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Information Circular 9156

Domestic Secondary Lead Industry: Production and Regulatory Compliance Costs

By R. Craig Smith and Michael R. Daley

**UNITED STATES DEPARTMENT OF THE INTERIOR
Donald Paul Hodel, Secretary**

**BUREAU OF MINES
Robert C. Horton, Director**

As the Nation's principal conservation agency, the Department of the Interior has responsibility for most of our nationally owned public lands and natural resources. This includes fostering the wisest use of our land and water resources, protecting our fish and wildlife, preserving the environment and cultural values of our national parks and historical places, and providing for the enjoyment of life through outdoor recreation. The Department assesses our energy and mineral resources and works to assure that their development is in the best interests of all our people. The Department also has a major responsibility for American Indian reservation communities and for people who live in island territories under U.S. administration.

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UNIT OF MEASURE ABBREVIATIONS USED IN THIS REPORT

A	ampere	km	kilometer
°C	degree Celsius	kW·h	kilowatt hour
cm	centimeter	lb	pound
¢/KW·h	cent per kilowatt hour	m	meter
¢/lb	cent per pound	mt	metric ton
¢/mt-km	cent per metric ton kilometer	mt/yr	metric ton per year
d/yr	day per year	µg	microgram
°F	degree Fahrenheit	µg/m ³	microgram per cubic meter
ft	foot	µm	micrometer
ft ²	square foot	min/d	minute per day
ft ³ /min	cubic foot per minute	Mmt	million metric tons
g	gram	pct	percent
ga	gauge	ppm	part per million
h	hour	spd	shift per day
h/d	hour per day	st	short ton
hp	horsepower	V	volt
in	inch	yr	year
kg	kilogram		

DOMESTIC SECONDARY LEAD INDUSTRY: PRODUCTION AND REGULATORY COMPLIANCE COSTS

By R. Craig Smith¹ and Michael R. Daley²

ABSTRACT

The Bureau of Mines conducted a study of production costs for the secondary lead industry and determined costs for present, pending, and proposed environmental legislation. Operating costs for smelters by capacity groups range from 16.8 to 19.6 ¢/lb of refined lead. Present regulatory compliance costs for these groups range from 2.2 to 2.4 ¢/lb. Pending compliance costs could add 3.5 ¢/lb of refined lead, and proposed regulations could add another 1.3 ¢/lb.

The individual capital costs necessary to comply with pending environmental regulations are estimated to be \$1.8 million for small smelters and \$10.4 million for large smelters. Proposed regulations could require additional expenditures from \$1.9 million for small smelters to \$4.9 million for large smelters.

These cost estimates, based on average 1985 dollars, indicate that pending and proposed legislation could add significantly to capital and operating costs of the secondary lead industry. These regulatory compliance costs may result in a loss of up to 40 pct of secondary lead production capacity.

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INTRODUCTION

The purpose of this report is to assess the economics of producing lead by the domestic secondary lead industry³ and to evaluate the costs and impacts for present, pending, and proposed environmental regulatory compliance. Because the industry produces approximately 50 pct of the refined lead in the United States, the resource of scrap material becomes a significant commodity, which should be considered in Federal minerals policy. The Bureau of Mines conducted this study as part of the Minerals Availability Program (MAP), which evaluates the availability of commodities. The production capability and economic assessment of each operation is an integral part of this program. The scope of this study includes an economic assessment of the domestic secondary lead industry and an estimation of the costs and impacts to the industry from regulatory compliance.

At the time this study was begun, in January 1986, there were approximately 24 operating smelters with production capacity greater than 3,000 mt/yr. Smelters with capacity less than 3,000 mt/yr were not included in the study because they represented less than 1 pct of total production capacity.

Over the past several years, there have been many reports published by consulting firms on the cost and implications of environmental regulatory compliance (1-4).⁴ In general, the findings in this report support their cost estimates. The following are the major differences:

1. The Bureau's capital cost estimate for compliance with all of the environmental regulations affecting the

secondary lead industry is less than some industry estimates, but is also based on fewer operating smelters, due to recent closures. At the time this study was conducted, there were 24 operating smelters with capacities greater than 3,000 mt/yr.

2. Published operating cost estimates, updated to average 1985 dollars for comparison, indicate that the Bureau's cost estimate is higher by approximately 2 ¢/lb refined lead. This is because the Bureau's estimate includes transportation charges and more regulatory compliance costs.

3. The Bureau's estimate for *present* regulatory compliance operating costs is higher than updated published estimates by approximately 1.5 ¢/lb. The difference can be attributed to the additional compliance presently being performed compared with that actually being performed several years ago. Assuming that this accounts for the higher operating cost, then the net total operating cost difference between previously published sources and the Bureau's estimate is approximately 0.5 ¢/lb refined lead.

4. The Bureau's estimate for *proposed* regulatory compliance costs is approximately 1 ¢/lb less than updated published estimates.

5. The Bureau's estimate of lost production capacity because of shutdowns is less than half of previously published estimates. However, the secondary lead industry has lost approximately 35 pct of production capacity since those estimates were made.

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METHODOLOGY

The secondary lead industry is extremely variable with respect to degree of integration, market conditions, production capacity, and products. To assess the economics of the industry, operating costs had to be standardized to reflect only those costs associated with acquiring and converting scrap lead into refined metal.⁵ For

³The secondary lead industry refers to companies involved in the recycling of scrap lead materials by smelting and refining the lead into reusable products. Presently (1986), approximately 80 pct of the scrap lead is in the form of spent automotive batteries.

⁴Underlined numbers in parentheses refer to items in the list of references at the end of this report.

⁵Refined metal is considered to be antimonial lead, soft lead, oxide lead, and calcium lead. Other types of refined lead are actually produced but are an insignificant amount of production and are not considered to affect operating costs.

example, some fully integrated smelter complexes purchase scrap, smelt and refine it, and use the refined lead to fabricate new storage batteries. The costs associated with making new batteries, beyond the refining stage, are not included in this study. The battery fabrication costs include labor, materials and supplies, administration, and a percentage of property taxes, insurance, and depreciation.

Procedures to obtain data for estimating operating costs included site visits to several smelters considered to be representative of the industry, industry canvassing to obtain specific operating details, and engineering studies of smelting and refining practices. Twelve companies responded to the canvass and supplied detailed cost data.

These companies represented approximately 67 pct of the 1985 domestic secondary lead production. Operating costs have been consolidated and averaged to conceal company-proprietary data. All costs are presented in average 1985 dollars.

For this study, initial capital costs have been excluded. Ongoing capital expenditures for improve-

ments, modifications, and regulatory compliance have been identified, and a percentage of these costs are included as depreciation. The purpose of this procedure is to show net operating costs for current market conditions so that future profits or losses for environmental compliance expenditures can be estimated.

DOMESTIC SECONDARY LEAD INDUSTRY

The secondary lead industry primarily recycles new and old scrap. New scrap is a waste product of fabrication, casting plants, purchased drosses, and other residues. Old scrap is a product of wornout equipment and materials, such as batteries, cable, and type metal. Most recycled scrap lead is in the form of spent automotive batteries. Availability of lead scrap is contingent on the amount of prior production, durability of lead-bearing goods, and incentive to recycle (1). In 1984, battery scrap accounted for 76 pct of recycled lead (5). In the first quarter of 1986, an estimated 80 pct of recycled scrap was in the form of spent batteries. Most scrap is reprocessed into storage battery materials, although a variety of other commodities are produced. There are approximately 70 companies producing some form of secondary lead, but in 1985, 23 companies operating 30 smelters produced 98 pct of the total (6). A generalized process flow is presented in figure 1.

Most secondary lead smelters have contracts with battery producers, other secondary smelters, and independent manufacturers. Secondary smelters, especially the large-capacity plants, have long-term contracts with battery producers. This is the most economical arrangement because these smelters supply lead to the battery producers and then back-haul spent batteries. However, this arrangement does not necessarily supply the majority of scrap lead, resulting in a competitive scrap lead recycling industry. Transportation distances up to 1,600 km are not uncommon, and scrap prices vary by region. The primary reason for scrap price variations is demand. The Northeast has competition with Canada and Brazil for scrap, and the west coast has competition with Asia, Brazil, and Mexico. The South currently has the least competition and the lowest price for scrap (table 1). Exports have been increasing to southeast Asia and Mexico for the last several years and have made the entire west coast a very competitive market (6-7). Foreign smelters can afford to bid a higher price for scrap because their capital, labor, and environmental costs are lower than U.S. producers. This puts west coast smelters in a low profitability position because of the high price of scrap.

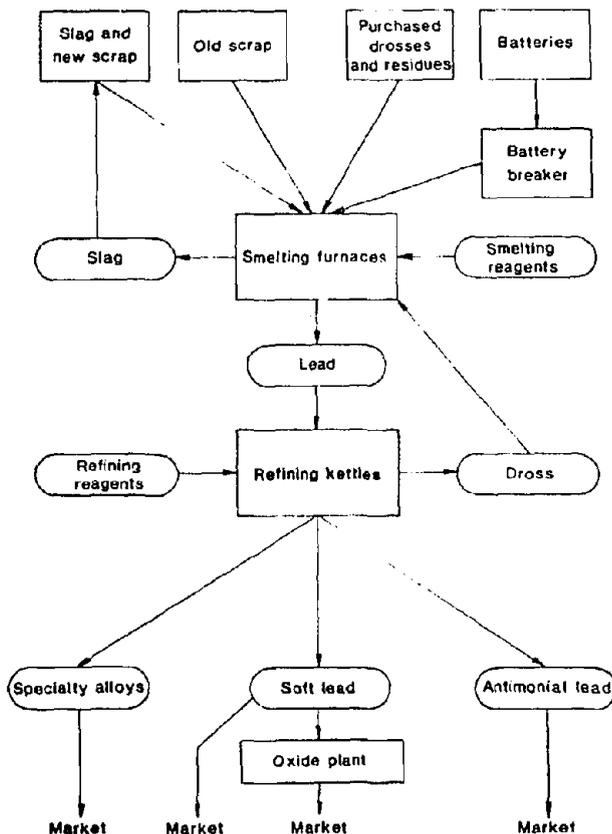


Figure 1.—Generalized secondary lead flow.

TABLE 1.—U.S. Regional average price variations for scrap batteries in 1985, cents per pound

Area	Whole batteries	Lead content
West.....	3.85	8.0
Northeast.....	3.00	6.2
South.....	2.65	5.5

Production capacity in 1981 was estimated to be 1.2 Mmt, but because of oversupply, weak demand, high prices for scrap, and environmental regulatory costs, several smelters have been shut down and dismantled. This represents a permanent loss of production capacity. Domestic installed production capacity is now estimated to be 900,000 mt. In 1985, due to permanent and temporary smelter closures, operating companies had a combined capacity of 800,000 mt, of which approximately 600,000 mt of refined lead was produced. More closures and resultant loss of capacity can be expected if current market conditions and proposed environmental regulations go into effect. In 1984 and 1985, battery scrap as a percentage of recycled secondary lead has been increasing (table 2). Secondary lead production has also increased as a percentage of total lead production. Strikes at the domestic lead mines in 1984 and low primary production, because of poor economic forecasts for 1985, were the main reasons for the increases (6). Capacity utilization for operating secondary smelters was 75 pct for 1984 and 1985, and worse in the preceding years due to significant overcapacity.

TABLE 2.—Historical refined lead statistics, thousands of metric tons of contained lead

Production	1981	1982	1983	1984	1985
Domestic ores	440.2	459.9	459.3	330.2	416.1
Foreign ores	55.1	52.3	55.2	85.4	71.4
Secondary lead, new and old scrap	641.1	571.3	503.5	633.4	594.2
Batteries, pct of secondary lead	75	77	74	77	78
Secondary lead, pct of total refined lead ..	56	53	49	62	55

Source: Woodbury (2).

The average 1985 price for refined lead was 19.2 ¢/lb. This represents a 25 pct decrease from 1984 and the lowest price this century in terms of constant 1985 dollars (8). The average price of refined lead for the first quarter of 1986 was 18.4 ¢/lb.

SECONDARY LEAD PROCESSING

The smelting and refining technologies employed in the secondary lead industry are significantly different from those used in the primary lead industry. The reasons are the high lead content of the feed, the absence of complex impurities, the preparation of scrap lead feed, and the types of products produced. The secondary lead

process flow includes battery breaking, smelting by either blast furnace or reverberatory furnace or both, and refining. A generalized process flow diagram presenting the most commonly used methods of smelting, refining, and product output is presented in figure 2.

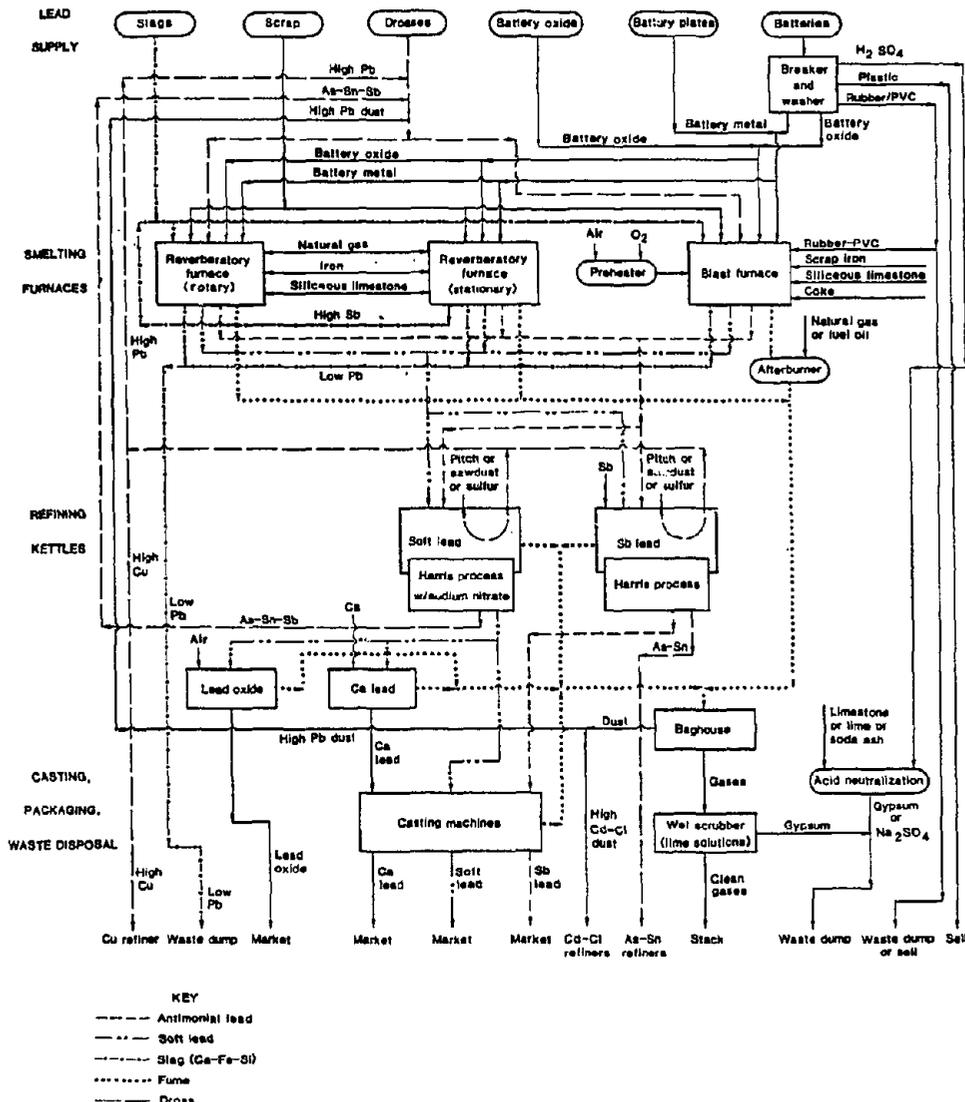


Figure 2.—Secondary lead smelting and refining process composite.

BATTERY BREAKING

Battery breaking is the first step in the lead recycling process. Because lead-acid batteries are considered to be hazardous material for processors, it has become standard practice to break batteries as soon as possible after delivery. This usually means unloading from trucks directly into the breaker. Most breakers are either the hammer mill or the saw-type breaker. The hammer mill is fed whole batteries. After the batteries are broken, the acid drains into a collection facility and the solids proceed to the flotation section. The saw-type breaker cuts the tops off the batteries, allowing the acid to drain. The batteries are then either manually emptied of plates and sludge and fed into a hammer mill, or used as direct feed into a reverberatory furnace.

If the batteries are manually emptied, the plates and sludge must be washed to remove all vestiges of acid. The tops of the batteries must be processed through a hammer mill to separate the posts and plate tops from the plastic and rubber. For the batteries not emptied manually, the entire battery, less acid, is fed to a rotary hammer mill for component separation and washing. Operations with direct-feed hammer-mill breakers are realizing considerable labor savings as a result of the smaller work force necessary for operation and maintenance. This results from the fact that the batteries feed directly to the mill from a conveyor and do not require constant monitoring and adjustment.

The flotation section separates the battery-casing plastic, rubber, and polyvinyl chloride (PVC) from the plates, posts, and sludge. Washing is also accomplished in this section. The plastic is recycled because it has a 16- to 18-¢/lb value (1985 prices) and each battery averages 1.5 lb of plastic. Rubber and PVC are generally discarded in hazardous waste dump sites. Plates, posts, and sludge (lead oxide and lead sulfate) are stored in open-faced concrete bins. Most of these storage bins are totally enclosed in buildings or are being converted to enclosed buildings because regulations require all materials with a lead content greater than 1 pct to be stored in such a manner.

SMELTING METHODS

Smelting is a pyrometallurgical method for the separation of metal from impurities. There are three basic operations involved in smelting: (1) initial burnout of the charge, which incinerates combustibles; (2) sweating the charge, which releases the metallics because of their low melting point; and (3) slagging the charge, which forms a molten lead layer and a layer of oxidized impurities. Smelting can be accomplished in a blast furnace, a stationary reverberatory furnace, or a rotary reverberatory furnace. Electric arc furnace technology is being tested or utilized, but is not included in this study. Many smelters utilize a blast and reverberatory combination, but rotary furnaces are generally used alone because of their versatility.

Blast furnaces are operated as large-scale batch smelters. This allows for greater utility because the charge can be adjusted to the base metal assay for each batch. Batch operations also allow for more variable feed stocks, such as high-lead drosses, high-lead slags, flue dust, scrap lead, and any combination of the above. Blast furnaces are top loaded and have a crucible at the bottom

(fig. 3). These furnaces range in size from 68 to 120 cm in diameter with a working height of 2.4 to 3 m. Crucible location prevents further reaction of the molten lead because of the overlying slag layer. Tuyeres extend through the water jacketed shaft above the hearth and supply air and oxygen for combustion. The blast furnace can simultaneously burnout and sweat the charge, thereby reducing fuel and time requirements. Coke is the standard fuel and makes up approximately 10 pct of the charge.

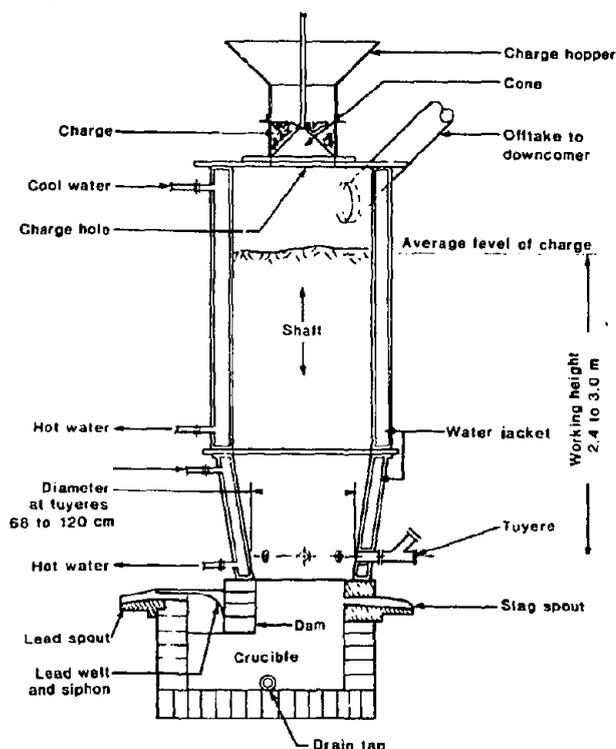


Figure 3.—Cross section of a typical blast furnace. (Modified from Murph (2))

As a charge is heated, the pure metal portion melts first, which leaves the flux (iron, silica, and lime) and the metallic oxides to be converted into slag. The molten lead accumulates at the bottom of the furnace and is tapped through the use of a weir-dam siphon. With the metallurgical reduction order being lead, then antimony, then tin, the charge balance of coke must be adequate to carry reductions at least through the antimonial stage.

The stationary reverberatory furnace is essentially a melting furnace. It is rectangular in shape and has a shallow hearth and an arched roof. The floor and roof both slope downward, roughly parallel, toward the firing end of the furnace. The other end of the furnace has a large hopper for continuous feed of the charge, generally through the roof (fig. 4). The dimensions are quite variable, with widths from 1 to 6 m, lengths from 1.8 to 12 m, and heights from 1 to 3 m. The furnace is ideally suited for smelting of homogeneous material, whereas heterogeneous material in a continuous feed system can develop problems in maintaining a balanced flux charge. The charge is melted by a flame, which extends half the length of the furnace. As the charge melts, it flows down into the molten pool on the hearth. The slag is tapped continuously while the lead is tapped periodically.

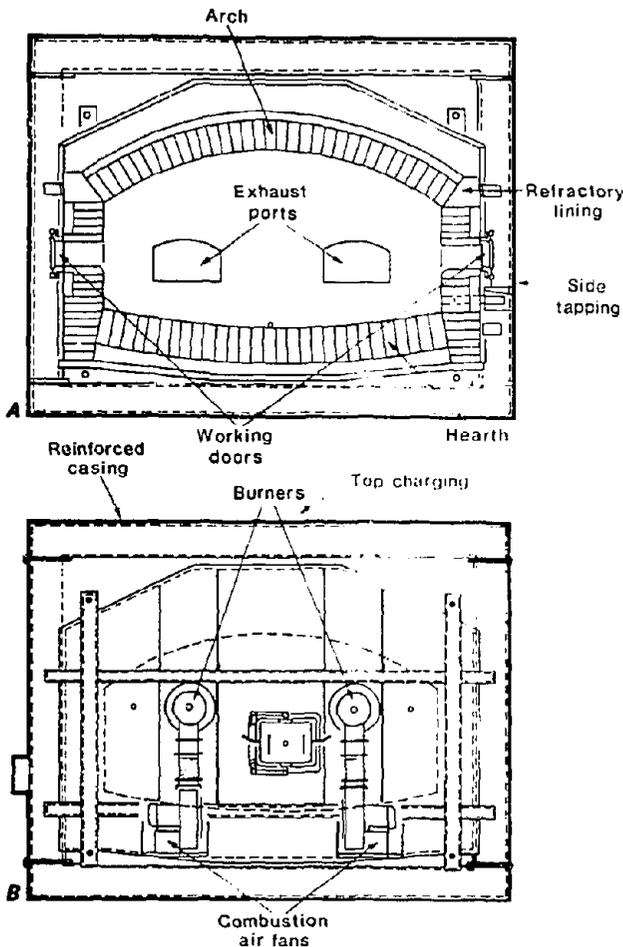


Figure 4.—Cross sections of a typical stationary reverberatory furnace. (Courtesy Tolltrek International Ltd.) A) Interior, exhaust end and B) Exterior, combustion end.

Because the throughput rate of a stationary reverberatory furnace is relatively slower than the rate of a blast furnace, refining within the reverberatory furnace is possible. In particular, high lead-content drosses may be formed and recovered, as well as slags with high lead and antimony content. These materials may be returned to the blast furnace for further lead recovery.

The rotary reverberatory furnace has some similarities with both the stationary reverberatory and the blast furnace. The rotary, like a blast, may handle a wider variety of feed materials because most charges are handled in batches. This allows the flux component to be adjusted to the specific assay of the material to be reduced. Like the stationary reverberatory furnace, it has an external fuel source so that after the reduction reaction has been carried out, it may retain the melt for drossing. The primary advantage of this system is the thorough mixing action, which optimizes the reduction recovery and rate. The mixing action also allows optimum reaction time for drossing.

Rotary reverberatory furnaces have a relatively simple design. They are barrel shaped, from 1.8 to 4.5 m in diameter, and 2.5 to 6.8 m long, with gas jets fixed in a stationary plate at one end and an attached charging door at the other end (fig. 5). One of the primary problem areas for rotaries in the United States has been a premature failure of the refractory linings within the furnace barrel.

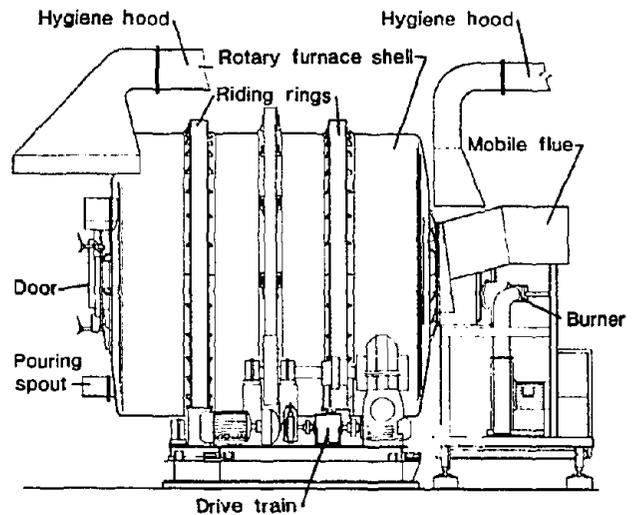


Figure 5.—Cross section of a typical short-rotary reverberatory furnace. (Courtesy Tolltrek International Ltd.)

These problems have been gradually remedied over the past few years, and now rotaries are being received more favorably in the United States. The rotary design is a compromise between the operating flexibility of the blast furnace for smelting and the refining capability of the stationary reverberatory furnace.

REFINING METHODS

Refining is the final step in the chemical purification process of secondary lead recycling. It is accomplished in open-topped containers, called refining kettles, that are usually semispherical in shape and are constructed of cast iron or steel. Kettles range in depth from 1 to 2.2 m, with capacities of 25 st or more. All are heated from below, with the kettle seated in a specially constructed, refractory-lined, steel-sheathed furnace (fig. 6). Melt agitation is accomplished by mechanical impellers or by specially designed air jets, which impart a stirring motion.

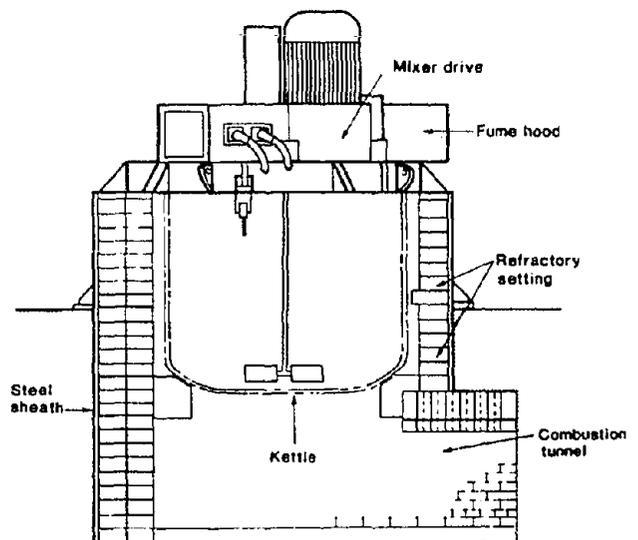


Figure 6.—Cross section of a typical refining kettle. (Courtesy Tolltrek International Ltd.)

The refining process upgrades lead bullion to soft lead (pure lead) or alloys. It is in this stage that reaction rates, and selective reactivity, become critical. If a particular reagent is added at the wrong time, a potentially toxic substance may be formed or a beneficial metal may be prematurely removed. In some cases, a potentially valuable byproduct may even be lost in the process and require additional processing to recover it. Table 3 is a summarized listing of the alloy metals that may need removal and some of the reagents commonly used for that purpose.

TABLE 3.—Lead refining: Elements removed and reagents used

Element removed	Principle used	Temp, ¹ °C	Basic reagent	Other alloying elements affected
Ag	Intermetallic	675	Zn	None.
As	do	675	Al	Sb, Cu.
	do	675	Zn	None.
	Oxidation	620	Air	Sb, Sn.
	do	455	K ₂ CO ₃	Sn.
Bi	Intermetallic	675	Ca, Mg	None.
Cu	do	675	Al	As, Sb.
	Limited solubility.	400	Pitch or sawdust.	Ni, Fe, Zn.
	Chemical	330	S	Sn.
	do	330	NaOH with S	² Sn.
Fe	Intermetallic	675	Al	None.
	Chemical	400	S	Cu, Sb, Ni.
	Limited solubility.	400	Pitch or sawdust.	Cu, Ni, Zn.
Ni	do	400	Pitch or sawdust.	Cu, Fe, Zn.
	Chemical	330	S	Cu, Sn.
Sb	Intermetallic	675	Al	As, Cu.
	Oxidation	620	Pb ₂ O ₄	Sn.
	do	620	Air	Sn, As.
	do	565	NaOH, NaNO ₃	Sn.
	do	425	NaOH, NaNO ₃	Sn.
Sn	do	620	Pb ₂ O ₄	None.
	do	620	Air	Sb, As.
	do	480	NaOH, NaNO ₃	As, Sb.
	do	425	NaOH, NaNO ₃	None.
Zn	Limited solubility.	600	Vacuum distillation.	None.
	do	400	NH ₄ Cl with NaOH	None.
	do	400	Pitch or sawdust.	Cu, Ni, Fe.
Fine solids	do	400	Steam	Finely divided
	do	400	Natural Gas	metallic solids.

¹ All temperatures are at or near upper range for the particular reactions listed.

² Sn interferes with the chemical reaction promoted by the NaOH, therefore, this reaction cannot be used when Sn is present in the melt. Source: Modified from Hudson (70).

Antimonial lead is the most common product of secondary lead operations, primarily because most production is derived from, and recycled into, lead-acid batteries. The initial step in the refining process is to decopperize the melt. If the sulfur method is to be used, the lead temperature is dropped from the smelting temperature to around 320° to 330° C and then elemental sulfur is mixed into the kettle. For the dry drossing method, the temperature is held at 400° C and pitch or sawdust is used instead of sulfur. These processes produce a copper sulfide dross, which can then be returned to the smelting furnace for lead recovery.

The softening process normally used to remove arsenic and tin is the bubbled air method. With the melt

at a temperature of 620° C, air is bubbled through the molten lead, and the dry dross is skimmed off. Some operations will use sodium hydroxide to form sodium stannates and arsenates in a dross. If a fully softened lead is needed (lead which contains no antimony, arsenic, or tin) then sodium nitrate (niter) can be used in conjunction with air. The niter speeds up the oxidation rate and acts as a catalyst so that all three impurities are removed at the same time. For those operations where the feed stock contains no arsenic, aluminum may be used to remove copper, antimony, and nickel. This procedure will remove copper and nickel to acceptable levels.

If the melt has appreciable zinc values that must be removed, then the sulfur method will be used to remove the copper. The pitch-sawdust method removes copper and zinc at the same time and produces a combined copper-zinc dross that is not as readily marketable as either copper or zinc drosses. Zinc is considered to be a very detrimental alloying agent in lead products. For those operations that treat scrap with appreciably large zinc assays, a vacuum distilled zinc process is generally used. This is accomplished by heating the melt to 600° C in a kettle with a specially fitted vacuum hood, which maintains a very low vacuum pressure to boil off the zinc. The hood has its own cooling system, which causes the zinc to condense and crystallize on the inside of the hood. This method requires no further processing to produce a marketable zinc byproduct.

When producing calcium alloys, the calcium is added to a mixed kettle of softened lead. Calcium is added in its metallic form or as a reactive carbide. Because of the susceptibility of the calcium to oxidation during this process, it is normal to have a layer of nonreactive material on the surface of the melt.

Lead oxide is made from softened lead or primary lead, commonly by the Barton process. Lead is melted in a melting pot, continuously fed into a Barton pot (reactor), and atomized. The atomization process involves rotating mixer blades just at the molten lead surface, which produces particles of Pb of 5 μm or less. As the lead is oxidized to PbO, it is entrained in the air stream and conveyed to the air pollution control system. Approximately 60 pct of the product is recovered in the settling chamber and 15 to 20 pct in the cyclone. The remaining product is collected in the baghouse. The product is then augered to storage bins or to a hammer mill. The hammer mill is primarily used to insure a uniform product and to meet specifications.

After refining and alloying, the metal is pumped to casting machines. The final cast form can range in weight from special-order 20-lb bars to 2,000-lb blocks. Forms may be rounds, bars, ingots, pigs, hogs, billets, or any of a number of different speciality shapes. Standard practice is to cast 65-lb ingots or 2000-lb hogs. The ingot casting chain is water cooled and usually requires personnel for skimming off the oxidized layer. For small custom operations, ingot casting may be done by hand with long-handled lead dippers used to pour the lead into single, twin, or five-cavity molds.

WASTE DISPOSAL

Because of the hazardous nature of the materials being handled at secondary lead operations, special

precautions are necessary to prevent air, water, and land contamination. Waste disposal is therefore an important

aspect of secondary lead recycling. The primary waste products are sulfuric acid, dust, organics, slags, and drosses. These wastes are either neutralized, recycled, or transported to hazardous waste-dump sites.

SULFURIC ACID

Acid neutralization is the most involved and costly aspect of waste disposal. Presently, there are three chemical processes being employed within the industry: lime neutralization, soda ash neutralization, and anhydrous ammonia neutralization. The Environmental Protection Agency (EPA) has determined that the lime neutralization method is the best available technology (BAT), and compliance with this standard is scheduled for March 1987. Lime neutralization involves mixing lime with acid, resulting in the formation of gypsum and water. The gypsum is placed in settling bins or is filtered to reduce the moisture content. It is then transported to hazardous waste dumps because it generally exceeds the EPA limit of 5.0 ppm lead or the variable state limits. This method of acid neutralization produces large quantities of gypsum. An average recycled battery produces about 0.6 kg of dry-weight gypsum. Disposal, therefore, becomes a very expensive operating cost item.

Neutralization with soda ash is a more expensive neutralization and monitoring process, but there are no waste product transportation costs. This process mixes the soda ash with the acid to form a weak sodium sulfate solution. Filtration and pH adjustment are required to keep lead levels at a minimum, and then the solution is pumped into the sewer system. The solution is generally alkaline (pH 7-10), which actually helps the water treatment plants because they can have serious problems with acidic solutions. This neutralization process is not as effective as the lime neutralization process for removing lead and also produces a large amount of dissolved solids in the waste stream.

The ammonia neutralization process produces ammonium sulfate, which is water soluble, nontoxic, and biodegradable. If the waste stream is low in metals (lead, arsenic, antimony, selenium, and cadmium), then ammo-

nium sulfate crystals can be produced for use as a fertilizer. The process also allows for pumping the solution into the sewer system, but most sanitation departments do not permit it because of the high biological oxygen demand (BOD) and the large amount of dissolved solids. This neutralization process is not considered to be BAT because the Clean Water Act (CWA) classifies ammonia compounds as "nonconventional pollutants." The regulation requires that 90 pct of nonconventional pollutants be removed from waste water discharges. Because of the regulation, this acid neutralization process is no longer considered to be a viable alternative.

DUST, ORGANICS, SLAGS, AND DROSSES

Dust, organics, slags, and drosses are additional waste products from lead processing. Several smelting and refining stages produce significant quantities of offgases, which contain lead particulates. To meet emission standards, it is common practice to use baghouses to filter the lead particulates from the offgas. Baghouse dusts are recycled as furnace feed until other elemental accumulations, primarily cadmium and chlorine, reach assay levels requiring other methods of processing. When this occurs, the dust is usually sold to smelters that can process the material.

Disposal of the organics (rubber, PVC, and battery-casing plastic) is handled in several ways. Some operations burn the rubber, plastic, and PVC in the smelting furnace and realize some energy savings. The most common method is to dispose of the rubber and PVC in hazardous waste dumps, and sell the plastic to battery-casing manufacturers.

Almost all slag is disposed of in hazardous waste dumps because it cannot meet structural integrity tests, or the leachable lead content is too high. Slags are usually hauled by contractors to State-approved disposal sites.

Drosses are reprocessed onsite to reduce the lead content until the impurity metals reach a level that cannot be handled by the smelter. The drosses are then sold to other smelters that can process the material. Copper drosses and arsenic-tin drosses are the most common drosses produced.

OPERATING COSTS

To evaluate smelters on a common basis, all dollar values were adjusted to average 1985 dollars, and only those costs associated with producing refined metal were considered. For example, a fully integrated smelter complex with an end product of packaged batteries would be evaluated only from battery breaking through refining. All additional costs for labor, utilities, materials, supplies, maintenance, and overhead associated with battery production are excluded. Cost items such as property taxes, insurance, and some general office charges are proportionally allocated.

The operating costs have been separated into conversion costs, lead supply costs, and miscellaneous costs for clarity and comparison. Conversion costs represent the cost of converting scrap lead into refined lead and lead alloys. Included in these costs are materials and utilities, maintenance, general services, labor, administration, environmental, property taxes, and insurance. Lead

supply costs represent the cost of purchasing delivered scrap lead. Miscellaneous costs represent cost items that affect individual operating economics, such as credits, transportation, and depreciation.

VARIATIONS IN OPERATING COSTS DUE TO SIZE

Table 4 presents the operating cost breakdowns for smelters grouped into size ranges. Grouping by size serves the purpose of disguising individual company-proprietary data and shows relative economies of scale for the size ranges. The table shows an economy of scale for the medium size range smelters over the smaller smelters, but a diseconomy between medium and large smelters. This diseconomy is primarily a result of under utilization of capacity for the large smelters. If the large smelters were

TABLE 4.—Average operating cost estimates for smelter size ranges, average 1985 dollars

Capacity	mt/yr. ¹	15,000-15,000 ²	15,000-40,000 ³	40,000-85,000
ANNUAL COSTS				
Materials and utilities:				
Electricity	124,570	215,540	587,800	
Natural gas	140,310	326,530	955,360	
Fuel	11,620	18,820	67,500	
Coke	165,470	450,510	456,880	
Scrap iron	30,130	130,860	190,300	
Limestone	9,060	7,210	8,040	
Arsenic	23,500	27,200	81,320	
Antimony	83,130	123,600	468,840	
Tin	81,330	44,980	-100,090	
Calcium	0	8,790	0	
Selenium	1,130	0	10,800	
Oxygen	28,200	128,910	76,830	
Zinc-aluminum	0	5,480	0	
Hydrated lime	400	11,580	69,560	
Caustic soda	28,570	20,200	31,800	
Caustic potash	500	4,470	2,660	
Soda ash	12,410	2,500	397,630	
Miscellaneous materials	64,690	177,180	342,060	
Subtotal	805,020	1,704,360	3,847,470	
Maintenance materials:				
Repair parts, mechanical	109,960	139,970	542,160	
Repair parts, consumable	75,140	185,650	285,300	
Purchased and rental service	42,340	184,560	176,580	
Subtotal	227,440	510,180	1,004,040	
Labor:				
Production labor	329,160	687,830	1,197,290	
Supervision	80,170	190,350	285,740	
Maintenance labor	55,300	118,680	347,160	
Supervision	65,730	45,840	78,070	
Administrative	91,430	338,990	638,280	
Payroll overhead	176,130	522,800	811,360	
Subtotal	787,920	1,904,490	3,357,900	
Indirect costs:				
General office	70,510	313,320	299,210	
Environmental (partial)	108,280	553,360	1,158,900	
Property taxes	4,350	86,140	146,590	
Insurance	43,470	74,570	41,540	
Subtotal	226,610	1,027,390	1,646,240	
Scrap lead supply:				
Batteries	552,130	2,395,030	5,077,820	
Primary lead	184,960	0	616,560	
Scrap and dross	195,270	213,770	445,980	
Subtotal	932,360	2,608,800	6,140,470	
Miscellaneous:				
Recycled plastic credit	-107,120	-263,300	-616,790	
Transportation	320,190	378,320	983,040	
Depreciation ⁴	-5,850	-192,620	-520,310	
Subtotal	207,220	-77,600	-154,060	
Net operating cost ⁵	3,196,570	7,677,620	15,842,060	
COST PER POUND REFINED LEAD				
Materials and utilities	0.049	0.037	0.043	
Maintenance materials .....	.014	.011	.011	
Labor .....	.049	.042	.037	
Indirect costs .....	.014	.022	.018	
Scrap lead supply .....	.057	.057	.068	
Miscellaneous .....	.013	-.002	-.002	
Total .....	.196	.168	.176	

¹ Average 1985 production is 7,384 mt refined lead.

² Average 1985 production is 20,751 mt refined lead.

³ Average 1985 production is 40,869 mt refined lead.

⁴ Depreciation is a percentage of 1985 identified capital expenditures and estimates of past capital expenditures based on the ACRS.

⁵ Data may not add to total shown because of independent rounding.

operating near capacity, then the economy of scale would be consistent through the size ranges.

In 1985, the larger smelters' average production was approximately 64 pct of capacity, whereas the medium size smelters were utilizing 91 pct of capacity. Economy of scale is consistent for production and maintenance labor throughout the size ranges because the labor force can be scheduled according to production requirements. Regulatory compliance costs indicate a reverse economy of scale for the smaller smelters for several reasons: they are

generally compact and require less capital for enclosure and retrofit, they are more capable of varying furnace operations for particulates emissions compliance, and they have been generally less regulated than the larger smelter complexes.

The amount of depreciation varies from smelter to smelter. In general, most of the small smelters and many of the medium size smelters were built in the 1940's and 1950's and are essentially depreciated, although many have rebuilt or replaced furnaces. Depreciable costs for these smelters are primarily attributable to capital expenditures for environmental compliance. Several of the medium and larger smelters are newer and, therefore, have a larger depreciation value for capital costs, but a smaller amount of depreciable environmental compliance costs. This is primarily because of better control technology incorporated within these newer smelters.

In an attempt to account for after-tax economics, individual smelters were evaluated for recent capital expenditures for regulatory compliance and original capital cost recapture. Capital costs for regulatory compliance were depreciated based on the Accelerated Cost Recovery System (ACRS). This schedule, based on 1985 tax laws, is anticipated to be the most advantageous tax schedule, which may come close to actual company accounting practices. As a common basis of depreciation, the second year rate of 22 pct was used for identified capital expenditures. Smelter capital costs are depreciated over a 30-yr period or 3.33 pct per year. These depreciable items are included in the operating costs for comparison purposes.

There are several cost items that are relatively inflexible to scale. The most significant conversion cost items are electricity, natural gas, coke, and antimony. These supplies are basic to the conversion of scrap lead into refined lead and lead alloys. Battery supply is a significant cost item and is probably the single most important item for determining refined lead profitability. In general, smelting practices have probably reached optimum efficiency, thereby reducing conversion costs to a minimum; therefore, the margin between conversion costs plus lead supply costs and the sale price of refined lead determines profitability.

In 1985, the "ask" price for soft lead was 19.0 to 19.5 $\text{¢}/\text{lb}$. The "bid" price was probably closer to 18.5 $\text{¢}/\text{lb}$. The 1985 average contract price for soft lead was approximately 19.2 $\text{¢}/\text{lb}$ (8). If the secondaries all produced soft lead as their only product, then the net profitabilities would be very low, and some smelters would have a negative cash flow. However, this is not the case because the secondary lead smelters products incorporate a "value-added," which commands a higher price. Value-added represents the additional value to a product for further refinement, metal alloying, or casting. The smelter operating costs presented in table 4 exclude the processing costs for value-added, and do not reflect the actual sale price or value of the products. The value of products sold has not been included because of the variability of products produced from each smelter, the degree of integration for each, and individual company contract prices.

For example, the smaller smelters generally produce products according to customer orders or internal demands. Customer orders may vary from special alloys to sailing vessel keels. The value-added is incorporated in the form of additional refining and metal content to fabrication of keels. Therefore, the sale of these products will include a profit margin for additional metal content or

fabrication. The bottom line would show a profit on production, but not per pound of refined lead. Degree of integration has essentially the same effect. A plant that converts scrap lead into marketable batteries has passed the profit along to the final product. The profit is, therefore, in terms of profit per battery and not profit or loss per pound of lead produced.

FACTORS AFFECTING OPERATING COSTS

Within the secondary lead industry, each smelter has some relative operating advantages and disadvantages. Size and age of the smelter are important factors because economies of scale do exist and some fully depreciated smelters are more economical, on an after tax basis, than partially depreciated smelters. Degree of integration and product diversity also have distinct advantages. Most of the smaller smelters cater to orders for small lots of various products and are able to include an added value to these products. The smaller smelters also show a greater degree of integration, some through battery marketing. This allows for the largest amount of added value to the

product. Smelter location is probably the most important factor affecting direct operating costs. Regional variations in prices for electricity, natural gas, scrap lead, coke, and labor significantly affect operating costs. Proximity to suppliers and consumers affects transportation costs. Truck transportation rates vary from 9.2 ¢/mt-km for local hauls up to 100 km, to 3.1 ¢/mt-km for long hauls. An increasingly significant cost factor is environmental cost. State and local regulations are quite variable. States such as California and Oregon are very strict and compliance is very costly, whereas most southern States are less strict. Local governments can even shut down smelters if actions are contrary to city planning and administration policies. Waste disposal is also becoming a very significant expense and is often a difficult task to perform. For example, smelters are required to test slag to see if it is classified as "hazardous." If tests indicate the material is hazardous, then special hazardous waste dumps must be used. There are very few dumps that can accept hazardous waste and, in some cases, they may be hundreds of kilometers from the smelters. California charges \$29.76/mt of hazardous waste as an additional tax. The total cost for testing, hauling, and dumping these wastes can be as high as \$105/mt.

ENVIRONMENTAL LEGISLATION AND COMPLIANCE COSTS

Over the past two decades, the EPA has been charged by Congress to enforce numerous laws intended to protect the environment, to reduce the amount of pollutants introduced into the environment, and to clean up the environment. All of these laws have impacted the secondary lead industry to varying extent. The Clean Air Act (CAA) and National Ambient Air Quality Standard (NAAQS) have resulted in lower lead emissions released into the atmosphere and lower exposure levels of lead for the industry labor force. The CWA and Solid Waste Disposal Act (SWDA) have insured monitoring of ground water for possible contamination around lead processing facilities and proper handling and disposal of hazardous wastes. The Resource Conservation and Recovery Act (RCRA), SWDA, and Hazardous and Solid Waste Amendments Act have helped to insure public health and decrease environmental degradation by setting disposal and monitoring standards for solid and hazardous wastes. The Comprehensive Environmental Response, Compensation, and Liability Act "Superfund" levies a tax of \$4.56/mt of lead oxide produced to generate funds to clean up polluted waste disposal sites. In addition, several Superfund reauthorization bills introduced in Congress propose a tax on all lead but, at the time of this report, the legislation has not been passed. The NAAQS is also being reviewed for possible reduction to 1.0 or 0.5 µg/m³ of lead in ambient air at fence line. The most important Federal regulations affecting the secondary lead industry are:

1. The EPA's CWA of 1977, as amended. This governs effluent limits based on type of smelter production or consumption of metal and the BAT, and became effective July 1, 1984. For current operations already indirectly discharging through publicly owned water treatment facilities, BAT pretreatment standards must be complied with by March 1987.

2. The Occupational Safety and Health Administration's (OSHA) inplant maximum permissible exposure limit (PEL) standard of 50 µg/m³ of lead in air. Final

compliance plans must have been filed by August 1, 1984, with full implementation of the plans completed by June 29, 1986. An interim standard PEL of 100 µg was allowed during the interval between these two dates. Variable combinations of engineering controls, administrative controls, and worker self-protection were allowed during the interim period and in the final compliance plan, but plans were negotiated on a plant-by-plant basis with OSHA and, where applicable, with the union. This negotiation process, known as Cooperative Assessment Program (CAP), has been made available to all lead processors. The program allows for greater flexibility by mutually agreed plans for compliance.

3. Public Law (PL) 98-616, the Hazardous and Solid Waste Amendments Act, enacted November 8, 1984, amending the SWDA of 1965 and its amendments, the RCRA of 1976, and the SWDA amendments of 1980. This law classifies as hazardous waste all effluents that have lead or lead compound concentrations of 500 ppm or greater with a pH of less than or equal to 2.0.

4. The OSHA's 1979 blood-lead standard. The final phase of that regulation became effective on March 1, 1983, with full implementation of the maximum allowable blood concentration of 50 µg of lead per 100 g of blood. At or above that level, an employee must be immediately removed to a nonexposure job site or furloughed with pay until the blood-lead level has been reduced to no more than 40 µg per 100 g of blood.

5. The CAA of 1963, (PL 88-206), with its amendments of 1970 (PL 91-604) and 1977 (PL 95-294), and the EPA established NAAQS of 1978. This standard is to be fully implemented by January 1, 1988. During the interim, the existing operations can operate under temporary, renewable variances, which are allowing for phased implementation of the statutes. Although interim compliance can be met by periodic curtailment of production, final compliance cannot.

COSTS OF COMPLIANCE

The capital and operating costs for environmental regulatory compliance are extremely variable from smelter to smelter. Variables such as smelter capacity, state regulations, plant technology, type of products, age, and degree of integration all affect the costs. In general, an industry average for present regulatory compliance costs is 2.3 ¢/lb of refined lead (table 5). Included in this cost are four general categories comprising employee health and safety, equipment operation and maintenance, supplementary labor, and hazardous materials handling and disposal. There appears to be a diseconomy of scale for the large smelters, but this is not the case. These costs are based on actual production at the time of the study. If the costs were based on rated smelter capacity, then the economy of scale would be consistent.

TABLE 5.—Current regulatory compliance operating costs, average 1985 dollars

Smelter capacity, mt/yr	Operating costs, ¢/lb refined lead
5,000 to 15,000	2.3
15,000 to 40,000	2.2
40,000 to 85,000	2.4

Employee health and safety includes costs for clothes, shoes, respirators, safety glasses, hard hats, shower time, laundry, blood-lead monitoring, administration, and medical removal for high blood-lead levels. Equipment operation and maintenance includes costs associated with running and maintaining equipment installed specifically to meet environmental regulations. Equipment items include baghouses, negative pressure atmosphere systems, floor scrubber machines, supplementary workstation ventilation, flue mufflers, scrubbers, and miscellaneous equipment. Supplementary labor costs consist of people required to operate and maintain pollution control equipment as well as administrative requirements. Hazardous materials handling and disposal costs include acid neutralization, precipitation and transportation, water treatment, slag analysis and transportation, permits, and other disposal costs. Also included in this category are well and air monitoring and water effluent monitoring.

Additional capital and operating costs for compliance with pending and proposed regulations are presented in table 6. The operating cost items represent only the costs associated with operations and maintenance. They do not include costs for interest on borrowed capital, depreciation, taxes, and insurance. The actual costs to the companies would, in all likelihood, be higher than the presented values. The costs are based on actual costs for installed systems or for smelters that have already engineered systems and have obtained cost estimates from contractors for installing the systems. The costs, therefore, represent actual site-specific industry costs for the various systems. Scaling these costs to a specific size smelter complex is not recommended because of the variability in size, design, and technology employed at each site. All of these costs do not necessarily apply to each smelter, because each smelter is in various stages of environmental compliance.

The Bureau's estimate for the average pending regulatory compliance operating cost is 3.5 ¢/lb of refined lead. This estimate is based on the present NAAQS standard of 1.5 µg/m³ ambient lead plus an estimated average for additional standards. If the standard is

TABLE 6.—Pending and proposed regulatory compliance cost estimates for secondary lead smelters¹

Regulation	Cost items or standards	Operating cost, ¢/lb refined lead	Capital cost, 10 ⁵ city, 2 10 ³ mt/yr	Smelter capacity, 10 ³ mt/yr
CERCLA ⁽³⁾	Liability insurance		NAP	NAP
	Estimated proposed tax on lead	50.21	NAP	NAP
CWA	80 ppm Pb in water	0.19-0.75	\$175-760	13-41
MRP ⁽⁶⁾	Removal from lead exposure at 50 µg per 100 g blood and return at 40 µg per 100 g blood		NAP	NAP
	(PEL): 50 µg/m ³	0.64	1,085	18
NAAQS	Current: 1.5 µg/m ³ Pb	1.20	\$5,750	36
	Proposed: 1.0 µg/m ³ Pb	0.72	1,500	12.5
	Proposed: 0.5 µg/m ³ Pb	1.13	3,050	12.5
	Annual mean of 80 µg/m ³ SO ₂ and 24-h mean of 365 µg/m ³	0.21	500-1,000	22.5-66
RCRA	Hazardous waste handling, transportation, and disposal	¹⁰ 0.34-1.6 ¹¹	113-1,000	4.5-87

NAP Not applicable.
¹ All costs are not necessarily applicable to every smelter because each may already be in compliance with one or several of the regulations.
² Used as basis for estimating costs.
³ Comprehensive Environmental Response, Compensation, and Liability Act (Superfund).
⁴ Undetermined cost. Industry sources indicate that this type of insurance is not available and if it were made available, they could not afford the insurance premiums.
⁵ Based on current tax rate for lead oxide.
⁶ Medical Removal Program.
⁷ Not determined because of too many variables, such as individual's ability to metabolize lead. Can be a significant cost item at some smelters.
⁸ MRP and PEL are regulations promulgated by OSHA.
⁹ Cost based on information developed from TRC report (17). Proposed standards are cumulative to the current standard.
¹⁰ Costs based on smelter capacities from 6,500 mt/yr to 87,000 mt/yr.
¹¹ Costs are extremely variable because of different requirements under the State Implementation Plans (SIP). Costs based on smelter capacities from 4,500 to 60,000 mt/yr.

amended to 1.0 µg/m³ ambient lead, then the average industry compliance cost is estimated to be an additional 0.5 ¢/lb of refined lead. If the NAAQS standard is amended to 0.5 µg/m³ ambient lead, then the average industry compliance cost is estimated to be an additional 1.3 ¢/lb of refined lead. These cost estimates are considered to have an accuracy of ±25 pct (fig. 7).

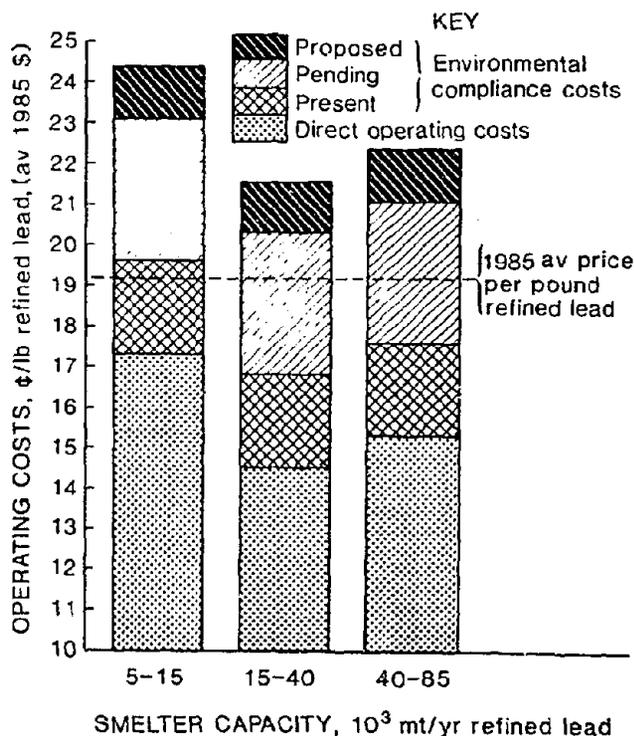


Figure 7.—Operating cost estimates for present, pending, and proposed environmental regulatory compliance.

The capital costs necessary to comply with these environmental regulations are presented in figure 8. The costs are grouped by smelter size and include estimates at the proposed NAAQS levels of $1.0 \mu\text{g}/\text{m}^3$ and $0.5 \mu\text{g}/\text{m}^3$, because meeting this standard is the most significant cost item. Although the costs account for all of the environmental regulations, the total cost is not necessarily applicable to every smelter because of individual degree of environmental compliance. The capital cost estimates are considered to have a ± 25 pct accuracy.

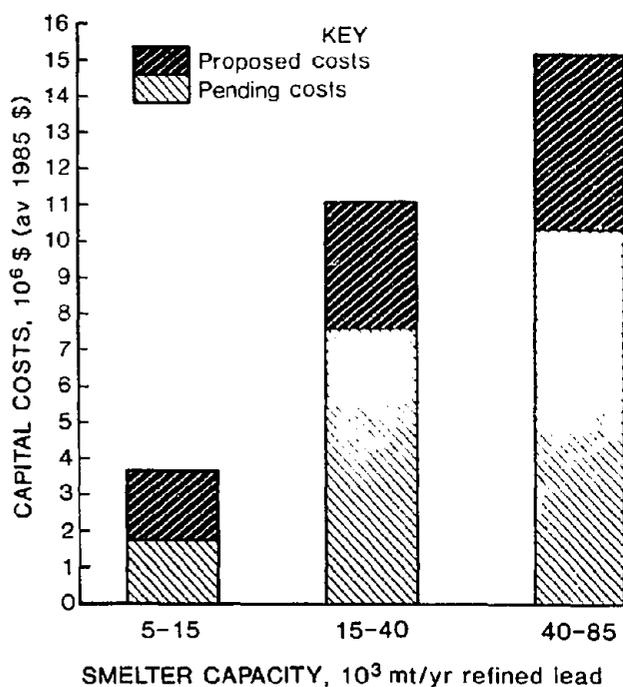


Figure 8.—Capital cost estimates for pending and proposed environmental regulatory compliance.

COMPLIANCE CAPABILITY

The ability of the secondary lead industry to comply with the environmental regulations and remain profitable is questionable. On a direct cost per pound of lead basis, the industry would be losing money. The vertically

integrated smelters, especially those that make high value-added specialty products, may be able to absorb the additional compliance costs, but profit margins will be severely reduced.

In addition, if current economic conditions continue and proposed environmental regulations become effective, many smelters will be forced to shut down. This will occur because some companies cannot afford the capital costs for compliance and also because many smelters' "book values" would be less than the capital expenditures. Companies would therefore consider alternative investments rather than risk capital expenditures into a business that offered a poor rate of return. Loss of production capacity is speculative, but could be as high as 350,000 mt/yr. This represents approximately 40 pct of the current industry production capacity. In general, the ability of the industry to survive is a function of size, degree of integration, efficiency, and ability to market products with value-added.

The cost of regulatory compliance and the resultant effects on the industry could create this particular long-term chain of events: The smelter closures will lower demand for battery scrap, which will create an oversupply of scrap. With low demand and large supply, the price for scrap will decrease. This will dampen the incentive to recycle because of reduced profit margins. In some areas of the country, the price for scrap is already approaching the break-even cost for recycling. Continued downward price pressure will begin breaking down the recycling industry, especially the independents, which account for approximately 50 pct of the industry. The net effect is a loss of battery scrap supply because of a lack of recycling. The effect of a breakdown of the recycling industry will probably result in a serious environmental problem (12). Batteries will probably be dumped in inadequate land fills, along back roads, and in ditches. Because of the hazardous nature of batteries, the effect on the environment would be the introduction of lead and sulfuric acid into the soil and possibly the water table, and the introduction of rubber and plastic into the soil.

The primary lead industry should also be considered, assuming that the environmental regulations apply equally to the primaries. The primaries will be faced with significantly higher compliance costs (13), which may result in loss of production capacity through plant closures. If this occurs, production from the secondary lead industry may increase although fewer secondary smelters will be operating.

CONCLUSIONS

The continued depressed price of lead and the additional costs for environmental regulatory compliance have severely impacted the secondary lead industry. Since 1980, plant closures have accounted for approximately 200,000 mt of lost production capacity and 200,000 mt of temporary shutdown capacity. Current potential domestic capacity is 900,000 mt/yr of refined lead. More plant closures can be expected if stricter environmental regulations become effective. Resultant loss of capacity could be as high as 350,000 mt/yr or 40 pct of remaining domestic production capacity.

Based on 1985 operating parameters and average 1985 dollars, the average operating costs varied from 16.8 to 19.6 $\text{¢}/\text{lb}$ of refined lead. The 1985 average sale price per

pound of refined lead was approximately 19.2 $\text{¢}/\text{lb}$. Industry profitability for 1985 was very low and for many companies, it was close to break-even. Profit was mostly achieved by vertically integrated companies capable of producing value-added products.

Present regulatory compliance costs, as an industry average, are 2.3 $\text{¢}/\text{lb}$ of refined lead. Pending environmental regulations could cost the industry an additional 3.5 $\text{¢}/\text{lb}$ of refined lead. It is estimated that proposed environmental regulations, assuming the NAAQS of $0.5 \mu\text{g}/\text{m}^3$, would cost an additional 1.3 $\text{¢}/\text{lb}$ of refined lead. This cost is in addition to the cost for pending regulatory compliance. These costs do not include discounted cash flow rate of return (DCFROR) analysis.

Capital costs necessary to comply with environmental regulations are estimated to be approximately \$1.8 million for smelters with capacities between 5,000 and 15,000 mt/yr, \$7.6 million for smelters between 15,000 and 40,000 mt/yr, and \$10.4 million for smelters between 40,000 and 85,000 mt/yr. Proposed regulations could add an additional \$1.9 million for smelters with capacities between 5,000 to 15,000 mt/yr, \$3.6 million for smelters between 15,000 to 40,000 mt/yr, and \$4.9 million for smelters between 40,000 and 85,000 mt/yr.

These cost estimates indicate that pending and proposed environmental legislation could add significant-

ly to capital and operating costs of the secondary lead industry, thereby reducing its capacity to recycle lead as marginal plants shut down. Ramifications could impact the recycling industry. The net result could be less scrap lead recycling, which could result in hazardous wastes, primarily batteries, being introduced into the environment. If this legislation significantly affects the primary lead industry, the result may be a loss of both primary and secondary production capacity, however, the remaining smelters' actual production would increase.

REFERENCES

1. Charles River Associates Inc. (Cambridge, MA). Economic Impact of the Proposed EPA National Ambient Air Quality Standard for Lead: Background Support Document. Mar. 1978, 127 pp.
2. _____ Economic and Environmental Analysis of the Current OSHA Lead Standard. CRA Project 536.60, 1982, 153 pp.
3. CRU Consultants, Inc. (New York). The Costs of Producing Primary and Secondary Lead. Implications for Prices, Competitiveness, Environmental Standards, and New Technology. Commodities Res. Unit LTD, New York, 1984, 340 pp.
4. Putnam, Hayes and Bartlett, Inc. The Impacts of Lead Industry Economics on Battery Recycling. Prepared for Office of Policy Analysis, EPA. June 13, 1986, 32 pp.
5. Woodbury, W. D. Lead. Ch. in BuMines Minerals Yearbook 1984, v. 1, pp. 563-594.
6. U.S. Bureau of Mines. Minerals Yearbooks 1970, 1975, 1980-1985. Chapter on Lead.
7. American Metal Market. Export Mart Still Strong. V. 94, No. 49, Mar. 12, 1986, p. 13A.
8. Zelms, J. L. Lead: Hope For Modest Recovery. Eng. and Min. J., v. 187, No. 3, 1986, pp. 32-34.
9. Murph, D. B., and J. L. Pinkston. Current Blast Furnace Practice at Murph Metals' Southern Lead Company Smelter. Metall. Soc. AIME paper A70-41, 1970, 13 pp.
10. Hudson, E. K. (Lake Eng. and Dev., Inc., Atlanta, GA). Personal correspondence, 1986; available upon request from M. R. Daley, BuMines, Denver, CO.
11. Hoffnagle, G. F., and W. A. Klinger. Exposure to Airborne Lead From Stationary Sources: An Evaluation of Proposed National Ambient Air Quality Standards for Lead. (Lead Ind. Assoc., project 3220-J51, TRC Environ. Consultants, Inc., East Hartford, CT), Mar. 1986, 48 pp.
12. Palmer, J. G., and M. L. Sappington. An Impending Crisis? What Would be the Impact on the Nation's Environment if 70 Million Spent Lead Acid Batteries Each Year Were Not Recycled? April 1986, 24 pp.; available from J. G. Palmer, GNB Incorporated, St. Paul, MN, or M. L. Sappington, Lake Engineering and Development, Inc., Atlanta, GA.
13. Smith, R. D., O. A. Kiehn, D. R. Wilburn, and R. C. Bowyer. Lead Reduction in Ambient Air: Technical Feasibility and Cost Analysis at Domestic Primary Lead Smelters and Refineries. BuMines OFR 67-86, 1986, 52 pp.; NTIS PB 86-216447.

BIBLIOGRAPHY

- Anderson, C. W., P. Behum, and F. Miller. Environmental and Occupational Health Regulations in the U.S. Lead Industry. BuMines OFR 3-86, 1986, 76 pp.; NTIS PB 86-155686.
- Everest Consulting Associates, Inc. (Princeton Jct., NJ), and CRU Consultants, Inc. (New York). The International Competitiveness of the U.S. Non-Ferrous Smelting Industry and the Clean Air Act. Ch. 4, 6, Apr. 1982.
- Gill, C. B. Nonferrous Extractive Metallurgy. Wiley, 1980, 346 pp.
- Kilgore, C. C., S. J. Arbelvide, and A. A. Soja. Lead and Zinc Availability—Domestic. A Minerals Availability Program Appraisal. BuMines IC 8962, 1983, 30 pp.
- Kohn, A. F., Jr. The Recovery of Soft and Antimonial Lead From Secondary Sources. Pres. at 1963 AIME Annu. Meet., Dallas, TX, Feb. 24-28, 1963, Metall. Soc. AIME preprint #47-M, 1963, 12 pp.
- Peterson, G. R., K. E. Porter and A. A. Soja. Primary Lead and Zinc Availability—Market Economy Countries. A Minerals Availability Program Appraisal. BuMines IC 9026, 1985, 44 pp.
- Raymond Kaiser Engineers. Capital and Operating Cost Estimating System Handbook for Lead Smelting and Refining Facilities (contract JO245003). BuMines OFR 81-86, 1986, 282 pp.; NTIS PB 86-246592.
- Sealey, C.J. Secondary Lead Smelter and Refinery. Tolltrek Limited, Droitwich, Worcestershire, England, Feb. 10, 1981, 15 pp.
- Tolltrek International Limited (Englewood, CO). General information brochures, 1985, 70 pp.

APPENDIX A.—EXAMPLE OF CAPITAL AND OPERATING COST ESTIMATES FOR ENVIRONMENTAL REGULATORY COMPLIANCE

An example of costing methodology has been included for a fictitious smelter with a 40,000 mt/yr refined lead capacity. It is assumed that this smelter approximates the industry's average level of compliance (fig. A-1). Therefore, the costs presented for each regulation reflect the additional costs necessary for compliance. Costs associ-

- 9. Smelter is partially enclosed _____
- 10. Existing process emissions control includes one baghouse: 120,000 ft³/min capacity _____
- 11. Small oxide plant _____

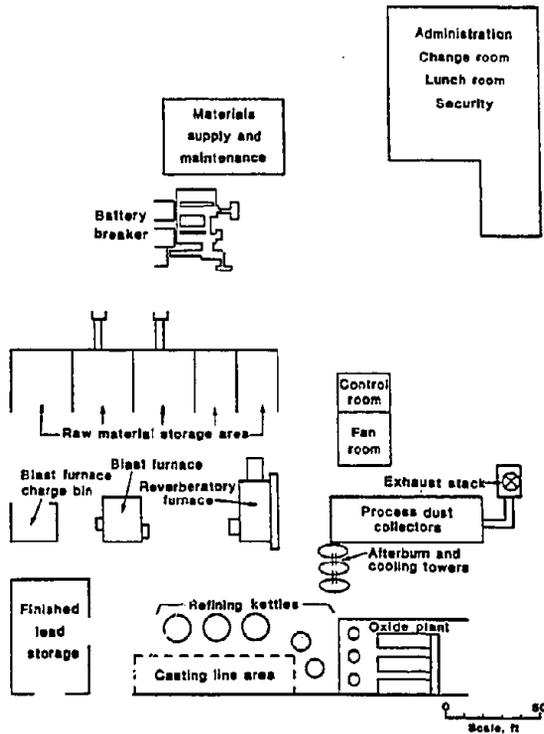


Figure A-1.—Original smelter facilities.

ated with these regulations should be interpreted with caution and with a complete understanding of the level of compliance for the example smelter. The components comprising the costs for each regulation are presented in this appendix. Contingencies for each regulation vary according to degree of confidence. These costs do not necessarily equal or approximate the costs presented in table 6 of the main text. The costs for each smelter are extremely variable because of smelter layout, existing technology incorporated at the smelter, and degree of environmental compliance. Smelter statistics are presented below in order to better understand cost estimates for this example:

- 1. Production capacity: 40,000 mt/yr refined lead
- 2. Primary feed material: 85 pct batteries
- 3. Operating parameters: 3 spd, 290 d/yr
- 4. Average hourly wage: \$9.30/h
- 5. Payroll overhead: 35 pct
- 6. Limestone: \$30/mt delivered
- 7. Electricity: \$0.05/kW·h
- 8. Current acid neutralization process is not BAT

CWA

The costs associated with the CWA are based on the use of lime and settle technology. This technology incorporates acid neutralization, heavy metal precipitation and sedimentation, and multiple stage pH control. All battery acid, process water, and water introduced onto the property requires treatment by lime and settle technology. For this example, it was assumed that lime and settle technology was not being used. The capital costs therefore include an acid neutralization and water treatment plant with a 3-stage settling pond system (fig. A-2). The cost items are presented in table A-1.

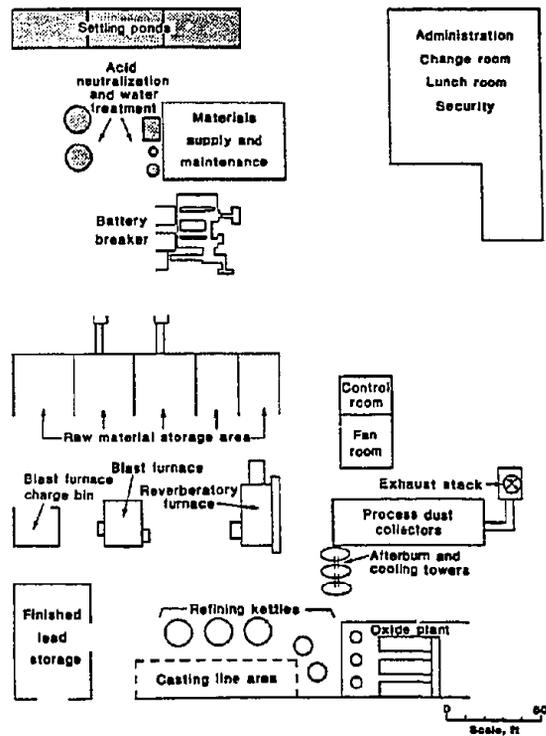


Figure A-2.—Additional smelter facilities for CWA.

The operating costs associated with the CWA include utilities, supplies, labor, payroll overhead, and general office charges. Lime is the primary supply used for neutralization, but coagulants and flocculants may also be added to enhance settling properties. Coagulants and flocculants were not added to this cost model because the parameters requiring these reagents are not identified for this example. Much of the labor associated with operating this treatment plant is not required on a full-time basis. It

TABLE A-1.—CWA capital cost estimate

Cost item	Unit cost plus installation, \$	Number	Total cost, ¹ \$
Acid sump pump	15,000	1	15,000
Acid transfer pump	8,000	1	8,000
Lime storage bin	6,000	1	6,000
Lime hopper & transfer system	110,000	1	110,000
Neutralization tanks	12,000	2	24,000
Clarifier	46,000	1	46,000
Thickener	24,000	1	24,000
pH control tanks	4,500	2	9,000
pH monitor system	14,000	1	14,000
Filter system	135,000	1	135,000
Grounds sump pumps	9,000	3	27,000
Grounds piping and electrical	218.00	890	16,000
Pond recycle sump pumps	11,000	3	33,000
Residue ponds	60,000	2	120,000
Recycle pond	60,000	1	60,000
Subtotal			647,000
Contingency @ 15 pct			97,000
Total installed cost			744,000

¹ Values rounded to the nearest \$100.
² Per foot.

has therefore been partitioned as a percentage of time required by labor category and average wage or salary category. Administration is considered to be one full-time "environmental specialist" to deal with all regulations affecting this smelter. The salary has been equally partitioned to each regulation. General office charges for all regulations are considered to include phones, utilities, office supplies, vehicles, public relations, and miscellaneous expenses. These costs are presented in table A-2.

TABLE A-2.—CWA annual operating cost estimate, dollars

Cost item	Total cost ¹
Utilities and supplies:	
Lime	100,800
Electricity (200 hp @ 5¢/kWh)	13,800
Repair parts	*6,600
Labor:	
General labor (2.5 people @ ² \$15,000)	37,500
Maintenance labor (0.5 person @ ² \$16,000)	9,000
Supervision (0.3 person @ ² \$24,000)	7,200
Laboratory-labor (0.3 person @ ² \$14,000/yr/person)	4,200
Laboratory-skilled (2 people @ ² .3 @ ² \$24,000)	14,400
Administration (0.25 person @ ² \$34,000)	8,500
Payroll overhead (35 pct of all listed personnel)	28,300
General office charges	*2,000
Subtotal	232,300
Contingency (10 pct)	23,200
Total annual cost	255,500

NOTE.—Cost per pound refined lead based on a production rate of 40,000 m/yr refined lead: 0.29 ¢/lb.

¹ Values rounded to the nearest \$100.
² Annual cost per person.
³ Estimated.

PEL

Cost estimates for PEL are based on a 50 µg/m³ standard and include engineering and personal hygiene controls. It is assumed that a combination of these controls will limit workers exposure to the PEL standard. Some controls can also be applied to NAAQS because they serve the same purpose. For this study, the cost items were distributed to the particular regulation for which they were most applicable.

The capital costs associated with PEL include wet-vacuum floor sweepers to control resuspension of lead, a ventilation dust collector with 10,000 ft³/min capacity, six down-cast ventilation stations, and all ductwork for both systems. The example's ductwork requirements, hood locations, and smelter layout are shown in figures A-3 and A-4. A summary of the capital costs are presented in table A-3.

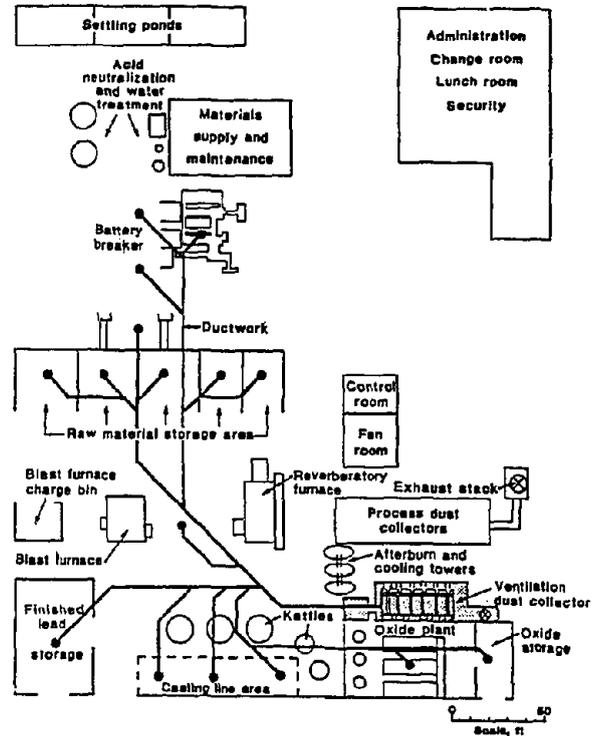


Figure A-3.—Additional process emissions control equipment and ductwork for PEL.

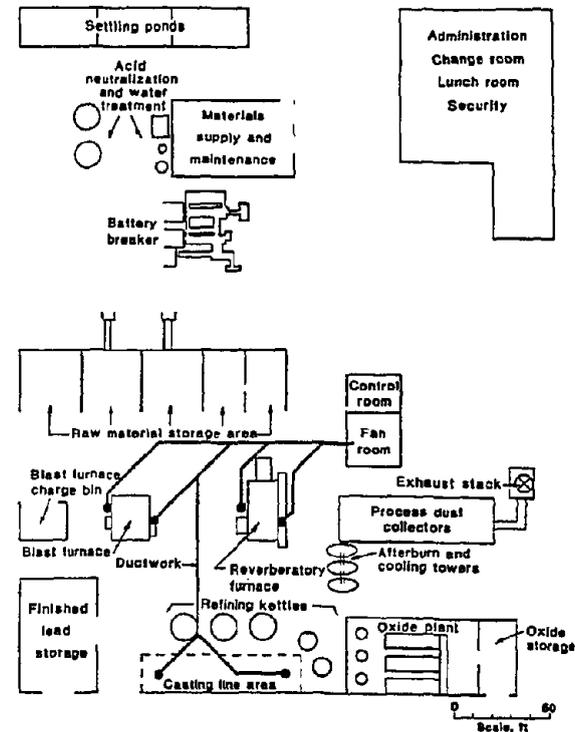


Figure A-4.—Additional downcast ventilation and ductwork for PEL.

TABLE A-3.—OSHA's PEL capital cost estimate¹, dollars

Cost item	Total cost ²
Floor sweepers (2 @ \$27,000 each)	54,000
Ventilation dust collector (450 hp fan; 460 V, 495 A, 100,000 ft ³ /min)	307,000
Ductwork (14 ga, gasket and flange connection, 1,020 lineal ft @ \$300/lineal ft)	306,000
Downcast ventilation (fan, 6 workstations, 480 lineal ft @ \$70/lineal ft)	33,600
Subtotal	700,600
Contingency (15 pct)	105,100
Total capital cost	805,700

¹ Smelter assumed to be in partial compliance with PEL. Therefore, costs do not represent the total cost for compliance.

² Values rounded to the nearest \$100. Total cost includes purchase, freight, and installation where applicable.

The operating costs associated with PEL are presented in table A-4. Safety equipment items include hard hats, respirators, earplugs, gloves, and uniforms. Laundry service includes daily washing of uniforms. The other cost items are described in the table.

TABLE A-4.—OSHA's annual operating cost estimate¹

Cost item	Annual cost per employee, \$	Number of people	Total cost ² , \$
Safety equipment	240	78	18,700
Laundry service	210	78	16,400
Medical examinations	240	92	22,100
Personal hygiene ³	440	78	34,300
Floor sweeping	NAP	41.3	32,800
Maintenance	NAP	52.4	105,000
Utilities ⁴	NAP	NAP	62,000
Baghouse liners ⁵	NAP	NAP	19,300
Administration	45,900	0.25	11,500
General office (estimated)			1,500
Subtotal			323,600
Contingency (10 pct)			32,400
Total cost			\$356,000

NAP Not applicable.

¹ Costs based on a 92-employee labor force.

² Values rounded to the nearest \$100.

³ Costs include overtime pay for shower time @ 7.5 min/d @ an average wage of \$9.30/h @ time and one-half pay.

⁴ Costs include 3 h/shift, 3 spd, 290 d/yr @ \$9.30/h plus payroll overhead @ 35 pct.

⁵ Costs include labor, maintenance supplies, administrative, and indirect costs.

⁶ Cost for electricity based on 178.2 kW-h draw @ 24 h/d, 290 d/yr, and 5¢/kW-h.

⁷ Replacement of baghouse liners is \$38,600. The liners are replaced every other year so one-half of the cost (\$19,300) is charged on an annual basis.

⁸ Cost per pound refined lead based on a production rate of 40,000 mt/yr refined lead: 0.40¢/lb.

NAAQS

In estimating the costs associated with the NAAQS, it is assumed that the smelter can achieve the 1.5 µg/m³ Pb standard, the annual mean of 80 µg/m³ SO₂, and the 24-h mean of 365 µg/m³ SO₂. The proposed process controls are considered BAT, but in reality, it is not known whether these process controls can meet the standards.

The capital costs include smelter enclosure, installation of an additional baghouse, ductwork, air monitoring systems for lead and SO₂, installation of an SO₂ gas scrubber, enclosure and surfacing of the entire yard area including sump stations for water runoff collection, a wheel washing station at the primary materials handling access, and an agglomerating system at the process dust collectors. Figures A-5 to A-7 show the smelter layout with the specific costing items highlighted. The most important items assumed to be already installed for this example smelter are the partial plant enclosure and the

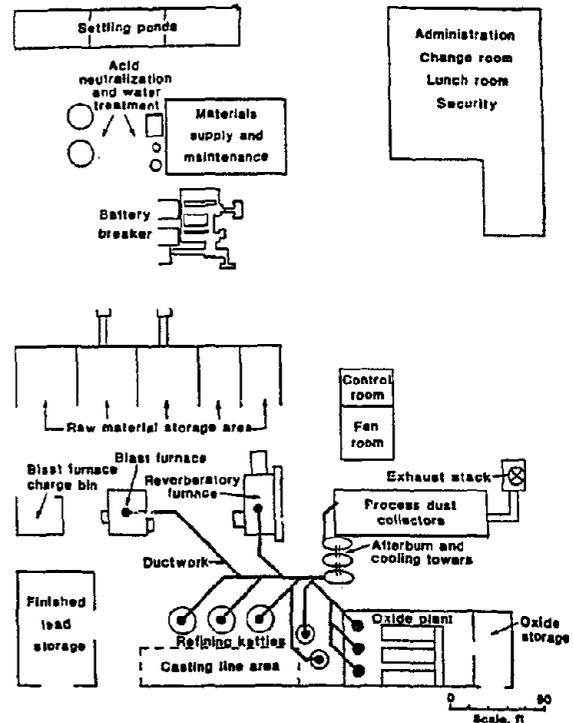


Figure A-5.—Original smelter process emissions control equipment, ductwork, and building enclosure.

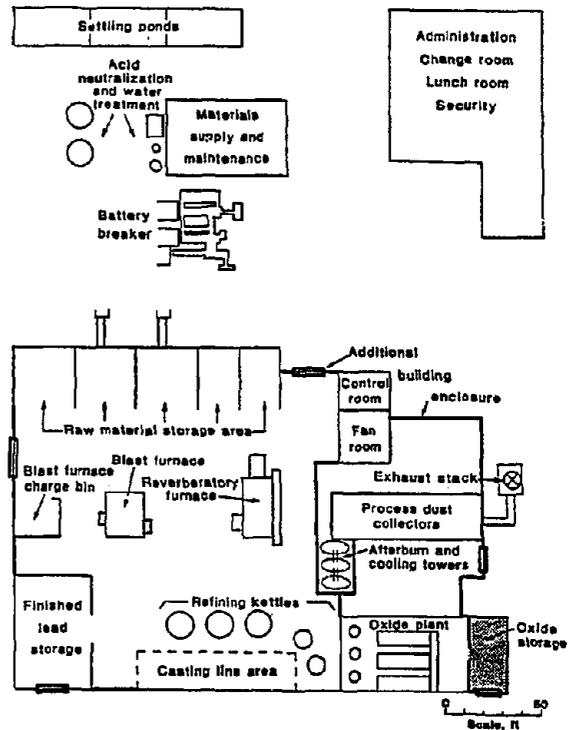


Figure A-6.—Additional building enclosures for NAAQS.

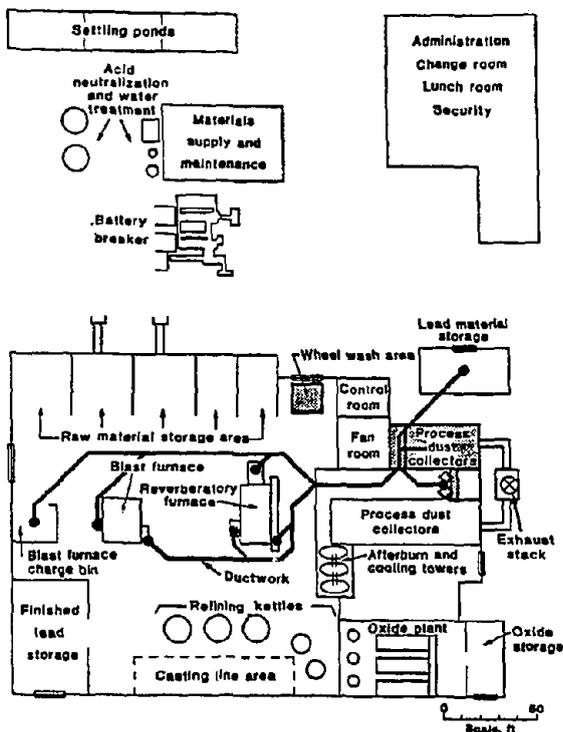


Figure A-7.—Additional process emissions control equipment and ductwork for NAAQS.

process emissions controls at the blast furnace, reverberatory furnace, refining kettles, and oxide kettles (fig. A-5). Also, this smelter has an afterburner and cooling towers, which are probably not standard level of compliance items for the lead industry. The capital costs are presented in table A-5.

The operating costs associated with the NAAQS are presented in table A-6 and are based on the operation and maintenance of the previously mentioned process controls.

TABLE A-5.—NAAQS capital cost estimate for the current regulation of 1.5µg/m³¹

Cost item	Total cost ² , \$
Plant enclosure:	
Strip doors (5 doors; 1,216 ft ² @ \$15.50/ft ²)	18,800
Plant enclosure (25,500 ft ² @ \$8.30/ft ²)	211,700
Foundation (350 lineal ft @ \$26.00/lineal ft)	9,100
Air monitoring:	
Lead monitor (photometer system)	51,000
SO ₂ monitor (fluorescent system)	32,000
SO ₂ gas scrubber	53,300
Yard paving (2 in asphalt, 4 in aggregate, 96,000 ft ² @ \$0.82/ft ² , plus mobilization)	79,800
Curb (6 in by 9 in with 8 in subgrade, 2,100 lineal ft @ \$7.25/lineal ft)	15,200
Baghouse (100,000 ft ³ /min system; 450 hp fan, 460 V, 495 A)	307,000
Ductwork (14 ga, gasket and flange connection, 520 lineal ft @ \$300/lineal ft)	156,000
Electrical system airflow monitor, fan restart system	50,000
Agglomerator system	34,000
Wheel washing station	16,000
Subtotal	1,033,900
Contingency (15 pct)	155,100
Total cost	1,189,000

¹ Smelter assumed to be in partial compliance with NAAQS. Therefore, costs do not represent the total cost for compliance.

² Values rounded to the nearest \$100. Total cost includes purchase, freight, and installation where applicable.

TABLE A-6.—NAAQS annual operating cost estimate for the current regulation of 1.5µg/m³

Cost item	Total cost ¹ , \$
Materials and utilities:	
Electricity	86,800
General supplies (10 pct of electricity)	8,700
Maintenance materials (60 pct of labor and supervision)	54,800
Baghouse liners	38,500
Labor:	
General labor (2 people @ ² \$15,000)	30,000
Maintenance labor (1.5 people @ ² \$18,000)	27,000
Supervision (4 person @ ² \$14,000)	9,600
Laboratory-labor (4 person @ ² \$14,000)	5,600
Laboratory-skilled (2 people @ .4 @ ² \$24,000)	19,200
Administration (.25 person @ ² \$34,000)	8,500
Payroll overhead (35 pct of above personnel)	35,000
General office (estimated)	3,500
Subtotal	327,200
Contingency (20 pct)	65,400
Total cost	392,600

Cost per lb refined lead based on a production rate of 40,000 mt/yr refined lead: 0.45¢/lb.

¹ Values rounded to the nearest \$100.

² Annual cost per person.

RCRA

Capital costs associated with RCRA include the "part B" permit, the ground water monitoring system, and the material testing laboratory and equipment. For this example, the well monitoring system includes eight wells (each 80-ft deep), well casing, pumps, pipe, electrical hardware, caps, and well-site paving. Material testing equipment includes an atomic-absorption spectrophotometer, multiple and single element tubes, and miscellaneous equipment for wet- and dry-test methods. The part B permit costs between \$30,000 and \$50,000 and generally varies because of smelter size. For this example, the cost is assumed to be \$42,000. Also included is the battery breaker enclosure. The ventilation and ductwork has been charged to the PEL regulation (fig. A-8). The capital costs for RCRA are presented in table A-7.

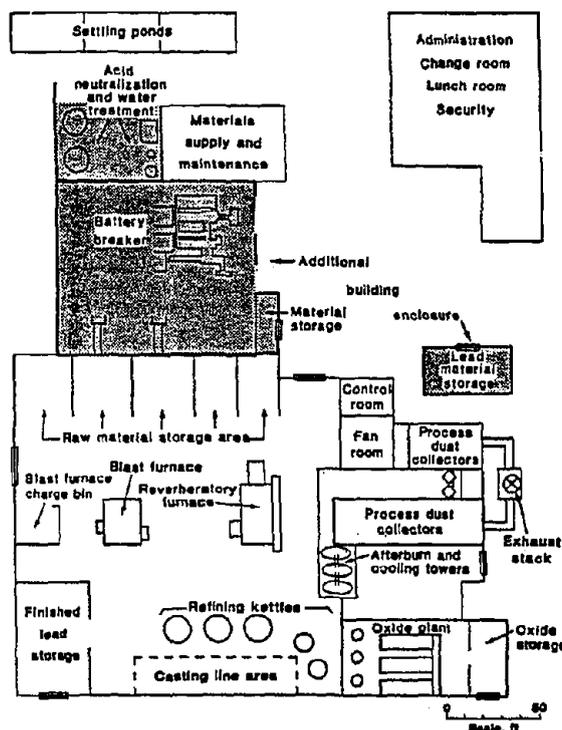


Figure A-8.—Additional building enclosures for RCRA.

TABLE A-7.—RCRA capital cost estimate

Cost item	Total cost ¹ , \$
Well monitoring:	
Drilling (10 wells, 80 ft deep, \$12/ft to drill and case).....	9,600
Pumps (10 @ \$400 each).....	4,000
Pipe and electrical (10 sites @ \$450/site).....	1,500
Overhead electrical (10 sites @ \$450/site).....	4,500
Cap and pave (10 sites @ \$250/site).....	2,500
Installation (10 wells @ \$250/well).....	2,500
Contingency (10 sites @ \$150/site).....	1,500
Drill rig mobilization.....	600
Subtotal.....	26,700
Battery breaker enclosure:	
Foundation (432 ft @ \$11/lineal ft).....	4,800
Siding and roofing (13,340 ft ² @ \$8.30/ft ²).....	110,700
Strip doors (4 doors; 928 ft ² @ \$15.50/ft ²).....	14,400
Contingency (15 pct of above items).....	19,500
Subtotal.....	149,400
Miscellaneous costs:	
RCRA part B permit.....	42,000
Atomic absorption spectrometer.....	55,000
Support equipment, lab supplies.....	8,000
General office (estimated).....	1,500
Subtotal.....	106,500
Total capital cost.....	282,600

¹ Values rounded to the nearest \$100. Total cost includes purchase, freight, and installation where applicable.

The operating costs for RCRA compliance include well monitoring and testing, and material testing. The costs are composed of labor, equipment operation and

TABLE A-8.—RCRA annual operating cost estimate

Cost item	Total cost ¹ , \$
Well monitoring:	
General labor (.3 person @ ² \$14,000).....	4,200
Laboratory-labor (.3 person @ ² \$14,000).....	4,200
Laboratory-skilled (2 people @ .3 @ ² \$24,000).....	14,400
Supervision (.3 person @ ² \$30,000).....	9,000
Payroll overhead (35 pct of above personnel).....	11,100
Materials and utilities (10 pct of labor & supervision).....	3,200
General office.....	2,000
Subtotal.....	48,100
Waste disposal:	
Contract haulage.....	173,000
Disposal fees.....	108,500
RCRA administration (25 person @ ² \$34,000).....	8,500
Payroll overhead (35 pct of administration).....	3,000
Subtotal.....	293,000
Contingency ³ (15 pct).....	51,200
Total cost.....	392,300

Cost per lb refined lead based on a production rate of 40,000 mt/yr refined lead; 0.44 ¢/lb.

¹ Values rounded to the nearest \$100.

² Annual cost per person.

³ For well monitoring and waste disposal.

* Estimated.

maintenance, laboratory supplies, and supervision (table A-8). Waste disposal is based on a 100-mile one-way haul distance by contract carrier. The dump site is considered to be a class II or better hazardous waste disposal site.