SECONDARY LEAD SMELTER NATIONAL EMISSION STANDARDS REGULATIONS

OPERATING AND MAINTENANCE GUIDELINES FOR AIR POLLUTION CONTROL

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April, 1987

ABSTRACT

The control of emissions from secondary lead smelters depends upon the procedures implemented to achieve initial compliance and remain in a state of continuing compliance with applicable emission standards. The ability to remain in compliance depends largely on operation and maintenance practices. This manual was developed as a technical reference incorporating operation and maintenance information for secondary lead smelting. It presents an overview of secondary lead operations, describes typical emission problems associated with the material preparation, smelting, refining and oxidation processes, and reviews the potential causes of the problems and possible corrective measures. It also describes the types of air pollution control equipment used in secondary lead smelting operations and typical operation and maintenance problems experienced with this equipment. A brief summary of current monitoring and analytical techniques used in determining the quality and quantity of emitted pollutants is also included as a useful reference tool.

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1 INTRODUCTION

In accordance with Section 7 of the Clean Air Act, the Governor-in-Council promulgated particulate and lead emission standards for secondary lead smelters. These national emission standards, establishing the maximum concentration of particulate matter which may be emitted into the ambient air and the lead content of such emissions, became effective August 1, 1976 and apply to all sources whether new or modified or existing prior to the effective date. They are applicable to operations involving the use of blast furnaces, cupolas, reverberatory furnaces, holding furnaces, kettle furnaces or lead oxide production units. They also cover lead scrap and lead material handling, crushing, furnace tapping, furnace slagging, furnace cleaning, and final casting. These ancilliary operations are considered part of the process of producing refined lead, lead alloys or lead oxide.

A secondary lead smelter is defined as a plant which processes lead bearing material to produce lead, lead oxides and lead alloys.

The control of lead emissions from secondary smelters are demonstrated to depend largely on operation and maintenance practices. Fabric filters are predominantly used to remove particulate matter from lead smelter process and ventilation gas streams. Because properly operated fabric filters are very efficient, the lead particulate matter emitted in stack gases is substantially reduced over that which would be emitted in an uncontrolled state. Fugitive emissions, however, may still remain a problem. Control systems are only partially effective in capturing fugitive emissions. Also, handling of the lead particulate matter after it has been collected is a potential cause of fugitive emissions. Continued compliance can be achieved only by applying the appropriate combination of engineering and administrative controls, and by adopting operating, maintenance, and housekeeping practices to make those controls work effectively.

This guide presents an overview of secondary lead operations and describes typical emission problems from the material preparations, smelting, refining and oxidation processes. It explains causes of the problems and possible corrective measures. It also describes types of control equipment used in secondary lead smelting operations and typical problems with control equipment.

2 SECONDARY LEAD SMELTER REGULATION

Two sections of the Clean Air Act govern the development of a National Emission Standard Regulation. Section 7 outlines the authoritative basis for the standard:

7.(1) Where the emission into the ambient air of an air contaminant in the quantities and concentrations in which it is consumed or produced in the operation of stationary sources of a particular class or classes specified by the Governor in Council would

> (a) constitute a significant danger to the health of persons,

the Governor in Council may prescribe national emission standards establishing the maximum quantities, if any, and concentrations of such air contaminant that may be emitted into the ambient air by stationary sources of such class or classes.

and Section 9 describes the prohibitive nature of the regulation:

9.(1) No operator of

> (a) any stationary source of a class in respect of which a national emission standard has been prescribed pursuant to section 7,
>
> shall operate such stationary source or federal work, undertaking or business, as the case may be, in a manner that results in an emission into the ambient air in contravention of that national emission standard or specific emission standard.

The general intent of the Secondary Lead Smelter National Emission Standards Regulations is to limit the concentration of emitted particulates and the lead content of such particulate matter.

Provisions of the regulation are applicable to blast furnaces, kilns, or reverberatory furnaces and more stringent provisions are applicable to holding furnaces, kettle furnaces or lead oxide production units. Also included in this latter group are operations involving scrap and material handling, crushing, furnace tapping, furnace slagging, furnace cleaning, and casting.

No facility subject to the provisions of the regulation shall discharge or cause the discharge into the atmosphere from a blast furnace, kiln or reverberatory furnace any gases which:

a) contain particulate matter in excess of 0.046 grams per normal cubic metre or
b) emit lead in particulate matter, the concentration of which exceeds 63 per cent by weight.

or in the case of holding furnaces, kettle furnaces or lead oxide production units shall not emit:

a) particulate matter in excess of 0.023 grams per normal cubic metre, or

b) lead in particulate matter, the concentration of which exceeds 63 per cent by weight.

The standards are not applicable during a malfunction or breakdown in the air pollution control equipment or the process equipment associated with the operations referred to in the regulations since these periods do not constitute representative operating conditions.

Under the regulations the definition of a regulated facility is based upon a process to which the standard applies. Questions of applicability should be referred to an appropriate authority as required.

There are no mandatory reporting requirements under the regulations except under Section 6 of the Clean Air Act where the Minister "requests information or samples which will enable the Minister to cause an analysis to be made of the nature, quantity and quality of any emissions into the ambient air that result from the operation". This section also requires that the Minister "has reasonable grounds to believe that the operation results in the emission into the ambient air of an air contaminant".

For the purposes of requests under Section 6 the emission tests shall be performed in accordance with the published Standard Reference Methods for Source Testing: Measurement of Particulate Matter and Lead from Secondary Lead Smelters - Report EPS 1-AP-78-3.

The Minister may also request information relating to malfunctions and breakdowns in the air pollution control equipment on the process equipment associated with the operations defined in the standard.

References

1. Clean Air Act, 1971.

2. Secondary Lead Smelter National Emission Standards Regulations SOR/76-464, 9 July, 1976.

3. Environment Canada Report EPS 1-AP-78-3, June 1979.

3 DESCRIPTION OF PROCESSES AND OPERATIONS

There are eight producers of secondary lead in Canada concentrated in major population centers. The reason for their urban location is that their basic raw material is lead based scrap which is collected by commercial scrap dealers. Thus the term secondary smelters refers to the source or origin of the lead and not to the quality of the ingots produced. The annual ingot production is about 70 000 tonnes, with an average facility producing approximately 10 000 tonnes per year.

The secondary lead industry is relatively complex in that a number of processing steps are combined in various combinations to produce seven principal products. Figure 1 is a generalized flow diagram for secondary lead smelting. There are three basic process steps at a secondary lead plant: pretreatment, smelting and refining. One or more furnace types (blast, reverberatory, and kiln) are used in each process; the furnace combinations selected depend upon the type of scrap processed and the desired product mix. These operations and the associated equipment are discussed in this section.

3.1 Production Process Overview

As shown in Figure 1, a secondary lead plant processes lead bearing materials such as automotive batteries and battery plates, battery manufacturing scrap, rerun blast furnace slag, reverberatory furnace slag, dross, flue dust, and scrap lead metal (e.g., pipe and flashing) to produce various lead products.

3.1.1 **Pretreatment.** The lead-bearing raw materials may be stored outdoors in large piles and are transported around the smelter in front-end loaders and/or trucks. These materials usually must be processed in some way before they can be fed to the smelting furnaces. For example, batteries are decased or crushed; some feed materials are subjected to sweating to recover lead and lead alloys with low melting points; battery plates and scrap may be premelted before charging to the smelting furnace; and collected flue dust and dross may be agglomerated before recycling.

The steps involved in preparing whole batteries for decasing vary. Incoming batteries are segregated by battery case material (e.g., plastic or rubber). The batteries are usually cut by a saw or a shear in an enclosure for removal of battery tops and posts, but some are crushed on the ground by a track bulldozer. The acid is drained from the batteries, and the lead plates, posts, and intercell connectors are removed from battery cases, collected, and stored in a pile for charging to the process furnaces.

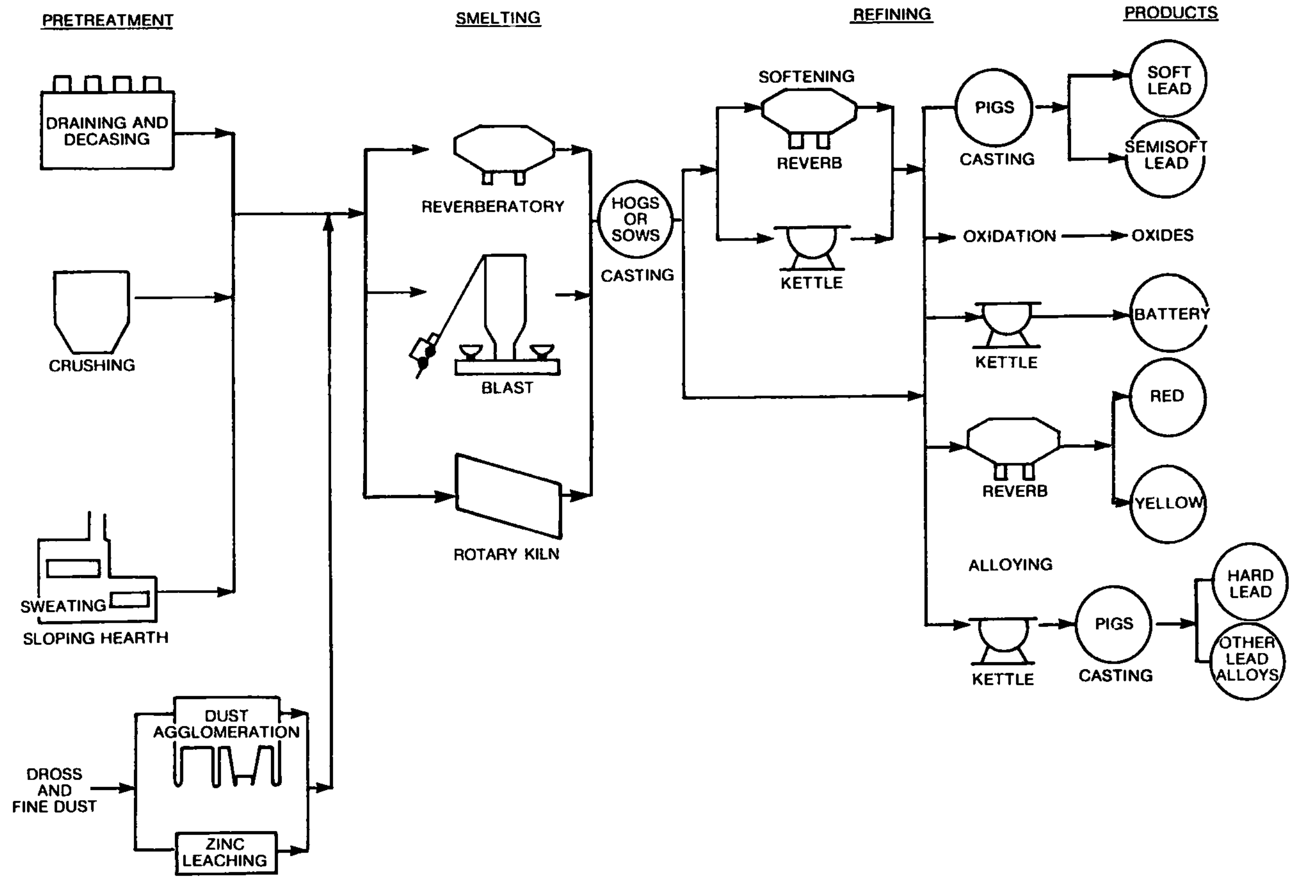

FIGURE 1 SECONDARY LEAD PROCESS FLOW DIAGRAM

In the sweating operation lead and lead alloys with low melting points (e.g., solder, babbitt) are selectively melted and separated from pieces of scrap iron, copper, or aluminum. Radiators, cables, bearing housings, and various items of soldered or lead-covered scrap are typical feed materials. Sweating is performed in direct gas or oil fired reverberatory or rotary furnaces. Reverberatory furnaces are typically used to process high lead content scrap and rotaries usually process low lead content scrap.

Fabric filter dusts from reverberatory, rotary, and blast furnaces and from kettles are remelted and agglomerated at many secondary lead smelters. The agglomerated product allows better lead recovery by the smelting furnaces and decreases fugitive emissions.

Other pretreatment operations may include; crushing large pieces of scrap with a jaw crusher to reduce the scrap to a suitable size and zinc leaching to dissolve zinc from collected reverberatory furnace flue dust to reduce the zinc concentration in the blast furnace feed. After the pretreatment operations, the lead-bearing materials are processed by the smelting furnaces.

3.1.2 **Smelting.** Smelting produces a purified lead by melting and separating lead from metal and nonmetallic contaminants and by reducing the oxides to elemental lead. This is accomplished by exposing the furnace charge materials to a reducing atmosphere at a temperature of about 950°C so that the oxides can be reduced and the sulfur and waste oxide components (silicon dioxide, iron oxide, and others) can be removed as slag. Smelting is carried out in blast furnaces, reverberatory furnaces and rotary kilns.

Hard or antimonial leads containing about 10 percent antimony are commonly produced in the secondary lead industry by blast furnaces (sometimes called cupolas or shaft furnaces). Pretreated scrap metal, coke, rerun slag, recycle dross, flue dust, scrap iron, and fluxes (e.g., limestone) are used as charge materials to the furnace. The process heat needed to reduce the lead components of the charge to metallic lead is provided by the reaction of the charged coke with blast air that is blown into the furnace.

Semisoft lead products that contain 3 to 4 percent antimony are commonly produced in reverberatory furnaces.

The lead is produced using metallic battery parts, oxides, drosses, and other residues. This charge is heated directly using either natural gas, oil, or coal.

3.1.3 **Refining.** Refining and processing the crude lead from the smelting furnaces can consist of softening, alloying, and oxidation depending on the final products desired.

These operations can be performed in reverberatory furnaces (discussed earlier) or kettles, but kettles are most commonly used.

Intermediate smelting products, especially from blast furnaces, may contain antimony or copper; either element makes the lead hard. Kettles are used for softening processes to remove these contaminants and thus produce a soft lead product. The process steps consist of charging the preheated kettle; melting the charge; agitating the flux into the molten charge; skimming the drosses; and pouring or pumping the molten metal. In some cases, molten lead is charged directly from the smelting furnace into the refining kettle. Often, separate kettles are used to remove various impurities.

Refining furnaces remove copper and antimony to produce soft lead and remove arsenic and nickel to produce hard lead. Sulfur can be added to reduce copper content while aluminum chloride, sodium nitrate, sodium hydroxide, and air can be used to reduce the antimony content. Aluminum chloride also removes nickel.

Alloying furnaces are used to melt and mix ingots of lead and alloy material. Antimony, tin, arsenic, copper, and nickel are the most common alloying materials.

Oxidizing furnaces are either kettle or reverberatory furnaces which oxidize lead and entrain the product lead oxides in the combustion air stream. The product is subsequently recovered in baghouses.

Kettles are also used to remelt final products for casting.

3.2 Process Operations

This section presents a more detailed description of the operation of a secondary lead plant.

3.2.1 Pretreatment.

Battery Handling

Practices for preparing whole batteries for decasing vary. Incoming batteries are segregated by battery case material (e.g., plastic or rubber). The batteries are usually cut by a saw or a metal shear in a enclosure for removal of battery tops and posts but batteries are also crushed in the open by a track bulldozer. Then the acid is drained from the batteries, and the lead plates, posts, and intercell connectors are removed from battery cases and stored in a pile for charging to the process furnaces. The drained acid passes to a sump, and the stored plates are sprayed with water to remove any retained acid. This acid has a pH of about 0.6 (Mezey 1979). The acid in the sump is neutralized with lime before it is discharged to a holding pond or sewer system.

Empty battery cases and battery tops can be washed and shredded for landfill or resale. Some smelters use battery cases in the blast furnace as a portion of the fuel. The charge is premixed to maintain a uniform material mixture in the furnace and control furnace temperatures. Because vulcanized rubber cases can be a source of sulfur resulting in sulfur dioxide emissions, they are normally removed and discarded to minimize generation of sulfur dioxide emissions in the smelting operation. From European experience, smelters which feed PVC plastic battery cases to blast furnaces on a continuous basis and recycle collected dust must eventually remove the lead chloride which builds up in the furnace by leaching (Burton et al. 1980).

Sweating

The feed materials for a secondary lead smelter typically contain various items of soldered or lead-covered scrap derived from radiators, cables, and bearing housings. In addition to the lead, the scrap contains metals with higher melting points such as iron, copper, and aluminum components which are undesirable in the smelting and refining stages. These undesirable components are separated from the lead components through a process termed sweating. Sweating is a physical separation of metals based upon differences in melting points. In the secondary lead process the scrap is heated in a direct gas or oil-fired furnace of the reverberatory or rotary type.

Reverberatory furnaces are typically used to process high content lead scrap such as battery plates, and rotary furnaces are usually used to process low content lead scrap (lead-sheathed cable and wires) type metal drosses. The furnace is operated at temperatures 340° to 540°C, which are above the melting point of the lead alloys and below those of the undesirable metals.

A sloping hearth type of reverberatory furnace is the most common type used for sweating. The scrap pieces are pushed or dumped onto the furnace hearth either by hand or with a mechanical loading device. After the metals melt and flow down the hearth, the furnace operator rakes the pieces of unmelted scrap off the hearth and out of the furnace. These scrap pieces may be sold to foundries or to secondary copper and aluminum smelters for recovery of the remaining metals. Hoes and rakes are used to remove the scrap through access doors. When a rotary kiln sweating furnace is used, the scrap falls into a bin at the end of the furnace. The lead or lead alloys are collected in a well or a holding kettle furnace. The metal can then be cast or pumped to other furnaces for further processing.

Agglomeration

Several secondary lead plants remelt and agglomerate fabric filter dusts from operating furnaces to increase lead recovery and decrease fugitive emissions (Section 4). Where agglomeration is not practiced, flue dusts may be recirculated directly to either the smelting blast furnace or reverberatory furnace or stored for later lead recovery. A large amount of this dust is entrained in the furnace flue gas system and must again be collected by the control system. If the flue dust is stored before recycling, the dust particles can become windblown and add to plant fugitive emissions. The agglomeration process melts the flue dust and fuses the particles together to form a large solid piece of material in the shape of the receiving vessel. Tipping the solidified contents of the vessel on the ground is usually sufficient to break the material into lumps small enough for recharging to the smelting furnace and large enough to prevent entrainment in the furnace flue gas system. Since less flue dust is generated and because the volume of recycle material is reduced by approximately 80 percent, additional lead bearing material can be charged to the furnace which increases the smelting rate. Blast furnaces that smelt battery scrap generate dusts that are amenable to agglomeration. Some dusts, however, that contain zinc or copper cannot be agglomerated (?) be processed in such a furnace either because their melting points are too high or because they raise the melting point of the mixture above the operating temperature. The agglomerated material is a suitable blast furnace feed. It can also be used as a detinning agent in kettle refining. Agglomeration, however, may not be applicable for such reasons as; the dust is not recycled to the blast furnace, ?(the chlorine content of the dust is too low,) the smelting furnace afterburner is not operating properly, or the furnace top temperatures are high enough to vaporize a significant quantity of metallic lead.

Published reports (Schwitzgebel 1981, Mackey and Bergsoe 1977, Coleman and Vandervort 1980, Coleman and Vandervort 1979) differ about the applicability of dust agglomeration to flue dusts from secondary lead smelters. Available data indicate that smelters differ widely in the type of scrap they use and in their operating practices. Research is required before a recommendation can be made about the use of flue dust agglomeration in a reverberatory furnace by any specific smelter. Flue dust reverberatory furnaces are in use and are similar to agglomeration furnaces. Items to consider include:

Dust composition, melting point, and generation rates
Fluctuation in dust production rates

Afterburner performance
Recycle practices
Changes in furnace feed materials
Furnace temperature control

Furnace operating temperatures depend on the dust composition. Temperatures ranging from 400° to 900°C are the most likely operating points for agglomerating dusts generated from battery scrap smelting.

3.2.2 **Smelting.** Blast furnaces, reverberatory furnaces and rotary kilns can be used for smelting. Reverberatory smelting furnaces are used to produce a semisoft lead product that typically contains 3 to 4 percent antimony. Blast furnaces produce hard or antimonial lead containing about 10 percent antimony. Rotary kiln furnaces produce semi-soft lead products similar to those produced in reverberatory furnaces.

Blast Furnace (cubilot, haut fourneau)

Blast furnaces (sometimes called cupolas or shaft furnaces) are commonly used for smelting in the secondary lead industry. The furnaces are refractory-lined, water-cooled, steel vessels, usually open at the top. Pretreated scrap metal, coke, rerun slag, recycled dross, flue dust, scrap iron, and fluxes (e.g., limestone) are charged into the furnace either in alternate layers or as a mixed feed. Charging devices that may be used, include skip hoists, conveyor belts, and front-end loaders (Figure 2).

The first step in blast furnace smelting is charging. A typical blast furnace charge contains 55 to 87 percent battery scrap; 7 to 20 percent drosses, oxides, leaching residue, and reverberatory slag; 5 to 8 percent coke; 2 to 6 percent rerun slag; 1 to 6 percent scrap iron; 1 to 3 percent flue dust; and 1 to 5 percent limestone. Lead drosses contain antimony, copper, caustic, and other residues from the refining processes. Reverberatory slag may contain lead, silica, tin, arsenic, copper, and antimony. Rerun slag is a highly silicated slag tapped from previous blast furnace runs. Not all blast furnace slag is necessarily recycled. Iron and limestone form an oxidation-retardant slag that floats on top of the melt to prevent oxidation of the reduced lead in the smelting furnace.

Hot blast air (sometimes oxygen-enriched) is introduced through tuyeres just above the slag level in the furnace. The air reacts with coke in the charge to produce heat, carbon monoxide, and carbon dioxide. The hot gas rises through the charge material in the furnace, preheats it, and provides the necessary reducing atmosphere for smelting. Smelting occurs at the tuyere level, where carbon and carbon monoxide reacts with lead

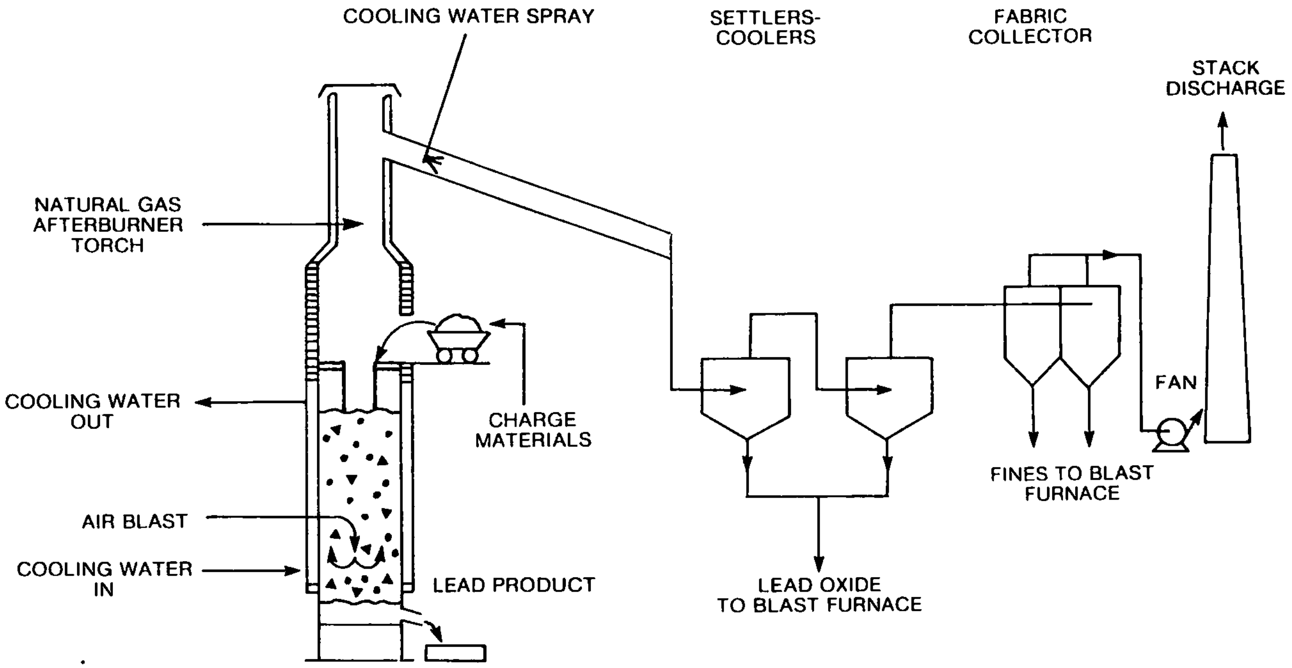

FIGURE 2 PROCESS FLOW SKETCH OF LEAD BLAST FURNACE OR CUPOLA

sulfates, oxides, and carbonates to form lead, sulfur dioxide, and carbon dioxide. Temperature at the tuyere level is approximately 1010°C.

Furnace slag floats on top of the lead in the furnace and is tapped intermittently from a hole that is drilled through the furnace refractory that is located at a higher level than the lead tap hole and usually 180 degrees from the lead tap hole. The hole is then sealed with a fire-clay plug after the slag is tapped. The furnace slag level is monitored by removing the tuyere covers, peering through glass inserts in the tuyere covers, checking the tuyere air pressure, timing previous slag taps, or a combination of these techniques. At no time should the slag level be allowed to rise above the tuyere level. Quite often, rods must be inserted through the tuyeres to clean slag accretions that form when slag splashes the tuyeres. This is commonly referred to as "punching the tuyeres".

Slag is usually tapped into crucibles for cooling. If enough iron is present in the furnace charge, a liquid called matte, which consists of lead, iron, and sulfur, forms at the bottom of the slag crucible. Matte differs from slag and lead bullion. Most of the sulfur (95 to 98 percent) in the feed material accumulates in the matte or slag/matte mixture. The matte can be broken from the slag when the slag crucible is cooled and dumped. Thus, the slag, with its higher lead content, can be charged to the blast furnace without recycling most of the sulfur. Not all the slag, however, is necessarily recycled.

Molten lead settles to a lead well at the bottom of the furnace. Normally, it is continuously tapped from the lead well through a hole in the furnace wall. The temperature of the molten lead is 871° to 898°C. Next, the lead is fed by gravity via a runner into a water-cooled mold or a holding kettle where the temperature is 371° to 538°C. The crude lead is then cooled and cast into 227-kg sows or into hogs, which range from 680 to 1360 kg.

Additional limestone can be added to the furnace to reduce the lead content of the ferrosilicate blast furnace slag. This addition, however, raises the melting point of the slag mixture, which contains silicon oxide (SiO_2), ferrous oxide (FeO), and calcium oxide (CaO). Adding extra limestone also increases slag viscosity, so that the slag is sticky and difficult to remove from the furnace. Oxygen lances can be used to heat such slag and make it flow. Extreme care must be taken, however, to prevent overheating of the refractory, causing hot spots and ultimately, a sudden furnace rupture. This is particularly critical where water cooling is used, because a furnace rupture would then result in water contacting molten metal, which would result in a "metal explosion" from the rapid steam generation.

Blast furnace capacities range from 15 to 40 tonnes of lead/day per square meter of furnace cross section. The operating capacity is usually limited by the amount of gas that can be drawn through the furnace without overloading the gas cleaning equipment. Each smelting furnace operator can vary a number of parameters to increase production, but as the upper limit of production is approached, the likelihood of upsets that create environmental problems increase (see Section 4).

Temperature control is accomplished by adjusting the coke feed rate, blast air rate, or oxygen content of the blast air. Some smelters also have blast air preheat temperature controls. A relatively high ratio of coke (8 to 9 percent) is used in the charge to maximize production, and a relatively large operating temperature range can be achieved within the furnace by blast air control. Rapid smelting can thus be achieved by raising temperatures throughout the furnace with high blast air rates, preheat temperatures, and oxygen ratios.

The blast furnace operator may lose control of the furnace temperature. If the gases ignite, the fire cannot be extinguished simply by shutting off the blast air. In such cases, additional charge material without coke must usually be added to reduce the heat and extinguish the fire. Placing a steel cover on top can also help put out the fire.

Reverberatory Furnace

Reverberatory furnaces are typically rectangular and have an arched roof. The melt is directly exposed to the furnace burner flame. Figure 3 shows a schematic diagram of a reverberatory furnace. As discussed earlier, reverberatory furnaces are also used for sweating, melting, dust agglomeration, softening, and refining. Typically, a specific reverberatory furnace is used for only one of these functions. The processing steps vary, depending on the furnace function.

Battery plates, lead oxides, drosses from refining kettles, fluxes, and collected flue dusts are feed materials for reverberatory furnaces. Typical feed mechanisms are ram feeders and top charging doors with conveyors. Both feed mechanisms require manual attention. The high temperatures within reverberatory furnaces immediately vaporize any water that is introduced with the scrap. The consequent rapid increase in gas flow from the furnace can cause temporary overloading of the exhaust ventilation and process gas handling systems. Predrying of the raw material can prevent this problem.

Furnace temperatures vary with the operation and the type of fuel fired. Oil flames produce cooler, more radiant flames than natural gas. Although furnace exit gas

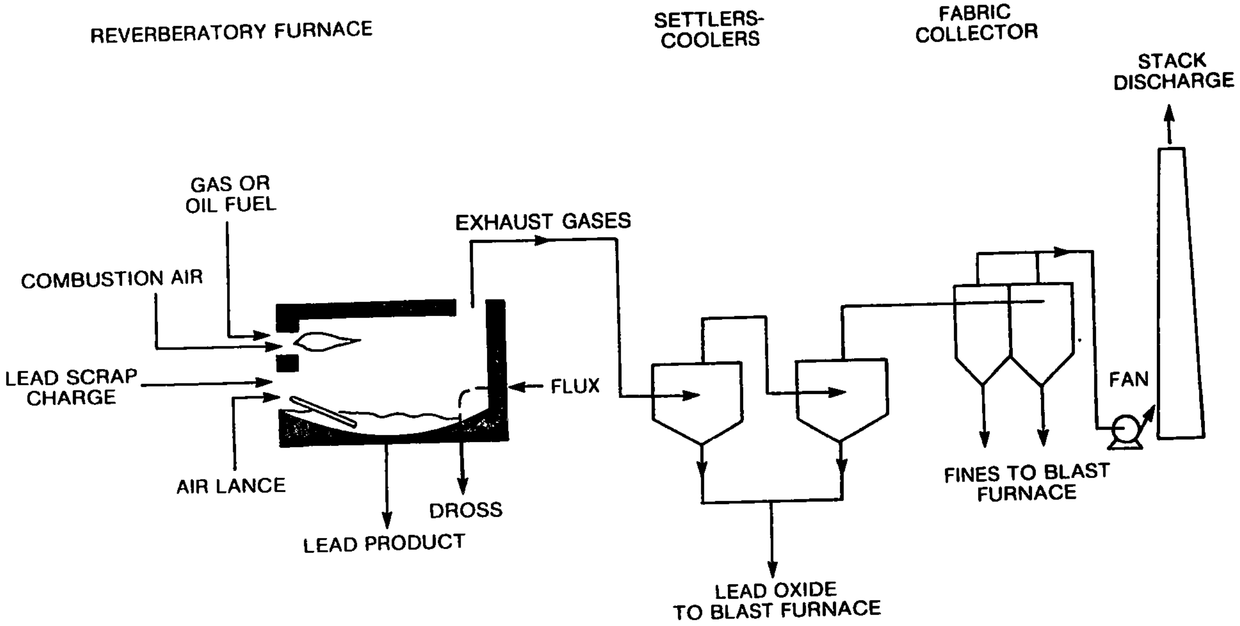

FIGURE 3 PROCESS FLOW SKETCH FOR LEAD REVERBERATORY FURNACE

temperatures may be as high as 1200°C in smelting applications, slag temperatures in the furnace rarely exceed 1010°C and metal temperature rarely exceed 955°C.

The slag floats on top of the melted lead and may be tapped from one or more locations around the furnace. Access or inspection doors are usually provided at or just above the desired slag level. When the desired slag level is reached, the tap hole is opened and the slag drained from the furnace. A refractory launder (chute) is usually provided to allow the slag to flow into a receiving ladle. The receiving ladle should be allowed to cool under an exhaust hood until a crust forms on the slag. Ventilation should be provided for the slag hole, launder, and ladle to allow access during slag tapping. In some cases, reverberatory slags are too viscous to flow freely from the furnace. In such cases, the tapping operation requires the furnace operator to rake out the slag through a slag door having a launder attached to it. If slag tapping can be done at only one location in the furnace, it may be necessary to push the slag from several points around the furnace toward the slag tap door.

Crude lead may be tapped (as described in the discussion of blast furnaces) or pumped from the reverberatory furnace. This lead has less impurities than that from the blast furnaces and is normally a soft lead. Often the lead is tapped into a holding kettle that is held at 425° to 540°C. The crude lead is either cast into sows or hogs for later processing or can be pumped to refining and/or alloying kettles or to a casting operation for final processing.

A number of secondary lead smelters use reverberatory furnaces to produce soft or semisoft lead directly from battery plates and lead scrap. The furnace can be adjusted to oxidize all of the antimony in the scrap, but only part of the lead. A highly oxidized, antimonial slag is produced as a result. This slag is typically processed in either a rotary or a blast furnace to recover the metal values. The soft or semisoft lead can be sent to the refining or alloying kettle furnaces.

The recent increase in demand for soft lead for the manufacture of calcium-lead-tin (Ca-Pb-Sn) batteries has increased the need for reverberatory smelting and softening capacity. The decision to use a blast furnace/reverberatory furnace combination or only a reverberatory furnace is usually based on site-specific lead markets. Smelter operators who receive Ca-Pb-Sn batteries and battery manufacturing scrap and who supply manufacturers of Ca-Pb-SN batteries may elect not to make antimonial lead.

Rotary Kiln Furances

Rotary kiln furnaces are not as widely used as blast furnaces and reverberatory furnaces. The furnace is inclined slightly to the horizontal. Brick is often used to form a dam around the perimeter of the discharge and to collect the metal.

Feed materials (lead bearing materials, fluxes and coke) can be fed by a conveyor system into the higher end of the kiln. The feed is exposed to furnaces temperatures of up to 1300°C, generated mainly by the combustion of coke in the charge. A burner is located at the discharge end of the kiln to initiate the coke combustion as well as for slag temperature control. At the discharge end, the slag is floating on top of the hot metal and is continuously removed from the furnace by flowing over the brick dam. Lead is tapped periodically by stopping the kiln, breaking open the tap hole located behind the dam, and then rotating the kiln until the tap hole points downwards.

3.2.3 Refining (softening, alloying, and oxidation). Refining and processing the crude lead from the smelting furnaces can consist of softening, alloying, and oxidation depending on the final products. Since intermediate smelting products, especially from blast furnaces, may contain antimony or copper (either element makes the lead hard), these contaminants must be removed to produce a soft lead product. Molten or cast lead bullion, fluxes (including sodium hydroxide, sodium nitrate, aluminum chloride, aluminum, sawdust, sulfur, and calcium chloride), and air may be inputs to this process. Sodium nitrate ($NaNO_3$), sodium hydroxide (NaOH), and air are used to reduce the antimony content of the charge. The addition of sodium nitrate and sodium hydroxide to the melt produces a slag/dross material that contains $NaSbO_3$. Aluminum reacts preferentially with copper, antimony, and nickel to form drosses that can be skimmed off the melt surface; sulfur is used to dross copper. Calcium chloride is used for detinning. Alloying processes involve adjustment of the metals content of smelting furnace lead to produce a desired lead alloy. Common alloying agents are antimony, copper, silver, and tin. Lead is oxidized to produce battery lead oxide (PbO containing approximately 20 percent lead metal), and lead oxide pigments such as lead monoxide (PbO) and red lead (Pb_3O_4).

Kettle furnaces are generally used to refine and process lead because they allow better control of impurities and further alloying. Most kettles are heated by oil- or gas-fired burners located in brick-lined pits below the kettles as shown in Figure 4.

Kettles are used for softening processes to remove antimony and/or copper and thus produce a soft lead product. Kettle sizes generally range from 1 to 135 tonnes. The process steps are: charging the preheated kettle, melting the charge, agitating the

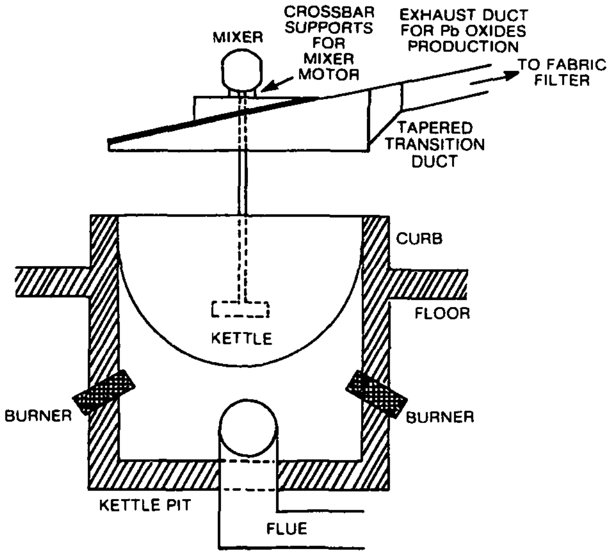

FIGURE 4 KETTLE, PIT, AND EXHAUST SYSTEM

flux into the molten charge, skimming the drosses, and pouring or pumping the molten metal. In some cases, molten lead is charged directly from the smelting furnace into the refining kettle. Often, separate kettles are used to remove various impurities. Fluxing temperatures generally range between 375° and 485°C. Sometimes copper is precipitated by lowering the temperature to 325°C. Aluminum chloride or sawdust may be mixed into the dross to decrease the chemical bond between lead droplets and dross. The dross is skimmed or tapped from the furnace before a softened lead is tapped. The dross is usually reprocessed in a blast furnace to recover metal values.

The process steps for alloying are similar to those used for softening except that alloying agents are added to the melted lead and mixed into the charge before pouring and casting into pigs.

Oxidizing Furnaces

Oxidizing furnaces are either kettle or reverberatory furnaces which oxidize lead and entrain the product lead oxides in the combustion air stream. The product is subsequently recovered in baghouses at high efficiency. Battery lead oxide (PbO containing approximately 20 percent lead metal) is produced by kettle oxidation. The process steps are: charging the kettle by gravity with molten lead, agitating the molten lead with paddles, inducing a draft of air over the surface of the melt through a duct leading to a baghouse, and collecting the lead and lead oxide fumes in a baghouse. Lead oxide pigments, lead monoxide (PbO), and red lead (Pb_3O_4) are produced by reverberatory oxidation. The process steps are: charging the preheated reverberatory furnace with molten lead, agitating and simultaneously oxidizing the molten lead, and removing the lead oxide form the furnace and cooling rapidly. Either lead monoxide (PbO) or red lead (Pb_3O_4) is produced by controlling the degree of oxidation.

3.2.4 Casting (Pigging). The softened lead and lead alloy products are cast into pigs (ingots) with a pigging machine. The pigging machine is similar to a conveyor with molds forming the conveyor belt. Molds receive the liquid hot metal at one end of the machine, and by the time the mold is moved to the other end, the lead ingot (pig) is solidified. The pig is then dumped from the mold which is then recycled to receive more hot metal.

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4 AIR EMISSIONS - GENERATION AND CONTROL

Furnace technology in the secondary lead industry has remained essentially unchanged for more than 50 years. Many furnace combinations are used, depending on the scrap supply and the desired product. Each furnace produces point source emissions and fugitive emissions. The lead content of particulate matter from each furnace varies with the furnace feed material, furnace temperature, and oxidation potential of the furnace gas. Figure 5 indicates the major sources of environmental emissions from secondary lead processes.

Table 1 lists sources of fugitive emissions from secondary lead smelters. Fugitive emission rates vary with each operation. When the furnaces are open (e.g., during charging) fugitive emission rates are highest. At other times, fugitive emission rates can be essentially nil. Smelting furnaces account for a significant portion of both process and fugitive emissions. On site vehicular traffic, flue dust handling and cleanup operations can create additional fugitive emissions problems independent of furnace operating conditions. In some older smelters, the accumulation of dust settled on the ground over the years has created a continual reentrainment problem arising from windblown dust that results in ambient lead being dispersed off the smelter property, even after the facility has been shut down.

Major changes in secondary lead smelters have been the addition of emission control systems and control methods for process and ventilation gases. Acceptable control practices can be divided into process controls, process emissions controls, and fugitive emission controls. Control practices are further classified as engineering controls and procedural controls. Engineering controls include the following:

Isolation of process
Enclosure of process
Ventilation (local exhaust and capture)
Substitution of materials, processes, equipment, or operating practices
Physical modification of contaminants (e.g., wetting the material)
Reduction or elimination of emission producing practice at the source (e.g., not overheating molten metal or not sweeping dry, dusty materials)
Use of applicable control devices (e.g., central vacuum systems or electrostatic foggers)

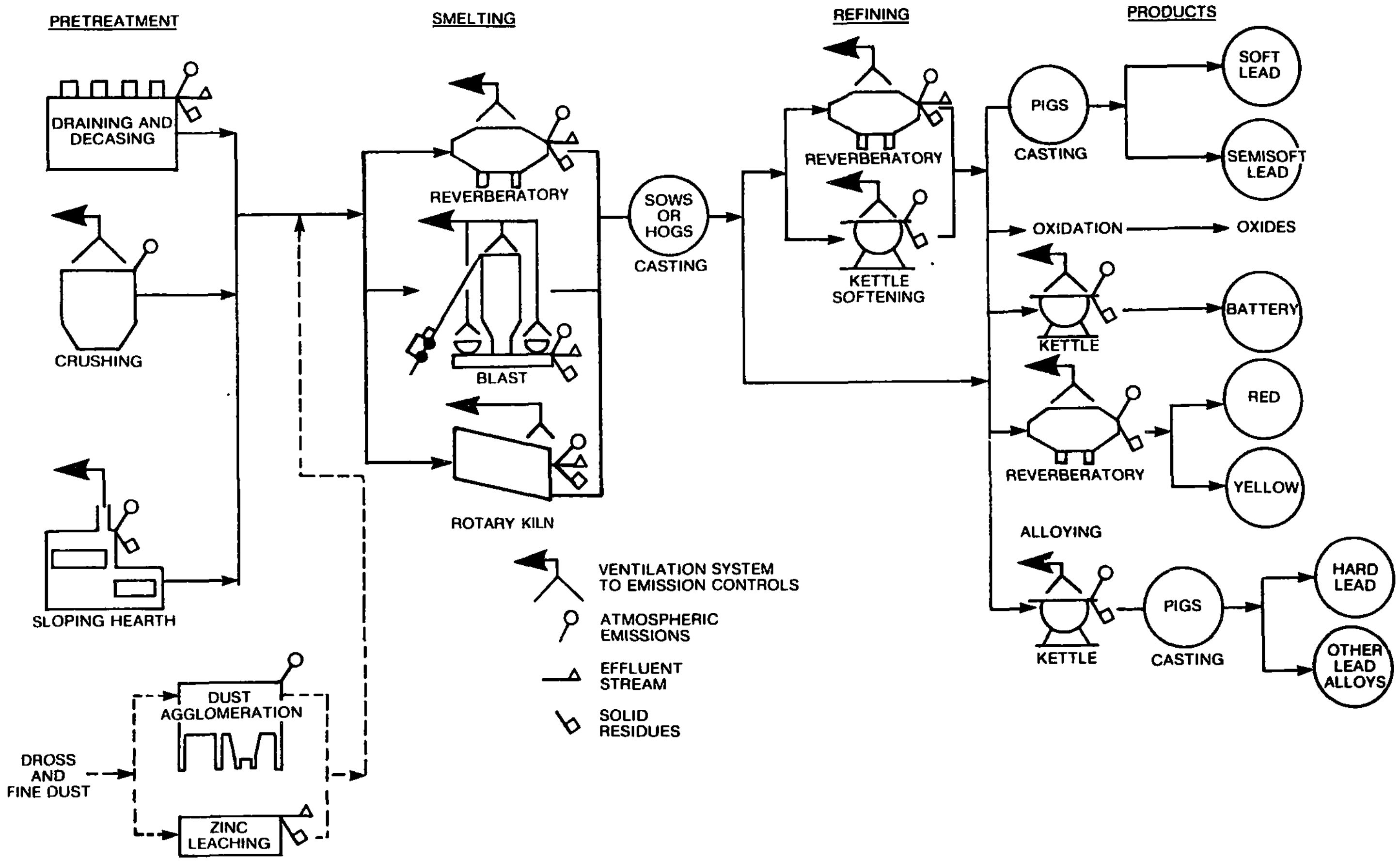

FIGURE 5 SOURCES OF AIR EMISSIONS FROM SECONDARY LEAD PLANTS

TABLE 1 SOURCES AND EMISSION FACTORS FOR POINT AND FUGITIVE EMISSIONS FROM SECONDARY LEAD SMELTERS[a, b]

	Point Source Emissions Kg/Tonne			Fugitive Emissions Kg/Tonne		
Source	Particulate	Lead	Basis[c]	Particulate	Lead	Basis[c]
Rotary or reverberatory						
furnace sweating	16-35	4-8	E			
Charging						
Tapping				0.8-1.8	0.2-0.4	E
Scrap removal						
Reverberatory furnace	74	17	B			
smelting						
Charging						
Slag tapping				1.4-7.9	0.3-1.8	E
Lead taping/casting						
Blast furnace smelting	97	22	B			
Charging						
Slag tapping				1.4-7.9	0.3-1.8	E
Lead tapping/casting						
Kettle softening/refining	0.4	0.1	B			
Charging						
Tapping (dressing,						
skimming, lead removal)				0.02	0.004	E
Kettle oxidation[d]	F 20		E			
Casting[e]				0.44	0.10	E

[a] Source: Reference 9

[b] All emission factors are based on the quantity of material charged to the furnace (except particulate kettle oxidation)

[c] The basis of the emission factor refers to the method from which the emission factor was obtained.
B Emission factor based on source test data
E Engineering estimate

[d] Factors based on amount of lead oxide produced.

[e] Factors based on amount of lead cast.

Procedural controls include the following:

- Operating practice instructions
- Employee work practices
- Housekeeping practices and policies
- Maintenance practices and policies

This section describes both point and fugitive process emission sources and their associated control alternatives.

4.1 Process Emissions

Air emissions are generated at all secondary lead plant operations. Raw material handling and preparation, smelting, and refining processes are sources of point as well as fugitive emissions. In addition to lead, antimony, nickel, tin, and zinc, arsenic is also a pollutant of concern. Arsenic is found in varying amounts in lead scrap. It is contained in primary lead unless removed in refining, and it is often added as a hardening agent during lead alloying. Antimonial lead (hard lead) is used primarily in the posts and grids of lead-acid storage batteries and for lead cable sheathing (PEDCo 1982). The arsenic in such alloys ranges from 0.15 percent for antimonial lead to no more than 0.5 percent for arsenical lead (Burgess 1976).

4.1.1 Raw Material Handling and Pretreatment.

Raw Material Handling and Transport

Lead bearing feed materials may be stored outdoors in large piles and are transported around the smelter in front-end loaders and/or trucks. If these materials are allowed to dry, wind erosion becomes a major source of fugitive emissions. Indoor storage is possible and would significantly reduce the fugitive emissions. There are no estimates available for fugitive emissions from raw material handling and transport operations.

Battery Handling

Battery handling and breaking consists of the following operations: segregation by the type of battery case material; battery sawing or crushing; acid draining; and lead scrap removal. Emissions consist mainly of sulfuric acid mist and dusts containing dirt, battery case material and lead compounds. There are no available emission factor estimates from battery handling operations.

Sweating

Sweating furnaces operate with gas exit temperatures of 538° to 816°C from both reverberatory and rotary sweating furnaces. Atmospheric emissions consist of particulate matter and combustion products, including sulfur dioxide (SO_2). The SO_2 emissions are from the combustion of sulfur compounds from both the scrap and the fuel. Particulate emissions from the stack range from 16 to 35 kg/tonne of material feed with dust loadings of 3.2 to 10.3 g/m^3 (EPA 1980). Lead emissions are estimated to be 4 to 8 kg/tonne (EPA 1980). Fugitive emissions are generated during charging and removing the scrap from the furnace. Estimated fugitive emissions from sweating furnaces are 0.8 to 1.8 kg/tonne for particulates and 0.2 to 0.4 kg/tonne for lead (EPA 1980).

Reverberatory furnaces for sweating require the removal of solid scrap parts after the lead or solder has been melted away. Hoes or rakes are used to remove the scrap through access doors. This operation can create fugitive emissions and drag dust from the furnace hearth.

Dust Agglomeration

Dust agglomeration is not performed at all plants. It is frequently used to minimize fugitive emissions when recycling fabric filter dusts from reverberatory, blast, and rotary furnaces. There are no readily available emission estimates for dust agglomeration furnaces.

4.1.2 Smelting.

Blast Furnace

The process gas temperature at the exit from blast furnaces normally range from 121° to 425°C. This temperature strongly influences the quantity and composition of material in the process gases from individual furnaces (Schwitzgebel 1981). Blast furnace emissions include carbon monoxide (CO), sulfur dioxide (SO_2), sulfuric acid (H_2SO_4), and particulate matter that contains lead, antimony, chlorine, sulfur, and organic materials. Table 2 shows lead distribution in blast and reverberatory furnace dust.

A Canadian study of fabric filter and flue dusts from 10 sources shows that the lead content in the sources ranged from 15.8 to 68.7 percent with an average of 51.7 percent (McDonnell and Hilborn 1978). Point source emissions from blast furnace

TABLE 2 LEAD DISTRIBUTION IN REVERBERATORY AND BLAST FURNACE SMELTING (Burton 1980) - % LEAD

	Raw Material Charge	Slag	Fumes and Dusts
Reverberatory furnace smelting	47	46	7
Blast furnace smelting	70	8	12

operation are estimated to average 97 kg/tonne of material charged for particulate, 22 kg/tonne for lead, and 27 kg/tonne for SO_2 (EPA 1980).

Fugitive emissions from the blast furnace result from the following operations:

Furnace charging
Tuyere punching
Slag tapping
Crude lead tapping
Process upsets

Emissions estimates are not available for each of these operations, but total fugitive emissions from smelting operations are estimated to be 1.4 to 7.9 kg/tonne of charge material for particulate and 0.3 to 1.8 kg/tonne for lead (EPA 1980).

Front-end loaders are potential fugitive emissions sources during the charging operation, as are the skip hoist, conveyors, and furnace charging area itself. Skip hoists and conveyors in this application are likely to collect dust and battery residue that may be subsequently dispersed into the air when the machine is impacted or vibrated vigorously.

Routine tending of a blast furnace involves examination of each tuyere either by removing the tuyere cover or by viewing it through a transparent window in the cover. When the tuyere cover is removed for inspection of the slag level or for punching, some emissions occur. The transparent window in the tuyere cover eliminates the need to remove the cover and hence reduces emissions.

Slag is tapped from holes bored through the furnace refractory between the lead well surface and the tuyere level. One to four tap holes may be used, depending on the size and shape of the furnace. This process is labor intensive and can be a source of fugitive emissions from the time the holes are tapped until they are sealed with fire-clay plugs. The slag tapping operation is repeated every 15 to 20 minutes, depending on the rate of operation and the material being smelted.

Crude lead tapping is another source of fugitive emissions from the blast furnace. These emissions occur as the crude lead is being continuously tapped from a tap hole below the slag level.

Fugitive emissions can also occur if the production limitation of the furnace is exceeded. Furnace capacity is usually limited by the gas handling capacity of the control equipment connected to the furnace. If the gas handling capacity is exceeded, excess emissions occur through leaks in the system; e.g., leaks from the furnace top, flanges, inspection covers, or doors. Even if local exhaust ventilation is provided for such fugitive emissions, fires and explosions can occur in any auxilliary baghouses because these fugitive emissions bypass the after-burner. At the high end of the temperature range, (e.g., 425°C gas exit temperature) fires in the scrap charge are a danger. Thus, control of the temperature profile within the furnace has an important effect on furnace emissions.

Reverberatory Furnaces

Reverberatory furnace off-gas temperatures range from 550° to 1300°C depending on the function of the furnace, the operation being performed, the firing rate, and the feed material. The furnace gases are usually well oxidized. In most furnaces, excess combustion air is supplied to ensure that adequate combustion occurs at the burner end where smelting occurs. The furnace is also operated at a slight negative pressure, typically between -2.48 and -24.8 Pa. This causes a slight flow of air into the furnace that helps to complete the combustion of hot gases and particulate matter.

Emissions from a reverberatory furnace can be expected to be similar to those from blast furnace smelting if battery scrap is the feed material. Reverberatory furnaces charged with crude lead instead of scrap will not emit chlorine or sulfur compounds; those compounds were already removed in the production of the crude lead.

Emissions from reverberatory furnaces have been estimated to be in the order of 74 kg/tonne of material charged for particulate, 17 kg/tonne for lead, and 40 kg/tonne for SO_2 (EPA 1980).

Fugitive emissions result from the following operations:

Furnace charging
Slag tapping
Crude lead tapping
Cooler (hairpin) cleaning (where applicable)

No specific fugitive emission data are available for reverberatory smelting. One estimate, however, for fugitive emissions from smelting is 1.4 to 7.9 kg/tonne of feed material for particulate, and 0.3 to 1.8 kg/tonne for lead (EPA 1980).

Furnace charging is a significant source of fugitive emissions. Ram feeders and top charging doors with conveyors are typical feeding mechanisms for reverberatory furnaces. Both feed mechanisms require manual attention. Although exhaust ventilation and partial enclosure is possible, the high temperatures within reverberatory furnaces immediately vaporize any water that is introduced with the scrap. The consequent rapid increase in gas flow from the furnace can cause temporary overloading of the exhaust ventilation and process gas handling systems. Fugitive dust is emitted from access doors and charge ports, and through the furnace refractory. Leaks through the refractory are probably the most difficult fugitive emission problem to solve with reverberatory furnaces.

Fugitive emissions can escape during slag tapping. Slag may be tapped from one or more locations around the furnace. Access or inspection doors are usually provided at or just above the desired slag level. Fugitive emissions escape when the doors are opened. When the desired slag level is reached, the tap hole is opened and the slag is drained from the furnace.

In some cases, reverberatory slags are dusty. Further they are often too viscous to flow freely from the furnace. In such cases, the tapping operation requires the operator to rake out the slag through a slag door having a launder attached to it. If slag tapping can be done at only one location, it may be necessary to push the slag from several points around the furnace toward the slag tap door. When access doors for pushing the slag are open, there is a great potential for fugitive emissions, especially if moist charge materials are being fed to the furnace.

During crude lead tapping, fugitive emissions will escape from the launder and receiving kettle or ladle, and from the casting operation during the metal taps.

Reverberatory gases may be cooled in hairpin type coolers or by dilution with process or ventilation gases prior to particulate collection. The long continuous run of ductwork which makes up a hairpin cooler appears as several verticle rows of hairpins. The gases are cooled because of the heat loss from the large surface area of the ductwork. Some particulate matter collects at the base of the coolers and must be periodically removed. Unless this collected material is conveyed automatically in an enclosed system, it can create a fugitive emission problem.

4.1.3 Refining (Softening, Alloying, and Oxidation). Process gases, fumes, and dusts are emitted from kettle furnaces used for refining processes. Combustion gases are often vented directly to the atmosphere without being mixed with the process gases. Emissions from softening and alloying are estimated to be 0.4 kg/tonne of material charged for particulate, and 0.1 kg/tonne for lead (EPA 1980). The upper limit for particulate lead oxide emissions following product collection from kettle oxidation is 20 kg/tonne of lead oxide produced (EPA 1980).

Lead refining and the production of lead, tin, and antimonial alloys pose potential fugitive emission problems because of the operator's continued contact with the process. Charging, melting, fluxing, mixing, drossing, skimming and tapping operations require the operator to open kettle hood doors and to partially disrupt local exhaust ventilation. Lead dust and fume, agitated molten metal, high temperatures, and a number of chemical agents all contribute to the potential for fugitive emissions. Total fugitives from kettle refining are estimated to be 0.02 kg/tonne of material charged for particulate and 0.004 kg/tonne for lead (EPA 1980).

Little charge preparation is required for kettles. Fugitive emissions may result from melting the residual lead inside the lead pumps (i.e., the lead in the pumps solidifies between uses and heating is necessary to melt the contained lead so that the pump impeller is freed) so that the pumps can be used. This can best be done by immersing the pump in the kettle, since the pumps are relatively portable and thus, lead fumes are captured by the kettle hood.

Fugitive emissions occur during fluxing, mixing, drossing, and skimming operations through openings required to carry out these operations. The proper use of the hood doors during these operations can minimize openings as well as fugitive emissions. The higher metal temperatures, additional agitation, and presence of dusty dross materials create a greater potential for fugitive dust.

Antimonial drosses are a major fugitive problem with kettle furnaces. These dusty materials are usually skimmed manually from the lead surface with hoes, rakes, or shovels. During the drossing operation, kettle temperatures are typically above 340°C, kettle doors are at least partially open, and the normal flow pattern of the local exhaust ventilation system is disturbed. Some dross is invariably spilled as it is removed from the kettle.

Fugitive emissions occur during molten metal transfer when the hood is opened to insert the pump. It is not practical to reduce the kettle temperature prior to opening the hood and inserting the pump to keep emissions low. A side-entry, slant-in pump assembly may be present however, to eliminate the need to open the hood during the pumping operation.

Casting

Fugitive emissions occur during the casting operation. These have been estimated to be 0.44 kg/tonne of metal cast for particulate and 0.1 kg/tonne for lead (EPA 1980).

4.2 Emission Controls

Process point and fugitive emission control systems are required to minimize pollution from secondary lead processes. These controls include capture and control of fugitive emissions by ventilation systems (i.e., hooding) and other techniques (i.e., sprays), point source control equipment such as fabric filters, wet scrubbers, and afterburners, and procedural controls such as plant operation and maintenance practices. This section will address the application of these control systems and techniques. The operation and maintenance requirements for these systems will be discussed in Section 5.

4.2.1 Fugitive Capture and Control.

Materials Handling and Preparation

Material handling operations emit coke breeze, and flue dust which may contain lead. These may be recovered at smelters by hand sweeping or mechanical and/or vacuum sweepers. Sweeping performed with mechanical or vacuum-type sweepers must avoid reentrainment of dust into the atmosphere. Motorized mechanical or vacuum sweepers or central vacuum systems should be used to recover the fine flue dust containing lead. Normally, the recovered material is recharged to one of the furnaces.

Paving of the entire smelter area including the raw material storage and preparation areas, transportation areas, emission collection areas, and temporary waste material or dust storage areas together with systematic, periodic wetting of paved areas minimizes the reentrainment of dust. Runoff water should be collected and combined with acid drainage and any process rinse water. After neutralization, this collected water shoud be sent to a holding pond or to a clarifier/thickener. Periodically the lead bearing sludge can be returned to the furnaces for additional metal recovery. The clarified and neutralized pond water can be recycled to the process.

If the plant area is unpaved, water spraying of the roads and storage areas should be performed on a routine schedule to minimize dust reentrainment. A wetting agent should be used in the water spraying operations. All vehicles transporting flue or waste dust or dusty raw materials should be covered or enclosed.

Raw material piles are commonly sprinkled with water to control wind erosion. The acidic runoff water must be collected. Although it can be neutralized easily, discharge of the treated water and disposal of the resultant sludge can be difficult. The treated water can be recirculated in a closed system, and the sludge can be recycled to the smelting furnace (Coleman and Vandervort 1980). This technique has been used with some success at a secondary lead smelter in England where high winds are a regular daily occurrence.

Indoor storage is a possible control measure. An alternative technique is to use outside storage sheds with sprinkler systems. Live-bottom hoppers that feed to conveyor belts have also been suggested as a feasible technique for enclosing and handling raw materials.

Enclosure and wetting techniques seem to be the most effective means of controlling fugitive emissions caused by front-end loaders. Lead smelters in Denmark and Sweden have attempted to enclose scrap handling and transport operations. Constant wetting of paved areas at these smelters helped to reduce ambient lead levels in the yard area to a range of 12 to 18 mg/m^3 during one test period (Coleman and Vandervort 1980).

The battery processing area (breaking and crushing) is usually controlled. Water spraying of crushed batteries to minimize acid mist fumes is maintained. The battery breaking station is hooded to prevent fugitive emissions.

Smelting

In the case of blast furnace operation, fugitive emissions occur during charging, tuyere punching, slag tapping, and crude lead tapping. To ensure maximum collection during charging, many smelters have successfully enclosed the furnace charging area with canopy or box-like hoods to contain any dust that is emitted. Local exhaust ventilation hooding above the tuyeres should be provided to help capture fugitive emissions. These hoods may also function as secondary slag tapping hoods.

The exhaust ventilation system is extremely important in minimizing fugitive emissions from slag tapping. Exhaust hoods must provide worker access to the slag hole without removing the hood. The design should ensure adequate ventilation of the slag launder and ladle and offer easy access for personnel to open the slag hole. Some slagging areas are completely enclosed having two swinging doors for removal of the slag pot or for opening or sealing the slag hole.

Necessary exhaust ventilation for the lead launder and receiving vessel for hog casting varies in design with the specific smelter tapping configuration. Hooding should allow access to the tap hole, launder, and receiving vessel while ventilation should maintain at least a 152-cm/s hood face velocity. Hooding should be as close as possible to the source of emissions. Every attempt should be made to eliminate cross-drafts near these hoods (i.e., hanging lengths of heavy chains on the hoods). Access doors should be considered to eliminate the need for hood removal when the tap hole is tended.

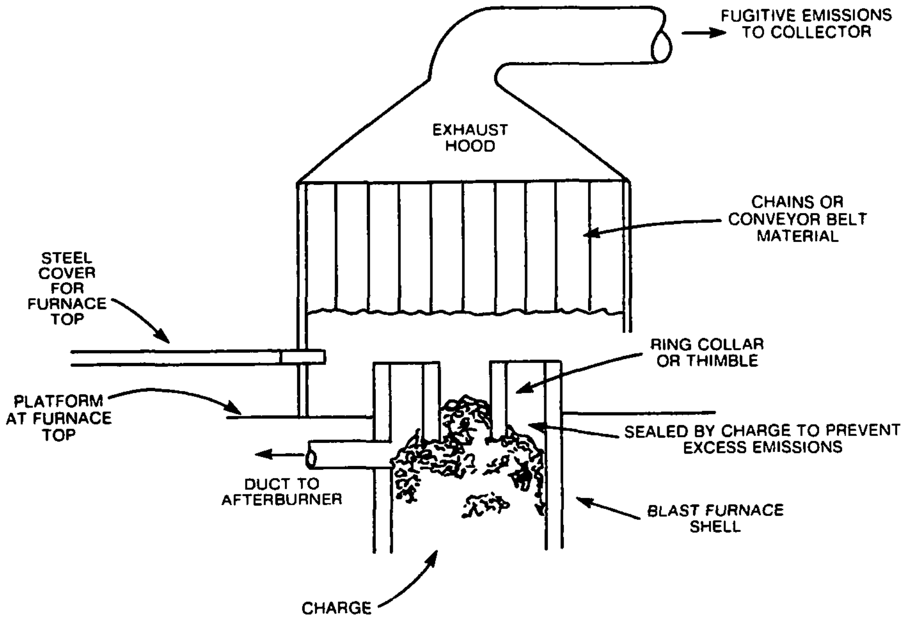

FIGURE 6 BLAST FURNACE CHARGING HOOD

In reverberatory furnace operations, fugitive dust is emitted from access doors and charge ports, and through the furnace refractory. Leaks through the refractory are probably the most difficult fugitive emission problem to solve with respect to reverberatory furnaces. Some smelters have attempted to enclose reverberatory furnaces with steel plate to prevent such emissions. Enclosures, however, cannot be made air tight because joints must be left in the steel to allow for furnace expansion and contraction. In addition, buckling of the plates is common and creates additional spaces for emissions to occur. More complete furnace enclosure and greater exhaust ventilation in the form of a canopy hood may be required.

Furnace charging doors, access doors, slag holes, and metal taps should be hooded and ventilated. A top charge reverberatory furnace with movable curtains and panels for the improved capture of fugitive emissions is shown in Figure 7. The exact configuration of the hoods and ductwork depends on the locations of the charging door, access doors, slag holes, and metal taps. The charging door hood may not be sufficient to capture emissions that result from a wet charge. If that is the case, enclosure of the entire furnace may be necessary to control fugitives. Fugitive emissions also escape from the launder and receiving kettle, ladle, or casting operation during the metal taps. Unlike blast furnaces, reverberatory furnaces are tapped intermittently. Exhaust ventilation should be provided at each emission point.

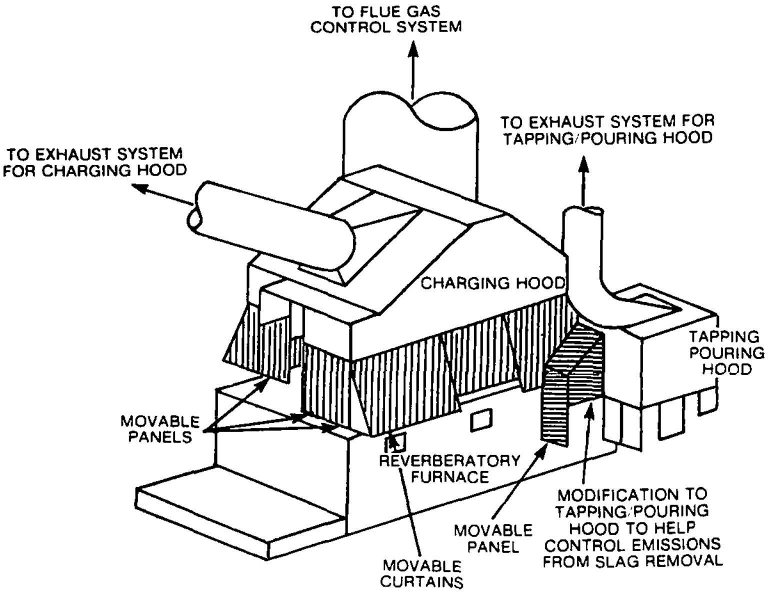

FIGURE 7 TOP CHARGED REVERBERATORY FURNACE WITH IMPROVED FUGITIVE EMISSIONS CAPTURE

Refining

Process gases, fumes, and dust are usually collected from kettle furnaces by a hood over the kettle. Kettles cannot be provided with close fitting exhaust hoods because of the need to open the hoods frequently.

The control objective is to ensure sufficient ventilation for worst-case conditions. The following engineering controls are recommended:

Design of hoods to provide adequate local exhaust ventilation (i.e., to provide face velocities greater than 152 cm/s in the hood openings when all hood doors open)

Construction of hoods from durable metal plates, which allow insertion/extraction of charge materials, drossing agents, drosses, pumps, mixers, and ladles with minimum hood openings

Use of ventilation systems that deliver clean, tempered air to each kettle work area

Complete enclosure of kettles and exhaust ventilation of the entire enclosure

Provision of vacuum and water hose connection and floor drains in the kettle area to facilitate cleanup and washdown after the kettles are charged

Casting

An exhaust enclosure for the pigging (casting) machine should be used. The molten metal reservoir or trough of the pigging machine is of primary importance. An enclosure can be fashioned with hinged, side access doors, but a canopy hood may suffice.

4.2.2 **Control Equipment.** The control equipment most commonly used in secondary lead smelters consist of fabric filters, scrubbers, and afterburners. Fabric filters are the most common devices used to remove particulate matter from secondary lead smelter process and ventilation gas streams. This section presents the application of these control devices while the operation and maintenance of the control equipment is discussed in Section 5.

Materials Handling and Preparation

The controls for these operations commonly consist of sprays and enclosures such that control equipment (i.e., fabric filters, scrubbers, and afterburners) are not usually necessary. When battery breaking is hooded, a scrubber is typically used to control sulfuric acid mist and particulates.

Smelting

The blast, reverberatory and rotary kiln furnaces used for smelting account for about 88 percent of total lead emissions from the secondary lead industry (EPA 1980).

The use of proper control equipment is essential to minimizing emissions from these processes.

The exhaust gases from the blast furnace and rotary kiln furnace are controlled in a fabric filter after passing through an afterburner. An afterburner torch in the top of the furnace combusts the carbon monoxide and hydrocarbons in the exhaust gas. Complete combustion ensures that fires or explosions do not occur in the fabric filter and that condensible hydrocarbons do not form sticky masses that can foul the fabric filter. Fugitive emissions from the blast furnace operations (i.e., tuyere punching, slag tapping, and crude lead tapping), can be ducted to the fabric filter without first passing through an afterburner.

Reverberatory furnace gases are usually well oxidized and do not require an afterburner. All exhausts from the enclosures and ventilation system can be sent directly to a fabric filter or scrubber. Reverberatory furnace particulates are larger than those emitted from blast furnaces and are thus more suitable than blast furnaces for control by scrubbing.

Refining and Casting

The hoods from kettle furnaces and casting operations are usually vented to a fabric filter or scrubber.

4.2.3 Procedural Controls. Procedural controls are those that use operating techniques or operating parameters to decrease emissions. These are mainly applicable to furnace operation and will be discussed, in this section, by furnace type.

Blast Furnace

Furnace operating parameters vary widely among smelters. Procedural controls can be illustrated with an example case study.

Table 3 shows a set of operating parameters for a 70-tonne/day blast furnace (Coleman and Vandervort 1980). Similar data are reported in Table 4 for a 37-tonne/day furnace (Coleman and Vandervort 1979). The top temperature of the larger furnace is between 77° and 180°C. That of the smaller one is 425°C. The higher top temperature results in greater emissions and makes temperature control more difficult. Additionally, the low afterburner set point (260°C) of the smaller furnace may result in incomplete combustion. No combustion occurs at all if the process gas temperature is high enough to cause the afterburner temperature control to shut the burner off. This represents a dangerous operating practice which may have an adverse effect on downstream emissions.

TABLE 3 OPERATING PARAMETERS FOR A 70-TONNE/DAY BLAST FURNACE[a]

Oxygen/flow rate	56 - 114 m^3/h[b]
Oxygen/air presssure	10 - 12 kPa
Oxygen/air temperature	472 - 495 °C
Blast air flow rate	3240-3740 m^3/h[b]
Water jacket temperature (inlet)	47.5° - 52.5°C
Water jacket temperature (outlet)	57° - 64.5°C
Furnace top temperature	77° - 180°C
Afterburner temperature (inlet)	90° - 175°C
Afterburner temperature (outlet)	700° - 800°C
Afterburner temperature (outlet after air dilution)	415° - 460°C
Afterburner temperature (outlet before mix point)	290° - 330°C
Fabric filter temperature (average inlet)	104° - 132°C
Stack temperature	82° - 90°C
Stack gas flow rate	115 000 - 120 000 m^3/h[b]

[a] Source: Coleman and Vandervort 1980

TABLE 4 OPERATING PARAMETERS FOR A 37-TONNE/DAY BLAST FURNACE[a]

Oxygen enrichment	0.5 to 2.5 percent
Blast air flow rate	3400 - 4250 m^3/h[b]
Water jacket temperature (inlet)	71°C
Water jacket temperature (outlet)	90°C
Furnace top temperature	425°C
Afterburner temperature	260°C
Fabric filter temperature (inlet)	104°C
Fabric filter lime injection rate	11.4 Kg/h
Fabric filter air-to-cloth ratio	27.3 m^3/h per m^2
Stack temperature	70° - 85°C
Stack gas flow rate	32 000 m^3/h[b]

[a] Source: Coleman and Vandervort 1979

[b] 20°C, 1 atm.

The operating parameters of each furnace must be examined on a case-by-case basis to determine the changes needed to improve emission control. The data in Table 3 can be used as a basis for initial comparison of blast furnaces. The operating parameters used by a given plant should take into account the associated emission control equipment. The blast furnace feed should be kept above the ring collar to minimize emissions during charging.

A thermocouple for measuring the melt tap temperature is not essential but can be helpful when operating the furnace to minimize emissions. The temperature of the melt is related to furnace operation and production rate. If this temperature is known, an operator can assess furnace operation. The production rate is typically measured and recorded, whereas material feed rates are not. Given the tapping temperature, an experienced operator can determine if the furnace feed rates and firing rates are proper and thus optimize production and minimize emissions.

Crude lead tapping and slag tapping are major sources of fugitive emissions from blast furnaces. Every attempt should be made to eliminate cross drafts near the exhaust ventilation for the lead launder and receiving vessel (i.e., hanging chains on the hood). Side access doors should be considered to eliminate the need for hood removal when the tap hole is tended.

The slag is generally cooled under the slag tap hood until a solid crust forms. The area should be provided with vacuum and water hose connections and floor drains to facilitate cleanup and thus help minimize fugitive dust emissions.

If the slag is stored or disposed of in an open storage area or slag pile, fugitive emissions may occur. Covering or wetting of the pile can be beneficial, but water disposal problems must be considered. Runoff from the slag pile should be neutralized before it is reused or discharged.

Reverberatory Furnaces

Procedural controls for reverberatory furnaces are similar to those for blast furnaces. There are, however, a few differences.

Reverberatory gases may be cooled in hairpin type coolers or by dilution with process or ventilation gases prior to particulate collection. Some particulate matter collects in the hairpin type coolers and must be periodically removed. Unless this collected material is conveyed automatically in an enclosed system, it can create a fugitive emission problem. If dilution cooling is used, the particulate handling and treatment problem is confined to the fabric filter area only.

Although exhaust ventilation and partial enclosure may be used to control reverberatory emissions, the ventilation system may become overloaded when wet charges are added. The high temperatures within reverberatory furnaces immediately vaporize any water that is introduced with the scrap. The consequent rapid gas flow can cause temporary overloading of the gas handling system. To prevent this occurrence wet charges may be pre-dried by use of a calciner prior to being fed to the furnace.

Reverberatory furnace slag is usually recharged to the furnaces. Storage safeguards as used for blast furnace slag should be observed. Slag from reverberatory furnaces should also be treated in the same manner as blast furnace slag.

Kettle Furnaces

Particulate emissions are released from kettle furnaces during charging, fluxing, mixing, drossing, and skimming. The following operating procedures can minimize emissions during these operations:

Start with kettle at 343°C, mixer raised and out of way, and all charging doors open.

Charge large metal scrap or sows (castings from smelting furnace) to the rear center of the pot.

Position mixer over mixer door in raised position and close mixer door.

Add bulk of flux material and complete charging to the front of the pot.

Close charge door and increase pot heating rate.

Lower mixer into molten pot and mix.

Add more fluxes or additives through a chute or feed pipe (with doors closed).

Stop mixer, open drossing hood doors, and skim off dross material.

Because large doors need not be opened for mixer insertion and fluxing while the pot is hot, major improvements in hood performance can be realized by keeping the doors closed.

Kettles cannot be provided with close fitting exhaust hoods because of the need to open the hoods. Major input materials include lead ingots, lead sows, and molten lead. Ingots and sows are typically loaded into kettles by chain hoists, mobile hoists, or other front-end loading devices. Kettle temperatures should be kept below 343°C until charging is complete to minimize fumes during loading. If lead is pumped into the kettle, hood doors should be kept closed while the molten lead is being charged into the kettle.

Drums, containing collected dross, that do not seal properly should be removed from service. Dross drums should not be reopened until the dross is to be recycled to the smelting furnace. No open drums of dross should be allowed outside an enclosed or exhaust-ventilated area. Provisions may be present to ventilate the dross containers as they are loaded and thus minimize fugitive emissions. The ventilation system, if present, may be an extension of the kettle system or a separate system.

Flue and Waste Dust Handling

Many of the precautions and operating procedures to minimize fugitive dusts from flue and waste dust handling activities were discussed earlier under raw material handling. This section will discuss the operational controls available from the time the dust is collected in control equipment until it is transferred to storage or directly recycled back to the furnace.

The dust collected in dropout chambers, spark arrestors, and fabric filter hoppers should ideally be recycled by enclosed conveyors directly to an agglomeration or slag furnace. If this facility does not exist and the dust is not recycled directly back to a furnace, provisions for temporary dust storage by means of drums or hoppers should be available. Drums or hoppers should also be available in the event that maintenance or malfunction of the furnace or screw conveyor precludes immediate recycle.

When flue dust is melted in an agglomeration or slag furnace, it is collected in a pot or thimble, and allowed to solidify. The solidified flue dust when dumped can be broken into lumps suitable for recharging to the blast or reverberatory furnace. Schitzgebel (1981) reports that the agglomerating furnace reduces the flue dust volume by 80 percent. When subjected to abrasion or severe weathering, the agglomerated dust can become powdery and be reentrained. During long-term storage, fugitive emissions can be minimized by covering, drumming, or wetting the material. Wetting requires water runoff collection and discharge to a sump for neutralization.

Flue dust conveyors should be enclosed, and conveyor transition points, discharge points, and storage points should be equipped with emission controls, such as capture hoods ducted to a collection unit. Collection hoppers, ladles, and thimbles should be covered. Where the flue dust is dumped from a container, ladle, or thimble for storage, an emission collection system should be used at the point of discharge and storage. Waste dust transported to a pond or storage area should be wetted prior to transport for fugitive emission control. A truck carrying flue or waste dust for off-site disposal should be enclosed, or the material should be encapsulated or pelletized prior to movement. The outside of the truck should also be washed down prior to leaving the plant.

Scrubber discharges should be neutralized and directed to a pond system. Solids can be prepared as a sludge or pug mill product and recharged to the furnaces. The clarified water can be reused for scrubbing. All ponds should be lined or made impervious to leaching.

If the collected material is discarded, the disposal area must be paved or lined to prevent leaching. Runoff from the disposal area must be collected and neutralized. If dust is stored, it must be covered or wetted to prevent reentrainment. If pond disposal is used, the pond must be lined, and its pH must be controlled. Landfill materials (e.g., battery cases) must be washed before disposal; all others (e.g., sludges and dust) should be properly neutralized or fixed and the soil should be prepared to avoid leaching.

Bags removed from the baghouse can be charged to a furnace for disposal and recovery of entrained metal. If stored, they should be placed in closed drums or containers.

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5 OPERATION AND MAINTENANCE

Compliance with air pollution control requirements over the long term depends on both appropriate design and construction as well as operation and maintenance procedures for emission control devices. Proper instrumentation and record keeping procedures are also critical to the success of a plant's operation and maintenance program which in turn results in fewer emissions from a secondary lead plant. This section discusses both the design considerations for emission control and ancillary equipment and operation and maintenance procedures required to provide reliable equipment operation and pollutant collection. Fugitive capture systems, fabric filters, and scrubbers, and ancillary equipment such as afterburners, fans, pumps, and ducting are addressed.

5.1 Fugitive Capture and Ventilation Systems

Ventilation systems serve two important functions: removal of pollutants from the workplace to protect workers from overexposure, and removal of the pollutants from the vented gas stream to provide environmental protection. Such systems are composed of two major components - the capture hood and an air pollution control system, usually a fabric filter called a baghouse.

The primary objective of the hooding/ventilation system is to catch all lead emitted by a given process and minimize lead concentrations in the workplace environment. This aspect is critical because any material that escapes capture cannot pass through the control equipment to be collected. Such material will thus escape into the atmosphere or settle nearby to create a potential reentrainment problem. In a lead smelter this problem is particularly severe because lead is a highly toxic material. To be effective, the hooding ventilation system must have a physical configuration that does not interfere with the operation and a sufficient flow of directed air to capture emissions under all operating conditions. Hood design principals are well known for most applications, and only a few general principals are discussed here. For a given situation, the size of the hood is influenced by the proximity of the hood to the source, i.e., close placement requires a much smaller hood than distant placement. As would be expected, a greater gas handling capacity is needed for a large (distant) hood in order to achieve the velocities needed to move the polluted air into the hood. Because larger hoods require the handling of larger gas volumes, they increase the cost of the pollution control equipment and operating costs. Hood size and placement are also influenced by the need for equipment access. Hoods may interfere with operators requiring access by overhead cranes or other materials handling equipment. Access can be restricted by close fitting hoods or larger, distant hoods which reduce overhead access. Movable hoods are used to solve access problems. These must be designed to minimize warpage, heavy surface wear, and other factors to maintain easy movement so that they will remain functional and be used conscientiously by the operators.

A properly designed hood is of such a shape and size that it encloses the process to the maximum extent practical and creates sufficiently high air velocities at exposed points to cause the emissions from a specific process to enter the exhaust system. Capture velocity is the air velocity necessary in front of a hood to overcome opposing air currents and to capture the contaminated air by forcing it to flow into the exhaust hood. Capture velocities for various conditions are given below (ACGIH 1980).

Condition	Capture velocity, cm/s
Contaminant released at low velocity into quiet air	25-50
Contaminant released at low velocity into air at low velocity	50-100
Contaminant released into rapidly moving air	100-254
Contaminant released at high velocity into rapidly moving air	254-1016

5.2 Fabric Filters

In fabric filtration, an assembly of tubular shaped fabric bags is housed in a steel fabricated structure called a baghouse. Because of this relationship, the terms "fabric filter" and "baghouse" are generally considered synonymous. The dust laden gas is passed through the bags to filter out the particulate; as the particulate collects on the bags, the pressure drop across the baghouse increases. The bags are periodically cleaned to prevent excessive pressure drop buildup. The cleaning cycle is controlled by a timing mechanism. Fabric filters are usually characterized according to the cleaning method used. There are three basic types of fabric filter used in the secondary lead smelters. These are the shaker, reverse flow, and pulse (or reverse) jet types.

Shaker and reverse air fabric filters are used to control process emissions from reverberatory and blast furnaces. Pulse jet fabric filters are used to control emissions in fugitive capture and ventilation exhausts, smelting furnaces, and refining furnaces. They are also normally used as the product recovery equipment in the production of lead oxides.

5.2.1 Fabric Filter Descriptions.

Shaker

In shaker-type units, the filter bags are hung from a structural framework. The structure is supported so that it will oscillate freely when driven by an electric motor. At set intervals, a damper is used to isolate a baghouse compartment so that no gas flows through it. The bags are then shaken for a preset period of time. The collected dust is dislodged from the bags (i.e., cleaning) and falls into a hopper from which it is subsequently removed. A conventional shaker-type fabric filter is shown in Figure 8. As shown, particulate-laden gas enters below the tube sheet and passes from the inside bag surface to the outside surface. Particles are captured on a cake of dust that gradually builds up as filtration continues. This dust cake is removed periodically by the mechanical shaking of the filter fabric. Shaking is accomplished by the rapid horizontal motion of the filter bag induced by a mechanical shaker bar attached at the top of the bag. The shaking creates a standing wave in the bag and causes flexing of the fabric. The flexing causes the dust cake to crack, and portions are released from the fabric surface. A portion of the dust cake remains on the bag surface and in the interstices of the fabric. The cleaning intensity is controlled by bag tension and by the amplitude, frequency, and duration of shaking. The residual dust cake gives a minimum resistance to gas flow, causing a static pressure drop that is higher than that of a new clean fabric. Woven fabric is used in shaker type collectors. Because of the low cleaning intensity achievable in this type of cleaning design, the gas flow is stopped before cleaning to eliminate particle reentrainment and allow dust cake release. The cleaning may be done by bag, row, section, or compartment.

Normally, shaker-type fabric filters are limited to low superficial velocities of less than 3 ft/min. This means that the total gas flow rate (at operating temperature and pressure) divided by the total cloth area available should not exceed the stated "velocity". This parameter is usually referred to as the air-to-cloth (A/C) ratio and is expressed in ft^3/ft^2-min. High values may lead to excessive particulate penetration or blinding, which result in reduced fabric life. Typical A/C ratios for shaker-type fabric filters range from 1.0 to 2.5 ft^3/ft^2-min.

Mechanical shaker-type units differ with regard to the shaker assembly design, bag length and arrangement, and the type of fabric. This design is applicable to both very small and large control systems.

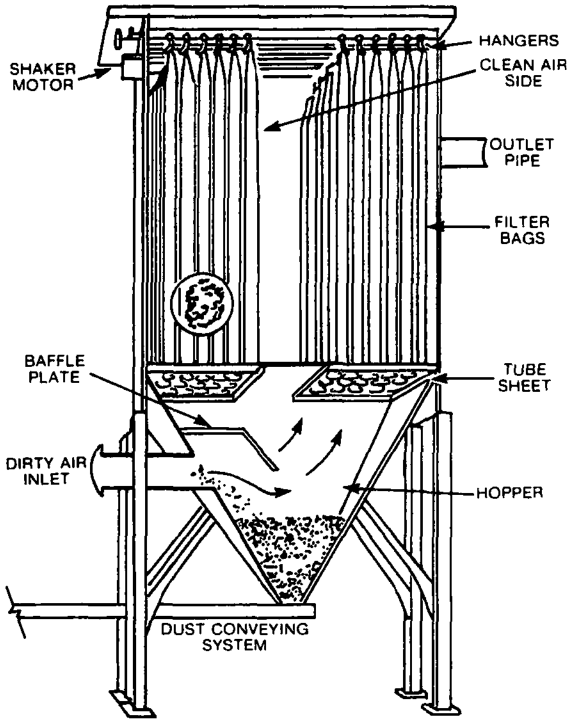

FIGURE 8 TYPICAL SIMPLE BAGHOUSE WITH MECHANICAL SHAKING

Reverse-Flow or Reverse Air

Reverse-flow baghouses are equipped with a secondary fan that forces air through the bags in an isolated compartment in the direction opposite to that of filtration. The reverse flow can be supplied by cleaned exhaust gases or by a secondary high-pressure fan supplying ambient air. This action collapses the bag and breaks the dust layer. When the filter bags are reinflated by being brought back on line, the broken dust layer is dislodged from the bag and falls into the hopper. If the main process fan is located downstream of the baghouse, the reduced pressure in the structure may eliminate the need for an auxiliary fan. Sometimes shaking and reverse-flow cleaning mechanisms are combined in the same baghouse unit.

The dust cake can be collected either on the inside or outside of the bag. In most reverse air fabric filters, an entire compartment is temporarily isolated for cleaning, as described above. Numerous other approaches are used commercially.

In filters with internal cake collection, cleaning is accomplished during off-line operation with individual compartments isolated. The filter bag may require anticollapse rings to prevent complete collapse of the bag and dust bridging. Cake release may be increased by rapid reinflation of the bag, creating a snap in the surface followed by a short period of reverse air flow.

Fabrics in reverse-air collectors may be woven or felt. The felts are normally restricted to external surface collection by means of high-pressure reverse air.

Reverse air filters are usually limited to A/C ratios of from 1.0 to 2.5 ft^3/ft^2-min, but the ratio may be higher depending on application. Although suitable for a wide range of applications, these designs are not usually competitive for use with very small gas flows, i.e., less than 5000 actual cubic feet per minute (acfm).

Pulse Jet

Pulse jet, fabric filters (also called reverse-pulse) use a short pulse of compressed air directed from the top to the bottom of each bag to clean the bags. This burst, usually less than one-tenth of a second, draws in other air as it passes through a nozzle or venturi. The resulting combined air mass expands the bag and loosens and removes the collected dust. In pulse jet units, the filtering is always done on the exterior bag surface.

The bags, supported by inner retainers (called cages), are suspended from an upper cell plate. Compressed air is supplied through a manifold-solenoid assembly (Figure 9) into the blow pipes shown in an end view. Venturis mounted in the bag entry area are intended to improve the shock effect. The baffle plate shown at the gas inlet is intended to prevent particles from abrading the bag.

By using pulse jet cleaning, the dust deposit is removed with only a brief interruption of the filtering flow. The fabric suffers a minimum of flexural wear and the filter installation is smaller because the fabric is in use practically all the time. Most pulse equipment utilizes felt rather than woven cloth. With felt, the filtration velocity can be 3 to 4 times that used in shake or reverse flow equipment, so the size of the pulse jet unit is smaller.

The components of a pulse cleaning filter include an air compressor, a storage or surge tank, piping, solenoids and nozzles, and some models use venturis and fabric support gridwork as well. Few, if any, ducting dampers and their associated controls are needed. Because no moving parts are required, the pulse method has an advantage in terms of maintenance. Many units also have top access to the bags so that the housing does not have to be entered to replace the bags.

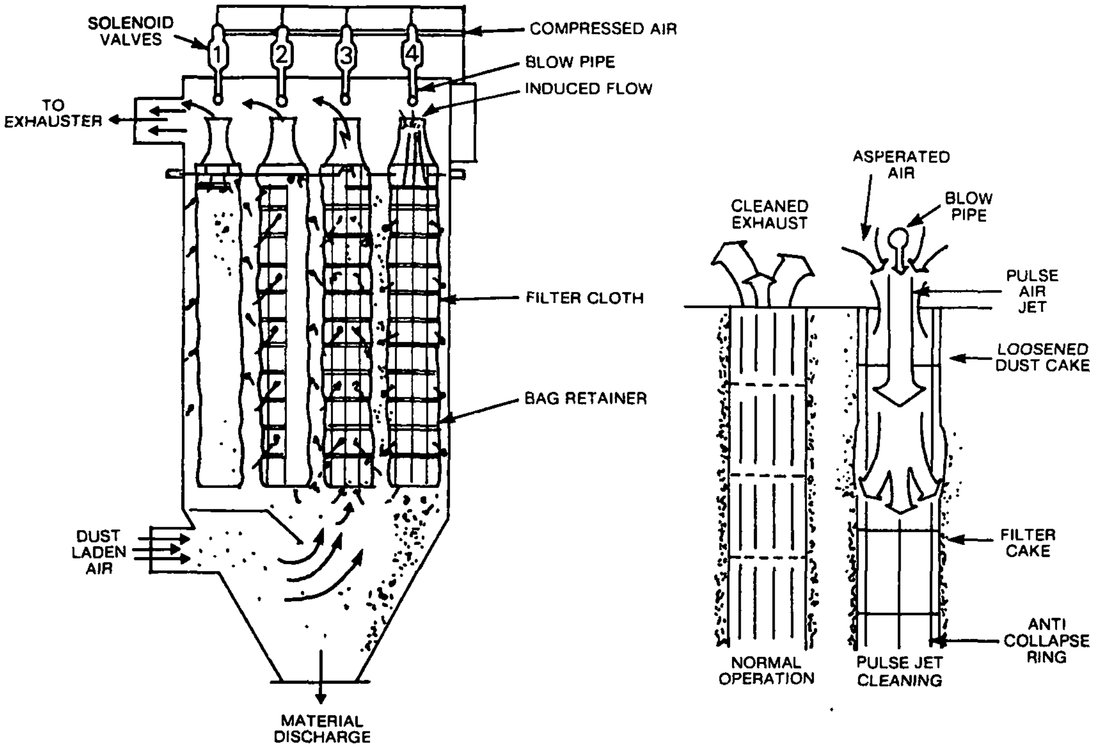

FIGURE 9 TYPICAL REVERSE-PULSE BAGHOUSE DURING CLEANING

Just as in shake cleaning, in which all the cleaning energy must be applied at one end of the bag, so in pulse cleaning the effectiveness of cleaning decreases with length of bag. For this reason short bags rarely exceeding three meters in length are used in pulse equipment. Since there is little fabric motion, the bags or tubes can be packed slightly closer without interchaffing.

Like other types of equipment, pulsed cleaning has its disadvantages. At present it is limited to temperatures of around 230°C because felt materials are not available for higher temperature. High pulse pressure can damage the fabric by overstretching it. Felts tend to plug in depth rather than blind. They may have to be cleaned rather than discarded because of their greater value. Felt, compressed air, power, and the compressor are all relatively expensive so that economic balances are different for pulse equipment. The electric power used to run the compressor can equal that for the primary fan. As a result, equipment sizes and shapes are different. Pulsed equipment may be best for some applications and simply not economical for others.

5.2.2 **Design Considerations.** Prior to design of any fabric filter, the following parameters must be determined: maximum gas volume, maximum gas temperature, temperature profile of cyclic operations, dust loading, particle size, and gas composition. These parameters dictate what type of fabric may be used and whether special corrosion-resistant material or insulation is needed. The buyer has considerable freedom in selecting the type of fabric filter (i.e., reverse-air, shaker, or pulse-jet cleaning) and the degree of accessibility and compartmentation of the fabric filter. Previous experience, however, has shown that some applications are more successful than others because of both initial design and maintenance considerations.

Generally, air-to-cloth (A/C) ratios are dictated by a combination of the application and cleaning mechanism used. Both shaker and reverse-air fabric filters have A/C ratios of 1.0 to 2.5; and ratios of 1.5 to 2.25 are most prevalent. The shaker fabric filter can have slightly higher A/C ratios because of the greater amount of energy available for bag cleaning when the bags are properly tensioned. Pulse-jet baghouses used to recover lead oxide or to control fugitive emissions from the furnace tapping areas and refining kettles typically have A/C ratios of 4 to 6.5. Pressure drops of 746 to 995 Pa are typical for these applications. Air to cloth ratios of fabric filters for material handling and transfer points typically range from 6.5 to 10 (with a pressure drop of 995 to 1493 Pa). An increase in A/C ratio decreases capital cost because the number of bags and size of the fabric filter decreases. As the A/C ratio increases, however, the pressure drop across the unit and the energy required to clean the fabric increase.

During the selection and design of a fabric filter, it is simple to incorporate design factors that improve accessibility and thus enhance the inspection and maintenance capabilities of plant personnel. Such factors generally increase initial costs, but can reduce maintenance time and costs. Easier, faster maintenance also reduces fugitive emissions from these operations. Large, easily opened doors enhance accessibility and allow easy entry by personnel wearing self-contained breathing apparatus and carrying tools. Larger walkways may also be required to minimize damage to the bags along the walkway caused by maintenance personnel during bag installation. In shaker and reverse-air fabric filters, access to the shaker mechanism and bag tensioning hangers enhances inspection and maintenance capabilities. In pulse-jet fabric filters, bag bleeding and pinhole leaks can easily be seen on the clean side of the fabric filter. Access for inspection (typically top access) must be provided. Both top access and top loading bags are recommended to reduce maintenance time for a pulse-jet fabric filter.

Selecting the appropriate fabric for the bags is very critical. The fabric types used in secondary lead smelter applications include acrylic/wool blends, wool, Orlon*, cotton, polyester, fiberglass, and polyester/fiberglass blends. Fibers used in air pollution control applications must be strongly resistant to chemical attack (acid in secondary lead applications) and moderately resistant to abrasion. The fibers have a maximum service temperature which is related to their chemical composition and strength-temperature relationship. Synthetic fibers lose strength at elevated temperatures and become plastic. Natural fibers (wool, cotton) char at high temperatures and become brittle.

Fabrics may be of woven or felted construction. Woven fabrics are typically used in reverse air on shaker applications where air-to-cloth ratios are low. Felted fabrics are typically used in pulse jet or reverse air (external filtering) where air-to-cloth ratios and cleaning energies are higher. The porosity of the fabric is influenced by the weave structure, tightness, and yarn weight.

Fabrics may have surface finishes or constructions that reduce dust penetration (napped or felted surface on woven fabrics) or improve cake release (by singeing). Fabric finish is extremely important for inside bag filtering where nodules develop, restricting filtering (increase pressure drop) and interfering with cake release. Singeing the interior surface to remove fibers not tightly bound in the weave reduces the formation of nodules.

Another important design consideration is "bag reach" (i.e., the number of bags in any row from the access walkway to the end of the row). A typical reach is five or six bags. Such a reach requires the removal of several bags to replace a bag far from the point of access and increases the chance of damage to surrounding bags. A reach of three or four bags represents a balance between increased baghouse shell size, and reduced maintenance cost.

Some pulse-jet fabric filters impose another maintenance hardship by providing only "dirty side" access without a walkway. In some units nearly all the bags must be removed to reach the farthest bag from the access hatchway. In this situation, changing all the bags is simpler and less costly than searching for and replacing worn or defective bags. Dirty side access to pulse-jets fabric filters is important, however, because it can reveal air inleakage at the hatch, cake release problems, and moisture problems in the cleaning system.

Pulse-jet fabric filters commonly encounter cake release and bag blinding problems because of dirty compressed air is being used for the cleaning pulse. An in-line air dryer or trap to remove water and oil from the supply line is recommended. The surge tank placement and the location of the pulse-air offtakes also affect the amount of water and oil blown into the bags. Placing the pulse-air offtakes above the surge tank allows water and oil to collect in the tank rather than pass into the baghouse and the filter media. A purge valve located at the bottom of the tank allows periodic bleeding of the collected water and oil.

Control of gas temperature requires attention in the design of fabric filters, particularly units serving "hot" sources. Cooling loops and dilution air usually keep gas temperature below the maximum that the bag fabric can handle. The thermal swing or temperature cycle encountered during normal operation is particularly important. Although many blast furnaces are equipped with afterburners without temperature controls, the gas temperature tends to decrease after each charge. The use of smaller charges at more frequent intervals will minimize gas temperature fluctuations. Duct systems are generally designed with dilution air inlets and cooling loops to decrease the gas temperature. If the gas is constantly cycling above and below the acid dewpoint, condensation and corrosion may occur. In this case, particulate matter becomes sticky and difficult to remove from the bags. Dust cake buildup causes a bag to stretch because of increased weight. Finally, the bag can tear loose from its hanger and could damage other bags. The stretching of the fabric tends to decrease cleaning efficiency, increase "bag bridging" (buildup of collected dust inside the bag), and cause excessive wear at the bag cuff. In shaker fabric filters, increasing shaker intensity to reduce dust cake buildup increases wear of both the fabric and the shaker mechanism. Feedback temperature controls on the afterburner and dilution air damper can maintain the temperature between set limits. The most successful facilities use Teflon-coated fiberglass bags in a temperature range of 138° to 163°C. Lower operating temperatures (to a minimum of about 95°C) are possible with Dacron bags and with acrylic and wool bags. The lower temperature limit is determined by the acid dewpoint (condensation temperature). One method to control the temperature of the gas coming from the afterburner is to permit outside air to be drawn into the system (i.e., the system operates under negative draft) before the baghouse with the air leakage rate controlled by a damper and a temperature sensitive controller located at the baghouse inlet.

Insulating the fabric filter helps maintain the temperature of the gas while it is being cleaned. Temperatures above the acid dewpoint minimize corrosion of hanger components, doors, and walls. Internal shell components can be lined with appropriate corrosion-resistant materials if necessary. Insulation should be applied to the baghouse shell, hoppers, and doors. Structural steel may be placed on the internal portion of the shell. The insulation may then be applied evenly across the shell to reduce "cold spots", which promote corrosion of the shell. In addition to reducing corrosion and improving cake release, insulation can reduce material handling problems in the hoppers.

Correct hopper slope angle, uniform insulation, sequential operating vibrators, and continuous dust removal can minimize hopper bridging. Access hatches (insulated) and anvils for vibrators or for manual rapping should be provided for dust removal in the event of hopper bridging. Continuous operation of the dust removal system may be assured by electrically interlocking rotary airlocks and screw conveyors to the exhaust fan.

After removal from the fabric filter, dust must be properly handled and disposed of. One option is to feed the dust to an agglomeration furnace, where it is melted for recycle to the smelting furnace. When dust is fed directly to the smelting furnace, much of the dust will be simply reentrained in the furnace off-gas and returned directly to the fabric filter.

In summary, selection and design of a fabric filter depend upon the specific process variables, the desired accessibility, and the available cleaning energy. If the unit is well designed and all other factors are held constant, costs resulting from increased bag accessibility and lower A/C ratios are generally offset by lower energy and maintenance costs.

5.2.3 **Operation and Maintenance Considerations.** Theoretically, fabric filters can achieve mass collection efficiencies in excess of 99.5 percent when particles are as small as 0.1 um. In practice, many process conditions and installation problems can reduce both the collection efficiency and the time available for service. Fabric filters require extensive preventive maintenance and inspection to reduce periods of excess emissions.

This section discusses malfunctions of fabric filters used to control process and fugitive emissions from blast, reverberatory and rotary kiln furnaces. It also suggests means of avoiding or correcting malfunctions. Such means include proper instruction and training in system maintenance, establishment of a preventive maintenance program, and use of instruments and records to diagnose and correct system deficiencies. The goals of the program are to ensure continuous compliance with standards, to extend system life, and to reduce operation and maintenance costs.

The discussion assumes that all normal mechanical, electrical, and lubrication procedures involved in plant operation have been conducted in accordance with good maintenance practices and as defined by equipment manufacturers' operating instructions or O&M manuals.

Factors Affecting Fabric Life

The fabric types used in fabric filters in the secondary lead industry are acrylic, acrylic/wool, wool, orlon, cotton, polyester, fiberglass, and polyester/fiberglass. Failure of the filter to maintain high efficiency is usually caused by fabric failure resulting from thermal degradation, chemical attack, or mechanical injury including abrasion. The reasons for failures may not be readily apparent and may result from subtle changes in the equipment caused by wear and deterioration. These factors are interrelated.

Dust is removed from the gas stream by passing the gas through a porous fabric upon which the dust deposits and builds a dust cake layer. The efficiency of dust collection depends on the integrity of the fabric structure supporting the dust cake. Any deterioration of the fabric structure that allows localized failure increases the penetration of dust through the system.

Each fabric has a continuous and maximum operating temperature suited to its properties. The temperature specified for continuous use is based on the rate of thermal degradation (polymer chain cleavage) that occurs at a given temperature. This temperature also influences the rate of abrasion and effect of chemicals on the fabric. For example, deterioration of the finish on fiberglass bags increases as the gas temperature increases. As the finish decomposes, the effective life of the fiberglass is reduced because of abrasion and/or chemical effects.

Temperature excursions — The most common cause of polymer chain breakage is exposure to high temperatures. Exposure to temperatures at or near the recommended continuous levels results in random chain breakage with reduced tensile strength over the life of the fabric. Typical life of acrylic bags at 104°C is between 6 and 18 months in service on a blast furnace. The life may be greatly reduced if the fabric filter is simultaneously exposed to acids and moisture.

Exposure to temperatures above the recommended continuous operating temperatures for a few minutes may not result in immediate failure, but will reduce the overall life of the fabric. The effects of repeated temperature excursions on tensile strength are cumulative.

The exposure of the fabric to temperatures above the maximum exposure temperature can result in immediate failure because of the complete loss of strength and permanent elongation (melting). Poor operation of the furnace and/or afterburner can result in burning the fabric by sparks and carbon and oil buildup on the bag surface.

Prevention of excessive fabric failure and periodic excess emissions requires installation of monitors to determine the temperature cycles of the system. It is an misconception that short temperature excursions do not cause permanent damage. It is necessary to inspect temperature charts to determine the potential for short-term failure caused by the excursions. Also a high-temperature alarm with an automatic method for bag protection (e.g., quenching or dilution) should be provided.

Chemical attack -- Polyester is generally rated as resistant to alkali attack, but at temperatures above 93°C in the presence of moisture, the polymer degrades rapidly. Cotton and Nomex are particularly susceptible to sulfuric acid attack below the acid dewpoint. The tensile strength of the fiber is reduced as the polymer chains are broken.

In general, the fiber begins to lose tensile strength immediately upon exposure to the gas stream. The life of the fiber depends on proper fiber choice for application to acid gases such as SO_2, hydrogen chloride (HCl), and hydrogen fluoride (HF). The fabric filter should be operated at the lowest temperature consistent with avoiding moisture or acid condensation.

Sources that frequently shut down can quickly destroy bags because of temperature excursions through the acid and moisture dewpoints. Shutdown should be accomplished by exhausting flue gases from the filter with dilution air (ambient) before cooling gases below the dewpoint. The purging removes the SO_2 and water vapor before condensation can occur on bag surfaces.

Mechanical injury/abrasion -- Mechanical injury is perhaps the most difficult type of failure to prevent as its principal causes are equipment deterioration and operator error. It may occur abruptly as from an inadvertent screwdriver puncture, or it may result over a longer period of time from accelerated wear caused by abrasion or excessive mechanical stressing.

The failure of the fabric may occur over a long period of time because of the abrasive action of dust particles on individual fibers in the structure. The failure may result from general abrasion over a large area or specific attacks in concentrated areas.

General abrasion of the fabric is a common occurrence and is accepted as the normal failure mode of the bag over its life. This type of failure cannot be prevented, but the rate of abrasion can be reduced by proper installation of bags to avoid bag-to-bag contact and by reduction of the amount of dust being handled. A cyclone may be installed as a precleaner to remove larger particles and reduce inlet loading.

Local intensive abrasion, which results in premature bag failure, is undesirable and can be prevented. High abrasion rates are commonly associated with improper bag installation or design flaws in the collector. Each case of abrasion failure must be addressed separately to determine if corrective action may be taken to reduce the frequency of failure.

Bag Installation

The improper installation of bags can result in premature failure of the bags and increased emissions. These failures can result in significant costs and also reduce production if downtime is required to change bags. This subsection is included to supplement manufacturers' instructions for installation of bags. The items covered are those that have been demonstrated by field experience to result in high bag failure rates.

Shaker and reverse-air systems -- Bags in shaker and reverse-air systems should be installed from the outer walls toward the center of the compartment. Bags should be hung according to manufacturers' recommendations by loop/hanger, eye-bolt/J-hook, or tongue/hanger assemblies. Each bag should also be inspected before hanging to ensure that it has no holes, is the proper size, and has a proper seam. Normally, the bags should be hung by row, the cuffs should be placed over thimbles, and the ring clamps should be attached. The fit of the bag over the thimble should be checked, and loose fitting bags should be discarded. Small bags that fail to meet specifications should not be forced over the thimbles.

In shaker and reverse-air fabric filters, the bag can be attached to the tube sheet by a thimble and clamp ring design or by a snap ring design. Dust enters the baghouse filter at the hopper in a horizontal direction and must turn vertically to enter the tube sheet thimbles. Heavy particles with higher inertia do not follow the flow and therefore do not enter the opening parallel to the thimble walls. The particles impact on the walls of the thimble and, if the thimble is short, on the fabric above the thimble. The action of the particles striking at an angle to the fiber surface increases abrasion. Roughly 90 percent of bag failures occur near the thimble. The use of double-layered fabric (cuffs) or longer thimbles reduces the failure rate.

In the snap ring system no thimble is used, and in some cases a cuff is not used. This exposes the bag to rapid abrasion a few inches above the snap ring. Add-on tube sheet thimbles may be used to reduce the effect.

Baffle plates or diffusers may be used to deposit large particles in the hopper before they contact the bags. The orientation of the plates is critical, however, because deflection of incoming gas into the hopper can resuspend collected dust and increase effective dust loading through the tube sheet.

The resuspension is reduced if the hoppers are operated with continuous dust removal; thus, dust remains below the gas inlet.

After a bag is clamped, the tension should be adjusted to the manufacturer's specifications by using a spring tensioning device or tightening the bag to a known length. In no case should the bag be allowed to hang freely and fold over the thimble. Also, tension must be uniform in all bags to provide uniform cleaning efficiency.

Each row should be installed in a similar manner. Installation from the outer walls toward the center of the compartment is required because of the deflection of the tube sheet as tension is applied. After installation, the tension of bags should be rechecked and adjusted as necessary. The use of proper tension reduces bag failures at the cuff, lessens wear on thimbles, and improves cleaning efficiency.

After bags are in service the fabric may stretch and cause slackness. The expansion is not uniform, and the seam may not stretch as rapidly as the woven portion of the bag. The bag can consequently take on the appearance of a "banana", and bags may come in contact with each other, resulting in abrasive damage. Such contact can be reduced by orienting the bags on each side of the walkway with seams facing to the outside of the compartment.

In the nonthimble design, improper installation of the snap ring can result in dust peneration between the tube sheet and the bag cuff. If there is a question concerning the seating of a ring, the bag should be removed and reinstalled. If an adequate fit cannot be achieved, the bag should be discarded.

Pulse-jet systems -- A pulse-jet fabric filter can be top load or bottom access. A top load system has the advantage of ease of bag removal without interference with adjacent bags. Normal installation in a top load system requires placement of a bag over a cage and placement of the cage and bag through a tube sheet. The venturi is then placed in the cage opening and secured by pressed fit or held down by clamps, depending on the manufacturer's design. Care must be taken that the bag has been correctly positioned over the cage, that the seam is not twisted, and that the bag fits tightly over the bottom of the cage. In systems using a receiving groove in the venturi for the cage, the cage tongue must be secured in the venturi groove before the retaining clamp is tightened. Failure to make a tight seal can result in bag/cage drops during pulsing and/or misalignment of the cage. During periods of complete system rebagging, it is advisable to use a pneumatic screw driver with adjustable torque to tighten clamps. This provides uniform installation, whereas hand tightening can vary because of fatigue of maintenance personnel. Uniform clamp tension and alignment of cages have been shown to reduce cage drops and excess emissions.

Bent or misaligned cages should not be used. Cages should be inspected for corrosion, broken wires, or sharp edges that may penetrate the bag surface.

Gaskets used between the venturi and tube sheet should be checked to ensure that they are elastic (not hard or deteriorated) and that the surfaces are sealed. Chemical attack can destroy gaskets or caulking. Such destruction allows dust penetration around the bag seal.

When a bag farther than the second row from the walkway must be replaced, the intervening bags should be temporarily removed to allow safe installation of the replacement bag. Otherwise, the intervening bags can be stretched and damaged, the proper installation and tensioning of the replacement bag can be difficult.

To avoid snagging and puncturing bags, maintenance personnel should not carry tools while in the compartment.

When dust is collected outside the fabric (e.g., by pulse-jet fabric filters), abrasion may occur in the lower portion of the bag because of the direct impact of particles on the bag surface. Baffles are required to distribute the incoming particles evenly and provide a uniform velocity over the bags. If a high failure rate is occurring in the lower bag area near the inlet, this mechanism should be investigated as the possible cause.

It is common practice not to remove dust that accumulates on the clean side of the tube sheet. The presence of dust is not a significant problem as long as penetration is not occurring. Heavy dust accumulation, however, results in rapid abrasive failure of serviceable bags. When the dust that has been emitted from previous bag failures settles on the tube sheet and collects around a bag, the weight collapses the bag and forms an orifice.

The reduction in area increases gas velocity and therefore abrasive damage to the bag in the area of the restriction. The increased tension of the bag also results in abrasion of the bag where it contacts the top edge of the thimble. Prompt removal of accumulated dust from the tube sheet after a bag failure can reduce damage to other bags.

If penetration occurs, deposited material should be removed from the tube sheet before installation or replacement of bags. This aids in location of failed bags and prevents damage to the remaining bags.

Bag Cleaning

The resistance to gas flow through the filter results from two mechanisms, fabric resistance and dust cake resistance. The fabric, when first installed, has a resistance defined in terms of the permeability. The resistance increases with gas velocity through the fabric and is a function of fabric construction and weight. The static pressure drop across the fabric increases as the dust cake increases on the fabric surface. At some preset point, the cake must be removed to reduce the resistance.

The effectiveness of removal is related to cleaning energy expended and dust cake properties. In general, sufficient residual dust penetrates the fabric structure to provide an additional static pressure drop after cleaning above the original clean fabric level. This incremental resistance caused by the residual dust cake remaining on the fabric is normal and attempts should not be made to obtain pressure drops achieved when the bags were new. Attempts to maintain static pressure drop at new bag levels by high cleaning energy cause rapid bag failure and also decrease the bag's efficiency to collect dust.

Cleaning Cycle — In normal operation, the cleaning cycle is controlled by timers and the bags are periodically cleaned on a time scheduled basis. The cycle is timed so that the system pressure drop remains between the upper limit and the lower level desired after cleaning. The duration and intensity of cleaning is controlled to achieve the lower pressure drop level (i.e., the after cleaning pressure drop) in as short a time as possible without undue wear of the bags. These are determined by experience. After installation of a complete set of new bags, the cleaning cycle time period should be reset after the bags have been in service one or two days. This allows the operator to set the timer to achieve the desired pressure drop range over the cleaning cycle (from the completion of one cleaning cycle to the beginning of the next). The operator or inspector (when reviewing the operation logs) should look for any increase (above the previous operating levels) in the lower (after the cleaning cycle) and upper (before the next cycle begins) pressure drops across the bags. An increase in these static pressure drops indicates a change in fabric/cake resistance. This change can result from changes in amount of cake buildup retained, furnace charge composition, afterburner temperature, oil deposits from plastics in the charge, or moisture from inleakage.

A measurement of static pressure drop should be made on a periodic basis to determine relative changes in dust cake resistance. A gradual increase in resistance can indicate oil deposits, fine particulate blinding of fabric, or moisture inleakage. The increase may be tolerated if it is not severe or if it does not decrease ventilation performance because of decreased volume of gas exhausted.

If an increase in pressure drop occurs, attempts should be made to diagnose the cause (oil, moisture, carbon), and corrective action should be taken. An increase in cleaning energy beyond manufacturers' recommendations should not be made, because it shortens bag life.

Because the stack pressure drop is a linear function of the filtering velocity, and thus the air-to-cloth ratio, the installation of additional bags (i.e., an increase in baghouse capacity) can be used to reduce an unacceptably high pressure drop where other remedies fail.

<u>Cake release</u> -- The ability to remove collected particulates (cake) from the fabric surface determines the cleaning frequency required for the filter system. Factors that affect the energy necessary to remove the cake include cake composition, porosity, and the effectiveness of the energy transfer to the cake/fiber interface.

The most common reason for poor cake release in the secondary lead industry is agglomeration in the bag due to oil, water, or carbonaceous particulates. Oil vaporized from the charge materials or from malfunctioning afterburner systems coats the bags and causes agglomeration of dust particles and coating of fibers. The cake does not break effectively when flexed, and additional energy is required to remove it from the surface. In severe cases the dust accumulated in fiber interspaces agglomerates and results in an increased cleaned bag resistance. As the blinding increases, the system static pressure drop increases sharply and cannot be reduced to the usual post-cleaning levels during the normal cleaning cycle. Because of uneven cake removal, gas velocity increases in local areas and reduces bag life through abrasion.

The presence of moisture either from operation below the dewpoint or from inleakage through the shell presents a similar problem. The cake release is impaired, and increased energy is required to remove the cake. As the cake adsorbs moisture, the specific particle volume increases. The swelling of the dust deposited in the fiber interspaces reduces porosity and causes fiber damage.

Specifically, wool fiber is hydroscopic and may adsorb two times its weight in water. Under these conditions, the fiber increases in volume by 150 percent. The increased volume reduces the open space between fibers and increases gas flow resistance.

Oil on bags may be detected by placing samples of the dust cake in water, agitating the mix, and then allowing the mix to settle. Oils will separate and appear as a sheen on the liquid surface. A small amount of oil or tar particles may be tolerated if the dust cake remains loose and removable. If oil interferes with cake release, a precoating material such as limestone may be introduced into the fabric filter inlet to adsorb the oils and protect the bags. The use of such systems must be carefully considered, however, because the coat treats the symptom and does not eliminate the cause of concern -- the oil. Attempts should be made to eliminate the source of oil or reduce amounts to acceptable levels.

If limestone precoats are used, it must be noted that bag failures which are not corrected result in increased emissions because of the higher grain loading entering the collector. Also, any inleakage or cooling that allows the gas stream to pass through the dewpoint promotes hardening of the dust cake and fabric failure. Continued operation below the dewpoint muds the bags; when the mud dries, a hard cake is produced. The cake cannot be removed without damage to the bags.

Proper design and operation of a furnace afterburner can eliminate the problems caused by carbonaceous particulate and oils. Dilution air or coolers can help insure condensation of metal fumes (particularly chlorides) prior to their entering the bag filter.

When the process is shut down, it is advisable to continue to operate the baghouse for one complete cycle (including cleaning). This operation purges it with clean air to avoid condensation and ensure that bag contaminants are removed.

Cleaning intensity -- The removal of the dust cake requires the breaking of the cake structure. The mechanism and energy (intensity) required to accomplish this is a function of previous items discussed.

Too little energy does not break the cake, and too much energy increases bag failure because of fiber abrasion. The proper intensity is defined as the minimum amount necessary to remove the proper amount of cake. Each system is unique, and identical systems at a site may not have the same cake release properties because of source variability and/or gas stream characteristics. Therefore, the required cleaning intensity must be matched to the system.

Because the intensity of cleaning is typically related to shaker amplitude and frequency in shaker collectors, it is assumed that cleaning is uniform in all compartments and that all bags in each compartment are equally clean. In practice this is not the case. The amplitude and force transmitted through each bag are functions of the distance from the drive mechanism in the shaker assembly, wear and clearance of linkages, bag tension, and dust cake properties between bag locations.

The natural segregation of particles by mass because of inertial forces in the collector inlet can result in a cake with large particles, higher porosity, and better cake release properties opposite the inlet. The segregation is greatly reduced if a baffle plate is used.

The proper cleaning of the bag requires the flexing of the surface to dislodge the cake. If bag tension is low, the bag may be flexed adequately at the top, but the standing wave dampens as it is transmitted downward. The installation of each bag must be checked to ensure proper tension. Manufacturers' literature should be consulted to determine the correct tension method. The fabric may elongate because of the weight of dust collected between cleaning cycles or bag tongues may slip in hangers. Thus, tension may change with time of service.

Assuming a reasonable dust cake depth before cleaning, the weight of dust before cleaning may be between 27 and 55 kg/bag. This can increase dramatically if oil or water reduces cake release.

A method used to evaluate the cleaning effectiveness and dust distribution across the tube sheet is to grasp the bag near the bottom just after a cleaning cycle has occurred and vigorously shake the fabric while the bag is tightly closed. The dust cake above is released and falls into the closed bag. The volume of dust above the restriction indicates the amount of separable dust cake remaining after cleaning. Several bags can be tested in this manner to assure that all bags are properly cleaned. When doing this test, proper precautions should be taken to avoid inhaling the dust emitted. The variation in cleaning should be noted with regard to possible causes. As mentioned, overtension can damage bags because of abrasion.

In reverse-air collectors, the cake is released by collapsing the bag with reversal of gas flow. The bag is flexed, and the cake removed from the surface by the cleaning gas. In systems with short bags (i.e., bags less than 2.5 m long), bags may be allowed to collapse almost completely. The bag must be reinflated in a snap action, and a dwell time must be allowed for the dislodged cake to flow from the bag before gas filtration commences. In this case low bag tension results in complete closure of the bag near the thimble, reduction of reverse gas flow through the bag, and consequently reduction of cleaning efficiency.

Tube sheet bridging -- In shaker or reverse-air fabric filters, dust cake is collected on the interior surface of the bags. The removal of the collected dust cake requires the free fall of the dust through the thimble and into the dust hopper. When systems are uninsulated or when the gas temperature is near the dewpoint, cake accumulates on the underside of the tube sheet and on the inside of the thimbles. Heat is transferred from the tube sheet to the uninsulated baghouse shell. The colder metal reduces dust temperature and causes agglomeration and deposition on the surface.

As caking increases, the ability of the dust to discharge through the thimble is reduced. Eventually, complete bridging of the bag results. In severe cases, the accumulation may extend several feet into the bag. The bridging occurs most commonly near the baghouse shell (outside rows) or near doors where air inleakage from deteriorated gaskets occurs. The bridge may normally be dislodged by flexing the bag with the hand near the top of the thimble. The dust above the bridge, because it is exposed to the gas stream, is free flowing and discharges after the cooler cake is broken near the tube sheet.

The breaking of the cake only returns the bag to service for a short period; bridging soon recurs. Continued operation in this condition decreases net cloth area and increases pressure drop. The higher A/C ratio increases bag abrasion and decreases bag life. The solution to the problem is to reduce heat loss through the tube sheet/shell by installing insulation or increasing the system temperature (e.g., increasing afterburner temperature).

Hopper bridging -- "Bridging" is a term applied to the blocking of dust discharge through an opening by the agglomeration of the dust. Bridging commonly occurs a short distance above the apex of fabric filter hoppers and results in partial or complete closure of the discharge.

Common causes of the agglomeration are moisture, oils, and temperature drop. In fabric filters that operate below or near the dewpoint, the added drop in temperature in the hopper as a result of radiative cooling initiates agglomeration of the dust. Moisture enhances agglomeration of the dust, and cake gradually builds up. The area available for dust discharge is reduced and complete bridging eventually occurs. Agglomeration can be initiated by a drop in dust temperature resulting from air inleakage through flanges, gaskets, doors, or weld failures in the hopper.

Continuous or repeated occurrences of hopper bridging indicate a chronic temperature or moisture control problem in the ventilation and control equipment system. Careful inspection of hoppers should be made to determine gas inleakage points, and repairs should be made. If an adequate temperature cannot be maintained, installation of insulation or an increase in afterburner temperature may be required. Bridging is not a common problem in tight systems that are insulated and that operate at proper temperatures.

Detection of Dust Penetration

To maintain continuous compliance with emission limits, the operator must identify and correct deficiencies in the system in an effective and timely manner.

The following subsections are provided to give guidance to maintenance personnel in detecting the point of dust penetration. The methods are designed to minimize the time required to determine the point of penetration and therefore reduce excess emission and/or equipment downtime.

Shaker and reverse-air systems -- As noted, excessive dust accumulation on the clean side of the tube sheet can damage bags. It is therefore necessary to remove the accumulated dust after a bag break. This removal allows the operator to evaluate the filter at a future date for evidence of penetration.

When a pinhole occurs in the fabric surface, an orifice is formed through which gas passes at high velocity. Particles that pass through the opening immediately begin to lose velocity, and the heavier particles settle to the tube sheet. The pattern of accumulated dust indicates the general area of the penetration. If the pinhole is near a walkway, the high velocity gas stream (jet) normally produces an impaction pattern. If the pinhole is farther back in the bags, the area between bags quickly fills with dust because of the impaction of particles on adjacent bags. The depth of the deposits normally indicates the general area in which dust penetration is occurring.

The operator should not enter the compartment without evaluating initial deposits on the tube sheet. It is almost impossible to use dust patterns for detection after an operator walks through them.

Cuff bleeding is usually indicated by a general deposit around the bag with a cone-like depression in the dust at the bag. The gases passing by the seal ring form small orifices and deposit dust around the bags. When the filter is isolated for inspection, the dust falls back into the orifice leaving a cone-like depression. These penetration points are easily detected if the tube sheet is cleaned frequently to remove accumulated dust.

Roughly 90 percent of bag failures occur near the bag thimble, primarily because of improper installation or tension. If the cause of failure is not immediately obvious, the inspector should begin at the thimble and then move up the bag.

Pulse-jet systems — Causes of dust penetration are not as easily detected in pulse-jet filters as in shaker or reverse-air systems. Because gas exits the cage opening (tube sheet) at high velocity, the particles do not deposit in the area of the penetration, but are generally spread over the whole clean side plenum.

Two mechanisms allow the identification of pinholes in these systems. Because the cleaning mechanism is semicontinuous and the gas stream is not interrupted for cleaning, small pinholes in the fabric are covered by the collected cake during filtering periods except shortly after pulse cleaning. The removal of the cake by the pulse allows penetration for a short period (2 to 3 seconds) before the cake is reestablished. The penetration results in an increase in stack opacity (puff), which coincides with the cleaning of the row containing the defective bag.

In systems in which the clean side of the filter is accessible, the penetrating dust accumulates on the underside of the compressed air blow tube at the stagnation point on the pipe. A routine check by sliding the hand along the blow tubes indicates the deposit. If these deposits are cleaned periodically, the method may be used to indicate the presence of a pinhole at a later date.

General System Operation

Continued operation of the collector system requires that all of the associated systems that interface with the collector function as designed. This subsection discusses several of the major failure mechanisms in these systems.

Dampers — Dampers are used to direct gas flows or isolate compartments for cleaning or repair. If these dampers do not function to seal the compartment in shaker fabric filters or to change the direction of gas flow in reverse-air fabric filters, proper cleaning of the bags cannot be accomplished. Malfunction increases pressure drop, but in multiple-compartment systems does not necessarily shut the system down. Because all dampers leak under adverse conditions, dampers and seats should be inspected to minimize leakage.

Compressed gas system — The air used to activate dampers and pulse-clean bags must be clean and dry. An in-line gas dryer (such as a dessicant, refrigerant, or filter) should be used to remove oil and water from the gas stream prior to introduction to the filter. As a safety precaution, a reserve tank with blowdown should be used at the filter to collect oil and water. If not collected, oil and water blind bags and can freeze in diaphragms during cold weather. The dryer should be serviced according to the manufacturer's recommendations. An internal inspection of the filter bags should be conducted periodically to check for oil and water.

Pulse-diaphragms -- Pulse diaphragms are used to open the valve seat in pulse-jet cleaning systems and provide a sharp finite surge of compressed gas through the blow tube to the venturi. The diaphragm in the closed position is held against the seat by compressed air and a spring. The compressed air is discharged through a solenoid valve and creates a pressure differential, which pulls the diaphragm from the seat. This momentarily allows passage of gas under the seat. Closure of the solenoid valve reestablishes the seal.

The solenoid commonly fails because of water freezing in the gas stream or because of electrical failure. In either case, the cleaning pulse cannot be initiated. If the solenoid does not seat, a constant release of compressed gas can be heard. The cleaning system can also fail because of diaphragm rupture or improper diaphragm seating. Constant bleeding of compressed gas into the blow tube can be heard. Both sounds will be a constant hissing.

A reduction in cleaning efficiency can occur if the diaphragm returns to the seat sluggishly. This can be caused by water, oil, or grit fouling the return spring, and can be heard as a sharp pulse that trails off.

In evaluating the pulse cleaning system, personnel should inspect the reserve air tank for water and listen for malfunctions of each pulse system through one cleaning cycle.

Preventive Maintenance

The proper timing of maintenance is important to maintain compliance with emission standards and reduce maintenance cost. Crisis maintenance cannot provide the level of continuous compliance required. When properly carried out, a preventive maintenance plan reduces maintenance time and makes efficient, effective use of the limited number of personnel employed at the plant.

Many problems with fabric filter systems result from long-term causes that gradually accumulate. A gasket leak around a door does not immediately result in system failure; but if allowed to continue, it can cause bag blinding, increased pressure drop, dust removal problems, and corrosion of the baghouse shell. Over many months, the shell can deteriorate, and gas penetration increases at an accelerated rate. Normally the symptoms (such as bridging or bag blinding) are treated, but the cause (the gasket leak) is not noted. If a crisis maintenance approach is used, the system can deteriorate almost beyond repair before it receives proper attention and it may be difficult to pinpoint the actual cause. Thus, such an approach can require replacement of major portions of the system. A preventive maintenance program, however, can be used to avoid such a situation.

In a preventive maintenance program, maintenance personnel should be advised of all factors that can cause component failures. Table 5 presents a guide for fabric filter operation and maintenance. Critical areas must also be regularly inspected, and accurate logs must be kept.

TABLE 5 FABRIC FILTER OPERATION AND MAINTENANCE GUIDE

Symptom	Cause	Remedy
Dirty discharge at stack	Bags leaking	Replace bags Tie off bags and replace at a later date Isolate leaking compartment if allowable without upsetting system
	Bag clamps not sealing	Check and tighten clamps Smooth out cloth under clamp and reclamp
	Failure of seals in joints at clean/dirty air connection	Caulk and tighten clamps Smooth out cloth under clamp and reclamp
	Insufficient filter cake	Allow more dust to build up on bags by cleaning less frequently Use a precoating of dust on bags (S, RF)
	Bags too porous	Send bag in for permeability test and review with manufacturer
High baghouse pressure drop	Baghouse undersized	Consult manufacturer Install double bags Add more compartments or modules

TABLE 5 FABRIC FILTER OPERATION AND MAINTENANCE GUIDE (Cont'd)

Symptom	Cause	Remedy
	Bag cleaning mechanism not adjusted properly	Increase cleaning frequency Clean for longer duration Clean more vigorously (must check with manufacturer before implementing)
	Compressed air pressure too low (PJ)	Increase pressure Decrease duration and/or frequency Check dryer and clean if necessary Check for obstruction in piping
	Repressuring pressure too low (RF)	Speed up repressuring fan Check for leaks Check damper valve seals
	Shaking not vigorous	Increase shaker speed (check with manufacturer)
	Isolation damper valves not closing (S, RF)	Check linkage Check seals Check air supply or pneumatic operators
	Isolation damper valves not opening (S, RF)	Check linkage Check air supply on pneumatic operators
	Bag tension too loose (S)	Tighten bags
	Pulsing valves failed (PJ)	Check diaphragm valves Check solenoid valves
	Air volume greater than design	Damper system to design point Install fan amperage controls
	Cleaning time failure	Check to see if timer is indexing to all contacts Check output on all terminals
	Not capable of removing dust from bags	Send sample of dust to manufacturer Send bag to lab for analysis for blinding

TABLE 5 FABRIC FILTER OPERATION AND MAINTENANCE GUIDE (Cont'd)

Symptom	Cause	Remedy
		Dryclean or replace bags Reduce air flow
	Excessive reentrainment of dust	Continuously empty hopper Clean rows of bags randomly, instead of sequentially (PJ)
	Incorrect pressure reading	Clean out pressure taps Check hoses for leaks Check for proper fluid in manometer Check diaphragm in gauge
High bag failure: wearing out	Baffle plate worn out	Replace baffle plate
	Too much dust	Install primary collector
	Cleaning cycle too frequent	Slow down cleaning
	Inlet air not properly baffled from bags	Consult manufacturer
	Shaking too violent (S)	Slow down shaking mechanism (consult manufacturer)
	Repressuring pressure too high (RF)	Reduce pressure
	Pulsing pressure too high (PJ)	Reduce pressure
	Cages have barbs (PJ)	Remove and smooth out barbs
High bag failure: burning	Stratification of hot and cold gases	Force turbulence in duct with baffles
	Sparks entering baghouse	Install spark arrestor
	Thermocouple failure	Replace and determine cause of failure
	Failure of cooling device	Review design and work with manufacturer

TABLE 5 FABRIC FILTER OPERATION AND MAINTENANCE GUIDE (Cont'd)

Symptom	Cause	Remedy
High bag failure: decomposition	Bag material improper for chemical composition of gas or dust	Analyze gas and dust and check with manufacturer Treat with neutralizer before baghouse
	Operating below acid dew point	Increase gas temperature Bypass and startup
Moisture in baghouse	System not purged after shutdown	Keep fan running for 5 to 10 minutes to purge exhaust gases from baghouse after process is shut down
	Wall temperature below dew point	Raise gas temperature Insulate unit Lower dew point by keeping moisture out of system
	Cold spots at structural members	Fully insulate structural members
	Compressed air introducing water (PJ)	Check automatic drains Install aftercooler Install dryer
	Repressuring air causing condensation (RF)	Preheat repressuring air Use process gas as source of repressuring air
High compressed air consumption (PJ)	Cleaning cycle too frequent	Reducing cleaning cycle if possible
	Pulse too long	Reduce duration (after initial shock all other compressed air is wasted)
	Pressure too high	Reduce supply pressure if possible
	Diaphragm valve failure	Check diaphragms and springs Check solenoid valve
Reduced compressed air pressure (PJ)	Compressed air consumption too high	See above
	Restrictions in piping	Check piping

TABLE 5 FABRIC FILTER OPERATION AND MAINTENANCE GUIDE (Cont'd)

Symptom	Cause	Remedy
	Dryer plugged	Replace desiccant or bypass dryer if allowed
	Supply line too small	Consult design
	Compressor worn	Replace rings
Reduced compressed air consumption (PJ)	Pulsing valves not working	Check diaphragms Check springs Check solenoid valves
	Timer failed	Check terminal outputs
High fan motor amperage/low air volume	High baghouse pressure	See above
High screw conveyor wear	Screw conveyor undersized	Measure hourly collection of dust and consult manufacturer
	Conveyor speed too high	Slow down speed
Material bridging in hopper	Moisture in baghouse	See above Add hopper heaters
	Dust being stored in hopper	Remove dust continuously
	Hopper slope insufficient	Rework or replace hoppers
	Conveyor opening too small	Use a wide-flared trough
Frequent screw conveyor/ air lock failure	Equipment undersized	Consult manufacturer
	Screw conveyor misaligned	Align conveyor
	Overloading components	Check sizing to see that each component is capable of handling a 100% delivery from the previous component
High pneumatic conveyor wear	Pneumatic blower too fast	Slow down blower

TABLE 5 FABRIC FILTER OPERATION AND MAINTENANCE GUIDE (Cont'd)

Symptom	Cause	Remedy
	Piping undersized	Review design and slow blower or increase pipe size
	Elbow radius too short	Replace with long radius elbows
Pneumatic conveyor pipes plugging	Overloading pneumatic conveyor	Review design
	Moisture in dust	See above

NOTE: When information applies to a specific type of fabric filter the following code is used:

RF - Reverse Flow
PJ - Pulse Jet
S - Shaker

5.3 Scrubbers

Wet scrubbers are used less often than fabric filters because they require more energy to attain the desired level of emission control and they require water treatment facilities. Wet scrubbers are not used to control emissions from lead oxide production or material handling and transfer because fabric filters are much more cost-effective for product recovery. When used, scrubbers are most frequently associated with control of emissions from refining kettles.

Gas streams to a venturi scrubber from kettles typically contain fine lead and lead oxide fumes and particulate matter generated by the addition of sulfur, phosphorus, sodium nitrate, sawdust, and other fluxes in the refining process. The gas temperature entering the scrubber in this application is typically 49° to 60°C because a large quantity of ambient air passes through the hooding. Thus, a presaturator stage is not needed to decrease the gas temperature. The water is typically introduced to the venturi throat either by spray nozzles or by a flooded weir system. In either case, the acceleration of the gas stream in the converging section and throat of the venturi provides the shear force to transform the incoming water to small droplets.

The primary collection mechanism for a venturi scrubber is particle impaction on the water droplets. The efficiency of this mechanism depends on the size of the particulates. Particulates with diameters from 0.1 to 0.5 µm require a high energy expenditure to obtain the high pressure drop needed for collection by impaction. Some of

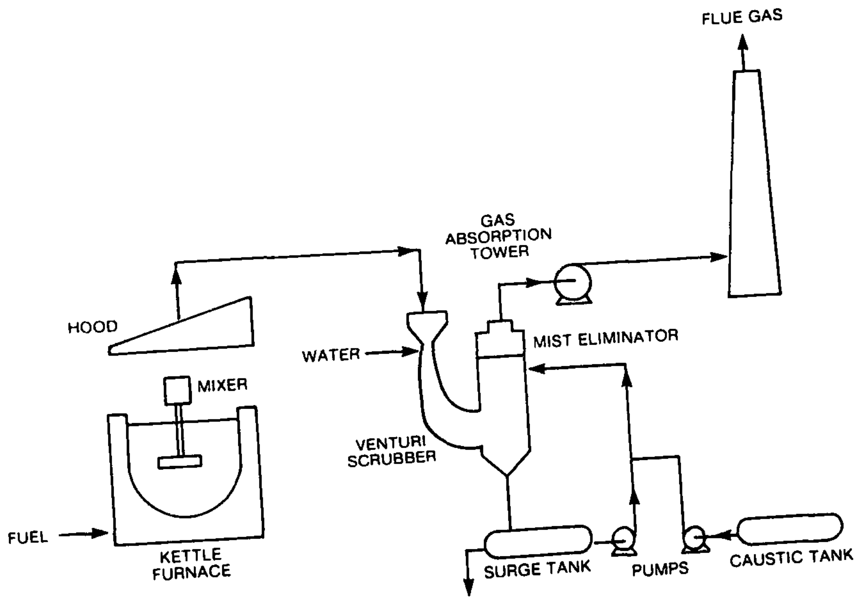

FIGURE 10 VENTURI SCR

these particles may be collected by a diffusion mechanism in the divergent section of the venturi, but collection efficiency by this mechanism is typically not very high.

After collection of the particle on the water droplet, the droplet must be separated from the gas stream. This is typically accomplished by a cyclonic separator that may be either a separate component or an integral portion of the stack base.

5.3.1 Design. Important factors in scrubber design are good water distribution in the scrubber throat and either use of nonplugging nozzles or provisions allowing individual removal of nozzles from the scrubber exterior for inspection and replacement while the scrubber is on line. A hatch to provide access for periodic inspection of the scrubber throat should be included. A method of determining water flow rate, venturi pressure drop, and fan power utilization is useful in determining venturi performance. Typically, venturi scrubbers are constructed of 316 L stainless steel to resist corrosion.

Most of the energy required by a venturi scrubber is used to accelerate the water droplets to the velocity of the gas stream. At the throat of the venturi, water droplets have essentially no velocity but gas streams typically have velocities of 7500 to 15 000 cm/s for optimum collection efficiency. This velocity gradient allows particulates to impact upon the larger water droplets. Adding more water provides more water droplet "targets" and increases particulate collection. Increasing the amount of water accelerated also increases the scrubber pressure drop and energy use. Typical pressure drops of wet scrubbers applied to refining kettles range from 5722 to 9952 Pa at liquid-to-gas (L/G) ratios of 0.4 to 0.6 liter/m^3.

Weir sumps are normally used to allow particulates to settle out of the scrubber water. Holdup times of 2 to 3 hours are typical. Bleedoff lines are usually not provided, and losses resulting from evaporation and droplet carryover are typically made up at the sump by maintaining a certain water level with a float and lever connected to a water valve. The sump must be periodically drained and emptied of sludge, which is usually landfilled.

5.3.2 **Operation and Maintenance.** Wet scrubbers can provide continuous, reliable service when they are operated properly and regular maintenance is performed. Poor operation and maintenance leads to component failure, which can result in poor scrubber performance and/or damage to the system. Most scrubber failures result from abrasion, corrosion, solids buildup, and wear of rotating parts. Common failure modes for individual components are discussed below.

Nozzle Plugging

Nozzle plugging is one of the most common malfunctions in scrubbers. Plugged nozzles reduce the L/G ratio or cause maldistribution of the liquid. Nozzle plugging results from improper nozzle selection, excessive solids in scrubbing liquors, poor pump operation, or poor sump design. Remedies for nozzle plugging include replacement with nozzles of a different type, frequent cleaning of the nozzles, and a reduction of liquor solids content by increasing liquor blowdown and makeup water rates. Nozzle plugging can be detected by observing the liquid spray pattern the nozzles produce. If the nozzles are not accessible while the pumps are operating, they should be checked during scrubber shutdowns for evidence of caking over the nozzle openings. A reduction in water flow rate during scrubber operation is an additional symptom of nozzle plugging.

Solids Buildup

Solids buildup is another problem common to wet scrubbers and one that is often difficult to control. The two types of solids buildup are sedimentation and chemical scaling. Sedimentation occurs when a layer of particles becomes attached to a surface or settles in areas of low turbulence. Sedimentation can lead to plugging of pipes and ducts or to buildup on internal parts. Chemical scaling results from a chemical reaction of two or more species to form a precipitate on the surfaces of scrubber components.

Solids buildup may occur in piping, sumps, instrumentation lines, or ductwork, and may lead to reduced scrubber efficiency and major equipment failure. Most scrubbers using open pipes cannot reliably tolerate liquor slurries of over 15 percent solids by weight. It is usually best to maintain solids content at less than 6 to 8 percent (Schifftner, 1979). Techniques to control scaling include increasing the L/G ratio, controlling pH, providing greater residence time in the holding tank, and adding other chemical agents such as dispersants. Solids buildup can be detected by inspection of accessible components and by inspection of the inner surfaces of piping, tubing, and ductwork at removable fittings and hatches.

Corrosion

Corrosion problems arise frequently in wet scrubbers, especially when the gases being cleaned contain acid-forming compounds or soluble electrolytic compounds such as the oxides of sulfur encountered in secondary lead smelting. The combustion of fossil fuels, especially coal, coke, and residual fuel oil, yields oxides of sulfur, which can produce sulfuric acids in scrubbing liquors. Recirculation of scrubbing liquors greatly increases the concentrations of any corrosive agents they contain. Chlorides contained in the scrubbing liquor can cause chloride stress corrosion of stainless steel.

Prevention of corrosion is best handled through proper choice of materials of construction and through pH control. When a pH control system is to be the principle defense against corrosion, it will require regular maintenance at frequent intervals, especially at the pH electrodes. Another common operating problem occurs when scrubber liquor blowdown rates are reduced to limit the emission of pollutants into surface waters. Reducing or eliminating blowdown can so greatly increase the acid and electrolyte concentrations in the liquor that otherwise acceptable materials of construction become ineffective against corrosion.

Abrasion

Abrasion can occur where gases or scrubbing liquors containing high concentrations of abrasive particulate are in the turbulent mode or are subjected to a sudden change in flow direction. Typical wear areas in scrubbing systems include venturi throats, walls of centrifugal mist collectors near the inlet duct, and elbows in the ductwork

(Schifftner, 1979). Solutions to abrasion wear include the use of precleaning devices and the use of large-radius turns in ductwork.

Pump wear is also a common problem in scrubber systems. Pump housings, impellers, and seals are subject to abrasion and corrosion by scrubber slurries. Rubber linings and special-alloy pump materials are often used to reduce abrasion and corrosion of the housing or impellers. Installation of a water flush in the seals can help reduce wear of the seals (Czuchra, 1979).

Preventive Maintenance

Preventive maintenance is an important tool in assuring the continuous operation of scrubber systems. Preventive maintenance programs for scrubbers should include periodic inspection of equipment, replacement of worn parts, periodic cleaning of components prone to plugging, maintenance of an adequate spare parts inventory, and recording of all maintenance performed on scrubber equipment.

All worn parts and malfunctioning equipment should be serviced as they are discovered to prevent deterioration of system performance and to prevent damage to equipment. This requires an adequate inventory of spare parts for the system. Parts that must be maintained in stock include nozzles, bearings, pump seals, liners for pumps with replaceable liners, pump impellers, wear plates for fan wheels with wear plates, pH probes, and valve parts (Fontana and Greene, 1967). Records should be made of all maintenance performed and all parts replaced. This information is useful in planning subsequent preventive maintenance schedules and in determining the type and number of replacement parts needed.

5.4 Afterburners

The primary function of an afterburner on a blast furnace is to oxidize carbon monoxide (CO) and hydrogen sulfide (H_2S) from the blast furnace to form carbon dioxide (CO_2) and SO_2. Afterburners may also be designed to oxidize organic particulates (residual hydrocarbons) that result from charging "plugs" (i.e., battery terminals) or pieces of battery casing. It is advisable to avoid the very tacky particulates caused by incomplete combustion of the plastic battery cases by reducing the quantity of plastic in the feed.

5.4.1 **Design.** The actual design of afterburners depends on temperature, contact time, and mixing of the gas stream. The temperature needed for complete combustion must be greater than the highest auto-ignition temperature of all of the individual components present. The contact time is usually approximately 1 second. Temperatures needed at these low contact times are approximately 980°C. Mixing must be insured by adding the necessary amounts of additional air or oxygen for the combustion to take place.

Some facilities use afterburners as gas reheaters because the quantities of air inleakage or dilution air lower the gas temperature enough to cause problems in the control equipment. In these cases, oxidation of CO, H_2S, and organic particulates is more difficult, and larger quantities of fuel and more reaction time must be provided.

Afterburners may be cylindrical or rectangular in cross section and are usually constructed of refractory materials inside a steel shell. The afterburner consists of a mixing section to provide for contact between the contaminated gases and the burner flame, and a combustion section where the hydrocarbons are destroyed by incineration.

5.4.2 Operation and Maintenance. Proper operation of an afterburner system requires control of contaminant quantity and characteristics and requires regular maintenance of the burners. As with other particulate control devices, complete instrumentation and an effective preventive maintenance program are necessary.

Burners

Burners are high-maintenance items because of the high temperatures and small orifices (Ross, 1977). When the contaminated gas stream is used as the combustion air, fouling of the orifices and/or deposits in the air delivery lines can occur. Impurities within the oil can lead to similar problems. A second problem is improper sizing of the burner(s). This can lead to low gas temperatures resulting in incomplete oxidation of particulate matter. Burners with poorly adjusted air-fuel ratios can generate soot, which fouls downstream heat exchange surfaces.

Minimizing of burner problems is facilitated by providing a means of visually checking the flame for proper luminosity, length, and stability. Also, an adequate inventory of spare parts should be kept. If fouling continues, a precleaner may be economical. Finally, afterburner instrumentation such as the flame sensor and the temperature controller should be checked regularly.

Flue Gas Characteristics

Variability of flue gas quantity and heat content should be minimized by controlling the process operation. Excess concentrations of combustible gases and vapors can lead to high temperature excursions, which damage the afterburner shell. High gas flow rates lead to poor particle oxidation resulting from decreased residence time and decreased reaction temperature.

Contaminants containing sulfur or chlorine compounds may be oxidized to highly corrosive species such as hydrochloric acid vapors and sulfuric acid vapors. These could result in chemical attack of the afterburner shell under certain circumstances. Special materials of construction are required when these contaminants are present.

5.5 Auxiliary Equipment

5.5.1 Fans. Either axial or centrifugal fans may be used in typical smelter ventilation applications. Axial fans are often selected for high-volume, low-pressure-drop applications such as building and local ventilation. Centrifugal fans are usually selected for high-pressure-drop applications such as process exhaust gas cleaning.

Centrifugal fans are divided into three subclassifications: forward curved, straight (or radial), and backward curved. Forward-curved centrifugal fans are compact, have low tip speeds, and thus are quiet. They are usually used against moderate static pressure (e.g., in air conditioning systems) and not recommended for the movement of dust or fumes, which can adhere to the short curved blades and cause imbalance. Straight (or radial) fans have intermediate tip speeds, are noisier than forward-curved fans, and are used in dirty environments. Backward-curved fans have high tip speeds and high efficiencies. Because material can adhere to the blades, these fans are seldom used to move extremely dirty gas streams.

As the air flow through a given system increases, so does the static pressure. As the flow rate increases through a fan, the static pressure increases, reaches a maximum, and decreases. For a given fan and duct system, the two characteristic curves cross at a point where the system will operate.

Any selected fan and duct system will equilibrate at a flow rate and fan static pressure. The flow rate can be increased by reducing the system resistance or by increasing fan performance. When changes are made, new performance criteria can be estimated by the following fan laws:

Air flow varies directly with fan speed.
Total pressure and static pressure vary with the square of the fan speed.
Fan horsepower varies with the cube of the fan speed.

Fan wear is a common problem. Forced-draft fans often suffer abrasion because of exposure to particulate-laden gases. Wear problems in forced-draft fans can be addressed by the use of special wear-resistant alloys, by reduction of fan rotation speeds (by installing a larger fan), or by moving the fan to an induced-draft location on the clean air side of the gas cleaning system. Induced-draft fans can undergo corrosion or solids buildup on the blades if mist is carried over from the liquid entrainment separator. Induced-draft fan problems can be addressed by use of corrosion-resistant materials or by improving liquid entrainment separation.

Table 6 summarizes causes and remedies for common ventilation system symptoms.

TABLE 6 VENTILATION SYSTEM OPERATION AND MAINTENANCE GUIDE

Symptom	Cause	Remedy
Dust escaping at source	Low air volume	See below
	Ducts leaking	Patch leaks so air does not bypass source
	Improper dust flow balancing	Adjust blast gates in branch ducts
	Improper hood design	Close open areas around dust source Check for cross drafts that overcome suction Check for dust being thrown away from hood by belt, etc.
Low fan motor amperage/ low air volume	Fan and motor sheaves reversed	Check drawings and reverse sheaves
	Ducts plugged with dust	Clean out ducts and check duct velocities
	Fan damper closed	Open damper and lock in position
	System static pressure too high	Measure static on both sides and compare with design pressure Duct velocity too high Duct design not proper
	Fan not operating per design	Check fan inlet configuration and be sure even airflow exists

TABLE 6 VENTILATION SYSTEM OPERATION AND MAINTENANCE GUIDE (Cont'd)

Symptom	Cause	Remedy
	Belts slipping	Check tension and adjust
Fan motor overloading	Air volume too high	See below
	Motor not sized for cold start	Damper fan at startup Reduce fan speed Provide heat transfer Replace motor
Air volume too high	Ducts leaking	Patch leaks
	Insufficient static pressure	Close damper valve Slow down fan
Excessive fan wear	Improper fan	Check with fan manufacturer to see if fan is correct for application
	Fan speed too high	Check with manufacturer
Excessive fan vibration	Buildup of dust on blades	Clean off and check to see if fan is handling too much dust (see above) Do not allow any water in fan (check drain, look for condensation, etc.)
	Wrong fan wheel for application	Check with manufacturer
	Sheaves not balanced	Have sheaves dynamically balanced
	Bearings worn	Replace bearings

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6 INSTRUMENTATION AND RECORDKEEPING

The use of instrumentation and recordkeeping procedures can provide a cost-effective method of improving and optimizing both process operation and control equipment performance. Well designed equipment is necessary to obtain maximum benefit from the instrumentation and recordkeeping. Performance problems caused by poorly designed equipment are likely to continue until such equipment is upgraded or replaced. Parameters measured by the instruments and data assimilated through recordkeeping should provide operators with information concerning both instantaneous and long-term performance characteristics of the process and the emission control equipment. The specific objectives are:

Instantaneous evaluation of process operation
Increased data for troubleshooting both process and emission control equipment
Optimization of process variables and control equipment performance
Enhancement of preventive maintenance scheduling
Operator alertness to conditions that may damage the equipment
Reduction of malfunctions

A comprehensive package of instruments and recordkeeping should be developed to aid in achieving the plant operating objectives. Although a comprehensive package of instruments and recordkeeping requires capital investment and manpower, costs should be offset by increased production and control efficiency and by reduced energy and maintenance cost for the process and emission control system.

The primary instruments used at a secondary lead facility are pressure and temperature indicators. These instruments provide static pressure and temperature profiles for each ventilation system. Profiles start from the process and end at the exhaust point. They can be used to determine a baseline case, which represents satisfactory operation as well as the design basis for the installed air pollution control equipment. Any major deviation from baseline parameters indicates either a process change or a malfunction requiring maintenance. With baseline values established, plant personnel may take steps to optimize O&M practices.

6.1 Instrumentation

Fabric Filters Applied for Furnace and Process Emissions

Instruments for furnaces and process emission fabric filters have been limited at most secondary lead facilities. The following minimum instruments are recommended: a temperature indicator (thermocouple) and a static pressure indicator (e.g., a magnehelic gauge) at the outlet of the furnace, static pressure and temperature indicators at the inlet and outlet of the process emission fabric filter, and an indicator of the fan motor current. These instruments allow operating personnel to determine the gas flow rate and the amount of gas cooling between the furnace afterburner and the outlet of the process emission fabric filter. Automatic temperature recorders should be used to provide operating records and may be used for automatic control of afterburner firing rate and air dilution. In addition, alarms can be connected to alert operators to temperature excursions. Temperature indicators at the inlet and outlet of the process emission fabric filter should be used to detect air inleakage, in conjuction with static pressure indicators to measure pressure drop across the fabric filter. The temperature and static pressure at the fabric filter outlet are also used to establish fan operating speed. Because fan speed is usually constant, only a periodic check is necessary. The static pressure, temperature, fan speed, and fan motor horsepower are used to establish the gas flow rate through the fabric filter. Additional sampling points (static pressure taps) should be installed to allow further analysis of the ventilation system. These sampling points should include the inlet to the blast furnace afterburner, the inlet to the cooling loops, and each leg of the cooling loops. Although permanent instruments are not needed at these points, provisions for troubleshooting with portable instruments should be included.

A static pressure indicator at the duct from the hood may be needed to assess the system performance. When combined with a visual check, use of such an indicator can confirm proper hood design and fugitive emission capture. Continuous measurement of hood face velocity is usually impractical although this should be calculated after hood installation.

At facilities that use pulse-jet fabric filters for fugitive emission control, a pressure indicator should be installed to determine the pulse header pressure. Further, an alarm can be connected to such an indicator to signal the operator when pulse pressure drops below a preset value.

Static pressure indicators must withstand high temperature and dust loadings. Because the most common problem with pressure indicators is plugging of the taps, provisions for cleaning the taps must be included. The use of portable instruments and the installation of pressure taps in the ductwork allow easy periodic checks of ductwork parameters. Pressure measurements alone indicate the permeability of the cloth, how heavy the dust deposit is before cleaning, how complete the cleaning is, and whether the fabric is starting to plug or blind.

Fabric Filters Applied for Fugitive Emissions

Fugitive emission fabric filters require a minimal number of instruments. Inlet and outlet static pressures and temperatures should be measured. These data can be used to determine pressure drop across the fabric filter, fan temperature, and fan static pressure. Also, the fan motor current should be measured to determine gas flow rate at the fixed fan speed.

Wet Scrubbers

When used, wet scrubbers are typically installed to control emissions from refining kettles. In this application, a single temperature indicator is necessary to determine fan operating temperature for calculation of gas flow rate. A simple dial thermometer at the inlet or outlet of the fan is sufficient. Periodic calibration checks are needed to ensure that vibration does not affect the accuracy of the thermometer.

The fan current, venturi pressure drop, and water flow rate should be monitored. As previously mentioned, fan speed is considered a constant until changed by plant personnel and need not be monitored on a continuous basis. Pressure drop can be monitored by the same methods as those used with fabric filters. Liquid flow rate to the scrubber can be monitored by various flowmeters, including rotameters, orifice meters, or ultrasonic/doppler shift meters. Measuring the pressure from the pump to the scrubber header does not eliminate the need to ensure that scrubber liquid reaches the scrubber in the prescribed quantities.

When materials of construction must be protected or when the scrubber is used to remove SO_2, the pH should be monitored. Continuous pH monitoring requires frequent inspection and cleaning of the probe, particularly when the monitor output is interfaced with a device to control addition of caustic solution. Many facilities use batch neutralization or add caustic according to a prescribed schedule because pH meters have typically not provided adequate service. One promising method of determining pH is sidestream monitoring, in which a sample of the sump liquor is withdrawn for pH analysis. Sidestream monitoring may be either continuous or periodic.

Afterburners

An afterburner requires an outlet temperature indicator, a fuel flow rate indicator, and a fuel use integrator. In oil-fired systems, air atomization pressure may also be measured to determine proper burner operation. The temperature indicator (i.e., thermocouple) may be connected to a feedback device that controls the fuel firing rate and maintains the design outlet temperature. An inlet thermocouple may be added to the system and used with the outlet thermocouple in a feedforward/feedback device that controls the afterburner firing rate.

Continuous monitoring of oxygen and carbon dioxide is not practiced at secondary lead smelters. Grab samples and an Orsat analyzer, however, can be used to optimize the performance of the blast furnace afterburner.

6.2 Recordkeeping Procedures

Some minimal records should be kept and periodically analyzed to determine correlations between operating practices and cycles. Daily records should include charts from all temperature instruments, data on the fabric filter pressure drop before and after cleaning (if applicable) and an estimate of the average or typical volume of gas handled. The A/C ratio should be calculated for fabric filters, and any changes should be noted. Also, daily records should indicate production rates and all upsets or malfunctions. Internal inspection results and bag failures should be recorded. Records should describe the general condition of each compartment and the specific location and nature of all bag failures. Periodic analysis of fabric filter records can indicate trends (e.g., specific types of bag failures in a specific location) and suggest the need for modification. In addition, periodic review of records can suggest optimization strategies for both production and preventive maintenance and thus can reduce unexpected downtime and lost production.

Similar daily records should be maintained for scrubbers and afterburners. Daily fuel consumption and fuel use rate cycles should be recorded for afterburners. Scrubber liquor flow rate, fan current, and pressure drop should be recorded. Again, both long-term and short-term trends are important for optimizing production and preventive maintenance.

Initially, static pressure and temperature profiles should be checked weekly or biweekly to determine system characteristics. As experience increases, checks can be less frequent. In addition, instruments should be checked at least weekly or biweekly, if not daily.

7 MONITORING

One purpose of monitoring the operations and maintenance of the furnaces at secondary lead smelters is to ensure that the performance of associated air pollution control equipment is maintained on a continuing basis.

From an air pollution control viewpoint, the major problems associated with secondary lead smelting are efficient capture of particulate matter generated by the furnaces and subsequent removal of the particulate by abatement equipment. With current air pollution control technology, particulate emissions from plants can be reduced to meet all applicable standards. Thus assuming proper design of the abatement system, the problem becomes one of proper maintenance and use of the equipment.

Specific or general monitoring requirements are in effect under various provincial or other implementation plans. To assist in choosing a monitoring plan that will assist these agencies or operators in determining whether each facility is meeting its designed capabilities or other performance standards a brief description of monitoring methods is provided in the following sections.

7.1 Continuous Particulate Monitoring

Continuous particulate monitors are very useful in association with other monitoring and inspection programs to define conformity to pertinent emission regulations. For example, in order to insure that process and control equipment conditions are remaining typical, a continuous monitoring device could be installed. They could also provide surveillance capabilities over sources where visible detection of plumes is not possible.

These instruments could also provide process engineers with the capability of real time evaluation of stack emissions resulting from process modifications, malfunctions and maintenance programs.

Continuous particulate monitors can also provide a means of verifying the manufacturers specified performance characteristics for newly installed pollution control equipment. In addition they can be used to insure that existing control devices are operating at their design efficiencies.

7.1.1 Systems for Continuous Measurement. Reliable continuous particulate monitoring is possible in stacks exhausting gases that have passed through efficient control equipment or gases containing particulate matter having constant physical and chemical properties over long time periods. They offer interesting possibilities for improving surveillance capabilities and contributing to the minimization of emissions from industrial sources on a 24-hour real time basis.

Transmissometers

Transmissometry is a direct measurement of the attenuation of visible radiation (opacity) by particulate matter. These devices are suitable for monitoring emissions from controlled sources provided that the fine particulate matter has significant absorptive indices of refraction.

Specifications for continuous measurement of visible emissions using transmissometry are given in terms of design, performance, and installation parameters in Environment Canada Report EPS 1-AP-75-2 under Method B - Transmissometer Systems for Continuous Measurement of Opacity. These specifications contain test procedures, installation requirements and data computation procedures for evaluating acceptability of continuous monitoring systems.

Light Scattering

This optical system uses a pulsed solid state light source to provide a collimated beam that is scattered in all directions by particulate matter in the stack gases. Backscattered light from a well-defined optical volume is returned co-axially to the instrument detection system. The response is proportional to the particle mass and can be calibrated by the manufacturer to provide a direct particulate concentration reading in milligrams per cubic metre. The response, however is dependent on particle size and index of refraction, but for practical purposes, it is relatively independent of size for the typical range encountered in well controlled processes in the secondary lead industry (0.2 to 10 microns).

7.2 Manual Source Emission Monitoring

In order to implement fully the objective of air pollution control, it is imperative that the rate of emissions from point sources be accurately determined from time to time. To accomplish this, testing must be performed at the source. The key to test procedure is to obtain a sample that will be representative of the total emission. The purpose of this section is to present an engineering approach to isokinetic stack testing. Specific test procedures and applications are contained in the following sources:

(1) Standard Reference Methods for Source Testing: Measurement of Emissions of Particulates from Stationary Sources, Report EPS 1-AP-74-1, Feb., 1974

2) Standard Reference Methods for Source Testing: Measurement of Emissions of Particulate Matter and Lead from Secondary Lead Smelters, Report EPS 1-AP-78-3, June, 1979

7.2.1 Total Particulates. Particulate matter is withdrawn isokinetically from a number of sampling points in the stack and its weight determined gravimetrically after removal of uncombined water. Sampling isokinetically means that the linear velocity of the gas entering the sampling nozzle is equal to that of the undisturbed gas stream at the sample point.

The procedure for conducting isokinetic tests varies depending on where the test is to be performed. Most provinces have published procedure manuals describing the procedures that will be acceptable when submitted for approval. While the specific procedure may vary, the basic approach to the test remains the same. The objective of the test is to sample and analyze a portion of the total gas stream which will be representative of the emission that leaves the stack.

The primary means of sample collection for particulate matter are cyclonic separation, filtration, impaction, and condensation (Figure 11).

The first mechanism, cyclonic separation, is applied at the end of the sampling probe. A glass cyclone designed to separate particulate material down to a size range of 3 µm when operating at the specified volumetric flow rate is the first collection device in the sampling train. The cyclone is usually housed in a heated compartment to prevent any moisture from condensing. On a highly controlled source where the particulate loading and size range of particles are low this item is sometimes omitted.

The filtration mechanism is used immediately after the cyclone. A fiberglass filter of specific porosity is used to capture solid particulate that passes through the cyclone. The filter should also be heated to prevent condensation and plugging.

The third and fourth collection mechanisms may or may not be used depending on the local requirements for the sampling train. Impaction and condensation are generally found to occur in the impinger section of the sampling train. The impingers are submersed in an ice bath to condense water vapor prior to the drying tube. They also act as a source of impaction at the striker plate located at the base of the impinger nozzle. Material that is collected in the impingers is usually water vapor, but some solid particulate may carry over from the filter. The federal standard reference method does not record this particulate material, however some provincial codes may call for the recovery of the condensed particulate.

There has been an attempt to standardize on one procedure as published in the previously mentioned document. The sampling train illustrated in the procedure is quite similar to most sampling trains required for individual provincial tests. See Figure 11. Most of the individual provincial procedures are either the same as or similar to the federal standard reference method. The physical testing equipment is generally the same, except for the possible addition of a cyclone at the end of the sampling probe, ahead of the filter. The primary differences among the individual provincial procedures lie in the treatment and analysis of the sample and in the calculation procedures. It should be noted that in Section 5.4.3.4 (EPS 1-AP-74-1), the impinger contents are discarded after being measured for condensate. There is no attempt to determine the amount, if any, of condensed particulate that may have been collected.

7.2.2 Lead. The methods described in this section are used in conjuction with those described in report EPS 1-AP-74-1 to determine the concentration of particulate matter and the concentration of lead in such matter that is emitted from applicable sources at secondary lead smelters.

To facilitate the collection and recovery of lead and associated lead compounds the procedures as described in Section 1.6 of Report EPS 1-AP-78-3 incorporate certain modifications and are used in place of Method E in Report EPS 1-AP-74-1 as previously described.

In summary, the modifications are the addition of a fifth impinger in the condenser portion of the sampling train. This is the section immediately following the filter. The procedure is then modified to increase the collection efficiency of the impingers for lead or lead compounds which may pass through the filter in either particulate or vapor form. One hundred millilitres of 5% aqua regia is placed in each of the first two impingers to facilitate the collection of any lead. These contents, following a completed test, are filtered through a Whatman 541 filter paper and the filtrate is analyzed directly by flame atomic absorption. The filter material is also digested and analyzed by atomic absorption and the weight of lead found in the impingers is recorded together with the lead emission calculated from the pre-impinger (dry) section of the sampling train.

Particulate matter collected in the other sections of the sampling train is first weighed and then digested under reflux in aqua regia. The extracted lead is measured by flame atomic absorption spectroscopy at 283 nm.

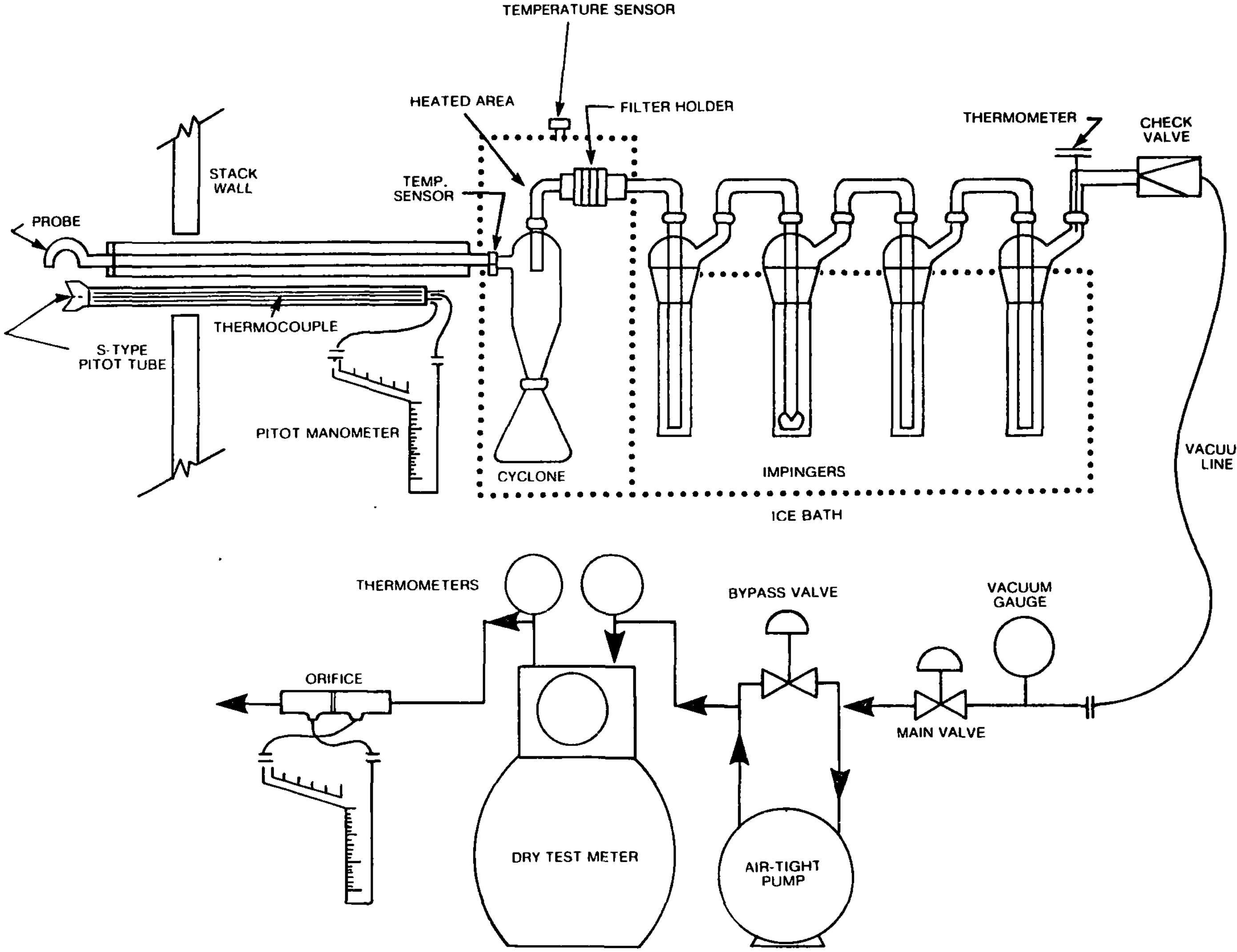

FIGURE 11 PARTICULATE SAMPLING TRAIN

For a more complete description of this method refer to Report EPS 1-AP-78-3, June, 1979, Standard Reference Methods for Source Testing: Measurement of Particulate Matter and Lead from Secondary Lead Smelters.

7.3 Ambient Air Particulate Lead Monitoring

Knowledge of environmental concentrations of lead is essential to assess its effects on human populations and to develop appropriate control strategies. Airborne lead, emitted from secondary lead smelters, is predominantly inorganic particulate matter. Sampling for lead at sites adjacent to industrial facilities is carried out using the standard hi-volume sampler which collects suspended particulate matter of up to 25-45 microns in diameter. The collected particles are deposited on a filter which is usually analyzed gravimetrically to determine total suspended particulate (TSP) loadings. Filter cuttings are then taken and analyzed for lead using atomic absorption spectrophotometry or X-ray fluorescence techniques. Samples are normally collected over a 24-hour period in the vicinity of industrial point sources.

Two federal standard reference methods are available for determining the concentration of lead and its compounds measured as elemental lead in the atmosphere. Report EPS 1-AP-73-2, Standard Reference Method for the Measurement of Suspended Particulates in the Atmosphere (High Volume Method) and Report EPS 1-AP-75-4, Standard Reference Method for the Determination of Lead in Airborne Particulates (Atomic Absorption Spectrophotometry).

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