will not be realistic to require filter collection efficiencies similar to those achieved in U.S. smelters, often >99%. These levels of filtration require sophisticated and expensive filter materials. Improving the present capture efficiency, which is probably less than 20%, for the total furnace batch, to greater than 80%, maybe to 90% should be achievable.

- Second, will the owners commit to operate only when the emission control devices are in proper condition? For example, bypassing the collector or running with torn or missing bags should not be tolerated by the smelter management.

- Third, how will the captured dust be smelted? This material represents a significant amount of lead, but due to the small particle size, will just blow through the furnace with present operating procedures. Some work is required, including field trials, to determine operating conditions for each smelter to recover the values contained in the dust.

I contacted some U.S. baghouse manufacturers to get an idea of fabricating costs for a baghouse. One fabricating shop said they had a cost around $12.00-$12.50 per square foot of cloth area for a multicell baghouse. This is for extra heavy wall (¼" plate) to allow for corrosion in lead smelter baghouses, and includes cells, hopper, floor plates, screw conveyors, shakers, dampers, but not controls, bags or blower.

The importance of a material balance for smelter upgrades is discussed in the attached report on the Soudi smelter visit.

Soudi Smelter Visit - September 24, 1998

The attached 9/27/98 trip report covers the main points of the visit to the Soudi smelter. Photographs attached to the original trip report are not included here. The following two items were inadvertently left out of the report:

1) The furnace operates from approximately 5 PM to 8 AM. Mr. Ismail says the furnace cools during the period it is not operating, so fuel usage per ton has increased over that experienced during 24 hour operations. I said that one source of cooling is

the air drawn through the furnace charging door around the burner opening and opening below the burner by the natural stack draft.

I suggested he fabricate a refractory plug that will fit snugly in the furnace opening in place of the door during prolonged periods of no operation. Since there is good access around the feed end door, it will be easier to block the feed end of the furnace rather than the gas discharge end, as he is presently attempting to do.

2) The second point is the furnace configuration. The furnace has a length to diameter ratio (L/D) that appears to be around 2. A shorter furnace with a somewhat larger diameter would have the advantage of reduced contact between the burner flame and furnace charge. This may reduce lead lost to dust by decreasing the dust transported by the furnace gases.

Awadallah Smelter Visit - September 24, 1998

I was accompanied on the visit to the Awadallah smelter by Mohammad Nassar and Nadia Mourad-Grethe, CAIP translator. Our discussions were mainly with Kahlil Kassas and Abdul Nabi Awadallah. I believe Mr. Kassas is a consultant to the company as his explanations of the process were not always correct when he checked with the plant operators.

This visit was not as extensive as the Soudi smelter visit. We briefly reviewed the work done on the new plant and discussed the desire of the Lead Pollution Abatement Group to improve the existing smelters. We explained that the site for the new plants will take at least 2-3 years to develop, so reducing emissions from present operations is a high priority.

This plant is an integrated smelter and refining operation as well as a smelter. The company produces specification material for its customers including the battery manufacturers.

Yield of lead in the smelter is 50% of material fed to the furnaces.

Smelting is done in two rotary furnaces that appear to be the same size as those at the Soudi smelter. Furnaces produce 2 tons of lead per batch.

A rudimentary scrubber is used to clean furnace exhaust gases. The unit is a vertical chamber with a square cross section. I estimate the unit dimensions to be 15 feet tall and 3 to 4 feet on the side. Water from the scrubber goes into a floor sump and is pumped back to the scrubber. Collected sludge is periodically removed from the sump, dried and fed back to the furnaces. Stack emissions were quite heavy even with the scrubber in operation.

Comments on Soudi Smelter Air Sampling Report

In the September 18, 1998, report by the CAIP Air Quality Monitoring Group on emission measurements at the Soudi lead smelter, the observation is made that dust collected early in the furnace operating cycle is coarser than dust collected later.

This indicates that there are two mechanisms for generating dust. The first is physical carry-out of particles by the gas stream. This is the principle mechanism during the start-up period when temperatures are lower. Later, when furnace temperatures increase, volatilization of metals and oxides becomes a contributor to dust formation. The finer dust captured in the second sampling period results from condensation of vapors.

The following tabulation of temperatures (°C) and vapor pressures for metals and oxides encountered in secondary lead smelting illustrates how volatile these compounds are at furnace temperatures (Data from *Chemical Engineers' Handbook*, Fifth Edition, Perry & Chilton, McGraw-Hill Book Company, 1973)

	60 mm Hg	**100 mm Hg**	**200 mm Hg**	**400 mm Hg**	**760 mm Hg**
Pb	1358	1421	1519	1630	1744
PbO	1222	1265	1330	1402	1472
Sb	1176	1223	1288	1364	1440
Sb_4O_6	873	957	1085	1242	1425
As	498	518	548	579	610
As_2O_3	310	332	370	412	457

The data indicate that control of furnace temperature and oxidation/reduction potential can help reduce the amount of vapor, and therefore dust, generated.

New Plant Design

Since the new smelter location has not been settled, the following items should be discussed before revised new plans are finalized.

Battery Wrecking

The breaking of batteries by a number of small smelters is inefficient, and, as it will probably be done manually with an axe or similar device, offers a high potential for bodily injury. Furthermore plastic cases are not easy to chop or cut manually, so the amount of polypropylene separated for potential recycling is reduced.

If the smelters are to be relocated, perhaps a centralized battery wrecker could be established at the same industrial site. All smelters would have batteries processed by the wrecker, the polypropylene recovery would be maximized, and, if regulations eventually disallow the draining of acid from used batteries, all the acid could be processed at one location.

If a shaft furnace is not used (see discussion below), then a batteries could be processed through a hammermill or other crusher rather than a saw. This is a common type of battery wrecker system installed throughout the world, and the resultant lead bearing material is very suitable for rotary furnace feed.

Furnace Selection

I am familiar with the shaft furnaces or blast furnaces in secondary smelting operations, and, although many good arguments can be made for their use, I would not recommend them for an Egyptian smelter. Egyptian smelters use rotary furnaces, and it will be easier to train workers to operate a rotary furnace of modified design, than an entirely new type of furnace.

Although I personally prefer a furnace that can be operated continuously, many factors in Egypt such as availability of labor and materials argue for a batch operation which means a rotary furnace is a good choice.

Rotary furnaces used in western European smelters have larger diameters than those observed in Egypt. Although these have large capacity than the Egyptian furnaces, the concept of using a shorter furnace barrel of larger diameter to give the same volume as present furnaces can be beneficial to operation. The greater diameter reduces the surface area in contact with furnace gases, decreasing dust carry-out, and a deeper bath allows better separation of metal and slag.

Degree of Mechanization and Equipment Sophistication

For various reasons, smelter owners and both sponsoring governments will probably want a “state of the art” smelter design, at least for the large smelter. This translates into a design that reflects current practices in the U.S. or western Europe.

For reasons of capital cost, labor skills, and the need to provide employment, the need for a design incorporating latest technologies should be carefully examined. This is not to argue for a smelter that will be a source of excessive lead emissions, but to consider major restraints that would make the installation and operation of the smelter too costly.

- There is a need to provide employment for a large number of workers.
- Ideally this employment should enable workers to be trained, so skill levels will increase.
- Generally, it is easier to train workers for operation and maintenance of less sophisticated machinery. As worker knowledge and abilities

increase, replacement machinery can be of increasing complexity, with incremental training building on established base.

- Where jobs do not present a high potential for lead exposure, manual labor will be the most economical approach.

- Generally, more sophisticated equipment means a greater level of mechanization and control, and maintenance of the equipment becomes a major consideration.

- For reduced capital costs, and to provide expanded benefit to the Egyptian economy, as much equipment as possible should be manufactured (and designed) in Egypt.

- Spare parts cost and availability can be a problem if parts must be imported.

Michael G. Weiss
October 9, 1998

Attachments:
September 27, 1998 memorandum, Mike Weiss to Tom Schwaller - Major program points for 2nd year

September 27, 1998 memorandum, Mike Weiss to Tom Schwaller - Site Visit -Soudi Smelter September 24, 1998

Attachment 2

Test Report on Saudi Secondary Lead Smelter Emission Measurements

CAIP FIELD OFFICE **INTEROFFICE MEMO**

Air Quality Monitoring Component

To: Zeinab Safar
From: Jim Howes
Date: 18 September, 1998
Subject: Saudi Source Emission Test

Attached is the Saudi secondary lead smelter emission test report. Please do not hesitate to contact me if you have any questions or comments regarding the report.

Cc: Stasys Rastonis
Tom Schwaller
Fathiya Soliman

TEST REPORT
ON
SAUDI SECONDARY LEAD SMELTER
EMISSION MEASUREMENTS

I. INTRODUCTION

Measurement of particulate and lead emissions from the Saudi secondary lead smelter in Shobra Kheima was performed on September 1, 1998. The tests were performed during smelting a batch of lead assumed to contain approximately two (2) metric tons of lead. The first test was performed during the earlier stage of the smelting period. This test was started approximately 20 minutes after startup of the process. Observed visually, the plume from the stack during the first test appeared black to dark grey. The second test was performed later during the smelting period. The plume from the stack during the second test appeared white. Sampling was performed concurrently at the inlet and outlet of the control device in order to estimate the particulate removal efficiency of the unit.

The procedures used to perform the emission measurements and the test results are presented in the following sections of the report. A description of the Saudi smelting process is provided in Attachment 1.

II. SOURCE TESTING PROCEDURES

USEPA Method 12 was used to collect source emission samples for particulate mass and lead determination. Gas velocity and volumetric flow were determined with a Type S pitot tube using the procedures described in USEPA Method 2. Oxygen and carbon dioxide in the gas streams were determined by Fyrite analysis. Moisture in the gas streams was measured concurrently with the Method 12 test using the procedure described in USEPA Method 4.

Tests were preformed over two time periods during the smelting process as described in the previous section. Sampling duration during the first and second test periods was 40 and 58 minutes, respectively. Samples could only be collected for a limited time during the 3.5 - 4 hour smelting process because the filters became plugged with excessive quantities of particulate matter. During both of test periods, samples were collected concurrently at the inlet and outlet of the control device system. A drawing of furnace exhaust system showing the location of the sampling ports is presented in Attachment 2. Method 12 sampling system operating conditions, emission stream conditions, and test results are provided in Attachment 3.

The Egyptian Geological Survey and Mining Authority (EGSMA) performed the gravimetric and lead analyses of the source emission samples. A copy of the EGSMA lead analysis report is provided in Attachment 4. The lead analyses were performed by flame atomic absorption spectrometry (FAAS).

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The procedures used to perform the emission measurements and the test results are presented in the following sections of the report. A description of the Saudi smelting process is provided in Attachment 1.

II. SOURCE TESTING PROCEDURES

USEPA Method 12 was used to collect source emission samples for particulate mass and lead determination. Gas velocity and volumetric flow were determined with a Type S pitot tube using the procedures described in USEPA Method 2. Oxygen and carbon dioxide in the gas streams were determined by Fyrite analysis. Moisture in the gas streams was measured concurrently with the Method 12 test using the procedure described in USEPA Method 4.

Tests were preformed over two time periods during the smelting process as described in the previous section. Sampling duration during the first and second test periods was 40 and 58 minutes, respectively. Samples could only be collected for a limited time during the 3.5 - 4 hour smelting process because the filters became plugged with excessive quantities of particulate matter. During both of test periods, samples were collected concurrently at the inlet and outlet of the control device system. A drawing of furnace exhaust system showing the location of the sampling ports is presented in Attachment 2. Method 12 sampling system operating conditions, emission stream conditions, and test results are provided in Attachment 3.

The Egyptian Geological Survey and Mining Authority (EGSMA) performed the gravimetric and lead analyses of the source emission samples. A copy of the EGSMA lead analysis report is provided in Attachment 4. The lead analyses were performed by flame atomic absorption spectrometry (FAAS).

III. EMISSION MEASUREMENT RESULTS

Particulate matter and lead emission results obtained from the Saudi tests are summarized in Table 1. The average control device inlet and outlet particulate emission concentrations obtained from the two test periods are 13,141 and 11,108 mg/dscm, respectively. The average control device inlet and outlet particulate emission rates are 52 and 39 kg/hr, respectively. Particulate mass emission concentrations and emission rates measured at the control device inlet during the two test periods varied from 18,127 to 8,154 mg/dscm and from 81 to 23 kg/hr, respectively. Particulate mass emission concentrations and emission rates measured at the control device outlet during the two test periods varied from 14,214 to 8,002 mg/dscm and from 56 to 22 kg/hr, respectively.

The average control device inlet and outlet lead emission concentrations obtained from the two tests are 10,358 and 8,413 mg/dscm, respectively. The average control device inlet and outlet lead emission rates calculated from the two tests are 41 and 30 kg/hr, respectively. Lead emission concentrations and emission rates measured at the control device inlet during the two test periods varied from 13,949 to 6,767 mg/dscm and from 62 to 19 kg/hr, respectively. Lead emission concentrations and emission rates measured at the control device outlet during the two test periods varied from 11,188 to 5,637 mg/dscm and from 44 to 16 kg/hr, respectively.

Table 1. Summary of Emission Testing Results

Sample No, (a)	PM Emissions		Pb Emissions		Percent Pb in Sample
	mg/dscm	kg/hr	mg/dscm	kg/hr	
SLS-090198-1-IN	18127	81	13949	62	76.9
SLS-090198-1-OUT	14214	56	11188	44	78.7
SLS-090198-2-IN	8154	23	6767	19	83.0
SLS-090198-2 OUT	8002	22	5637	16	70.4
Inlet Average	13141	52	10358	41	
Outlet Average	11108	39	8413	30	

a) IN - Sampling performed at control device inlet; OUT - Sampling performed at control device outlet.

IV. DISCUSSION

The test results show that both particulate and lead emissions from the smelter are very high and vary significantly over the period that a batch of lead is smelted. Emissions during the early part of the smelting period were over twice those measured later in the smelting period. The particulate removal efficiency of the control device estimated from data obtained during the first test is approximately 30 percent and approximately 4 percent from data obtained during the second test. The higher removal efficiency at the start of the smelting period is believed to be due to the fact that the emissions contain larger sized particle matter. Later in

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IV. DISCUSSION

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The emission levels determined from the Saudi test are very much higher than those obtained from recent tests of other similar rotary furnace smelters. Due to space limitations, the Saudi control device is closely coupled to the furnace exhaust. The condition of the sampling probe used at the control device inlet indicated that there was slag carry-over from the furnace. The close coupling of the furnace and control device results in inlet gas temperatures in excess of 500° C and outlet gas temperatures up to 280° C during the latter part of the smelting period.

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Attachment 3

Awadallah Smelter #1 Test Report (Revised)

INTEROFFICE MEMO

CAIP FIELD OFFICE
Air Quality Monitoring Component

To:	Zeinab Safar
From:	Jim Howes
Date:	21 June, 1998
Subject:	Corrections to Awadallah Smelter #1 Emission Test Data

An error in the Awadallah Smelter #5 results reported by the analytical laboratory (EGSMA) led me to recheck the analytical data from the Awadallah Smelter #1 testing conducted on February 24, 1998. I reviewed the analytical results with EGSMA and found that mistakes were also made in the Awadallah Smelter #1 data. The errors in the Awadallah Smelter #1 data are summarize below:

- The total quantity of lead reported in all the Filter and FHR samples is in error due to using an incorrect dilution factor to convert the quantity of lead measured by the AAS analysis to the total quantity of lead in these samples. The initial results reported for the Filter and FHR samples for Runs ALS-2 and ALS-3 are 1/10th of the actual total quantity of lead in these samples.

- The total quantity of lead initially reported for the Filter and FHR sample for Run ALS-1 is also 1/10 of the actual total lead in this sample. In addition, there was a mathematical error in calculating the total quantity of lead.

The corrected data reported by EGSMA and pages of my 1 March 1998 Awadallah Smelter #1 Test Report that have been revised to include the corrected lead analysis data are attached.

cc: Stasys Rastonis
Ahmed Gamal Abdel-Rehiem
Tom Schwaller
Ahmed El-Sotouhy
Mounir Labib
Noha Samaha

Awadallah Smelter #1 Test Report - Revised (a)

Three (3) source emission tests were performed at the Awadallah Secondary Lead Smelter No. 1 on February 24, 1998. During the period that the source emission tests were conducted, sampling was also performed for particulate matter (PM10) in the workplace atmosphere in the vicinity of the smelting furnaces. Both the source emission and the workplace samples were analyzed for particulate mass and lead (Pb) content. Scrubber liquor and make-up water samples, taken during the test program, were analyzed for lead content. Procedures used to perform these measurements and the test results are presented below.

Source Tests

USEPA Method 12 was used to collect source emission samples for particulate mass and lead determination. A copy of the test method is provided in Attachment 1. Three (3) tests. identified as ALS-1, ALS-2, and ALS-3 were performed. Drawings in Attachment 2 show the location of the sampling ports and the sampling points within the scrubber outlet duct. The sampling system operating conditions, emission stream conditions, and test results are also provided in Attachment 2. Particulate mass emission concentrations and emission rates obtained during the three tests varied from 607.9 to 1832.7 mg/dscm and 4.01 to 13.67 kg/hr. respectively. **The average particulate matter emission concentration and emission rate determined from the three tests are 1212.0 mg/dscm and 8.85 kg/hr, respectively.**

Lead mass emission concentrations and emission rates obtained during the three tests varied from **511.3** to **1337.9** mg/dscm and **3.38** to **9.98** kg/hr, respectively. **The average lead emission concentration and emission rate determined from the three tests are 905.7 mg/dscm and 6.59 kg/hr, respectively.** The variation in the emissions data are assumed to be due to changes in process conditions. However, we were unable to relate any specific process conditions or operations with the emission variations. The percentage of lead by weight in the particulate emission samples obtained during the three tests ranged from **73 - 84** percent.

The three tests were performed for a duration of 9 to 45 minutes during the approximately 5-hour period required to smelt a batch of lead. No test data were obtained during the pouring operations. Sampling proceeded normally during the first two tests (ALS-1 and ALS-2). However, severe plugging or blinding of the sampling system filter occurred during the third test (ALS-3). The first filter became plugged after six (6) minutes of sampling. The filter was changed and the second filter became plugged after three (3) minutes of sampling. Therefore, the test was terminated after nine (9) minutes of sampling since it was impossible, due to the high pressure drop across the filter, to maintain isokinetic sampling conditions.

a) Changes in report are shown in **bold** type.

Workplace Sampling

Workplace samples for particulate matter were collected at three (3) locations in the smelting furnace area. The sampling locations are shown on the diagram provided in Attachment 3. Sampling was performed with AIRmetric PM10 samplers during the period that the source testing was conducted. The results of the workplace PM10 and airborne lead measurements are provided in Attachment 3. PM10 and lead mass concentrations in the workplace atmosphere ranged from 692 to 754.8 $\mu g/m^3$ and from 104.5 to 167.0 $\mu g\ Pb/m^3$, respectively. The percentage of lead by weight in the PM10 samples was in the range of 13.8 to 24 percent

Water Sampling

Grab samples of the scrubber make-up water and the scrubber liquor were taken during the test program and analyzed for lead content. Lead was not detected in the make-up water, which is taken from a nearby well. The sample taken from the scrubber water sump contained solids. After thorough mixing, an aliquot of this sample was filtered and the lead content of the solids and liquid phases was determined separately. The lead concentration in the liquid and solid phases of the water sample were determined to be 7.44 µg/ml and 719912 µg/g, respectively. The solids content of the water sample was 0.589 g/l. The analytical results for the water samples are provided in Attachment 4. The make-up water and scrubber liquor samples are designated "Water Before Filter" and "Water After Filter", respectively, in the lead analysis report.

Gravimetric and Lead Analysis

Gravimetric and lead analyses of the source emission, workplace atmosphere, and water samples were performed by The Egyptian Geological Survey and Mining Authority (EGSMA). A copy of the EGSMA lead analysis report is provided in Attachment 4. The lead analyses were performed by flame atomic absorption spectrometry (FAAS).

Quality Assurance

Two (2) filters from the batch used for the source emission tests and three (3) filters from the batch used for the workplace measurements were used as gravimetric analysis blanks. The blank filters were taken to the test site, but were not used for sampling. Thus, differences between the tare and final weight reflect any error due to filter handling and/or filter weighing procedures. The maximum difference of the tare and final weights of the source test filter blanks is 0.0001 g. The average difference in the tare and final weights of the workplace (AIRmetric) sampler filter blanks is 14 µg. The final weight of all AIRmetrics filter blanks was higher than the tare weight and the tare/final differences were approximately the same value. The nature of the differences suggest that a slight constant bias may have been introduced by balance drift and/or differences in filter conditioning before the tare and final weights were obtained. Considering the mass of particulate collected on the workplace samples, the error in mass introduced by the observed bias is less than 2 percent.

Determination of solids content and the quantity of lead of the scrubber liquor (Water After Filter) was performed in duplicate. The average difference between the duplicate determinations of the scrubber liquor solids content is ± 1.8 percent. The average difference between the duplicate determinations of lead in the scrubber liquor solids is ± 0.6 percent.

Two lead reference samples (Pb-S-1-D and Pb-S-4-D) were analyzed in triplicate with the test samples. The average difference between the analysis results and the certified value for the standard containing 5.02 µg Pb/ml is + 11.2 percent. The average difference between analysis results and the certified value for the standard containing 19.99 µg Pb/ml is + 0.2 percent.

The results obtained from the above quality assurance procedures are presented in Attachment 5.

Lead was not detected in the source test and workplace sample blanks, thus confirming that the samples were not contaminated during the sampling or analytical process. See Attachments 2, 3, and 4 for the lead analysis results for the blank samples.

The results of all the quality assurance data indicates the accuracy of the measurements are within the expected range for the measurement method employed.