LEAD SMELTER DESIGN FOR EXPOSURE CONTROL

Niels Gram, Metallurgist
Paul Bergsoe & Son
Denmark

ABSTRACT

The need to produce a product more competitively while meeting regulations on worker health and the environment led to the design and construction of a new smelter at the firm of Paul Bergsoe & Son in Denmark. The new design incorporates the use of a special blast furnace (the S-B furnace) along with two or three short rotary furnaces. A number of design features built into the new plant help to reduce environmental pollution as well as worker exposure to air contaminants, particularly lead. These design features include:

1. Post combustion of furnace gases to incinerate soot and organic matter and to react SO_2 with lead oxides to form a filterable material - lead sulphate.

2. Cooling of hot gases from the afterburner by mixing the gases with other exhaust air streams to reduce the cleaning problem caused by condensation of fume on the cooling surfaces.

3. Flue dust agglomeration to control dust discharge during handling, transport and recharging of material collected by the baghouses.

4. Flue duct and exhaust ventilation systems designed to avoid deposition of dust within the system.

5. Baghouses selected which allow filter replacement from the outside and long bag life.

6. Solid construction to prevent disuse of workplace control measures because of damage to ventilation hoods, doors and screens.

7. Separation of "clean" from "dirty" areas so that the greatest majority of jobs can be performed without personal protective devices or isolation into ventilated enclosures.

CHOICE OF SMELTING TECHNOLOGY

In the early 1970's the Danish non-ferrous secondary metal smelter firm of Paul Bergsoe & Son realized that its lead smelting section needed to be rationalized and modernized in order to avoid closure of the operation either by competition or by antipollution regulations, or by both. It soon became clear that this meant building a new smelting plant rather than modifying and extending an existing plant which comprised two comparatively small blast furnaces, one reverberatory furnace, and a number of conventional rotary furnaces (drum furnaces). Following experimental smelting of a variety of secondary raw materials in these furnaces, the decision was reached to select a special shaft furnace and the so-called short or deep rotary furnaces (Kurztrommelöfen) for installation and further development.

Special Shaft Furnace

Incorporating a number of special features, the special blast furnace (later called the S-B furnace) would be able to smelt unbroken batteries and would thus enable the company to operate more freely on the market, buying conventional battery scrap or unbroken batteries without having to resort to its own battery breaking. A variety of charge mixtures containing whole batteries, conventional battery scrap, lead dross, and recycled flue dust and slag can be smelted in the S-B furnace. It also offers good productivity because of its continuous mode of operation.

Short Rotary Furnaces

In the short rotary furnace, the flame coming from the burner at the aft end revolves inside the furnace, and the exhaust gases are again extracted at the rear. This furnace can also be used for smelting battery scrap, but to do this requires decased scrap. It is technically difficult to obtain a high yield simultaneously with a safe, disposable slag in this application. On the other hand, the deep rotary furnace is well suited for smelting secondary lead materials other than battery scrap. Solder and printing metal residues, and other tin-containing materials cannot be smelted economically in a blast furnace, and the variance in their composition makes batch-wise smelting more desirable.

It was felt that with the combination of an S-B furnace to smelt batteries, battery scrap and related materials, and two or three short rotary furnaces to smelt all other lead-based raw materials as well as a number of internal byproducts from the refining of lead and lead alloys, the company would have an adequate smelting capacity for many years to come and still possess the flexibility that is so necessary in the recycling industry.

SAFETY AND HEALTH CONCERNS

The choice of these two smelting technologies was also governed by the demand for environmental protection and occupational safety. We have not been able to find other smelting systems that offer the same scope of protection. The deep rotary furnace is already a well-known process unit, well established in Europe and now also in America.

The use of the blast furnace for secondary lead smelting is by no means new, but the conventional type, frequently called the cupola, is not very acceptable from a pollution point of view, and it is usually impossible to rebuild it into something acceptable today. Although working on the same principle, the S-B furnace is a very widebodied type of shaft furnace, provided with air preheat and oxygen enrichment. Factors such as these allow a very low and compact smelting zone, a thorough preheating of the charge materials on their way down through the shaft, and an efficient cooling of the combustion gases on their way up. In this way, the battery case material can be effectively destroyed (burned) and the off-gases are much less loaded with flue dust and, therefore, easier to control and clean to a high standard.

Design Guidelines

Even with the inherent advantages of the furnaces selected, it took a lot of engineering to design these two types of furnaces into an occupationally acceptable smelting plant. To do so we developed and followed a number of guidelines, some of which are quite unusual in the metallurgical industry. Several of our design criteria seem related to the environmental protection rather than to work hygiene, but it will be pointed out how important they are also from that point of view.

Post Combustion--
All furnace gases are taken through post combustion where they are reheated to temperatures in excess of 900°C, so that all soot and organic matter is effectively combusted. At the same time, gaseous SO_2 is allowed to react with lead oxides to form lead sulphate that can be filtered away from the smoke. Both effects mainly improve the environmental protection.

Gas Cooling--
The hot gases from the afterburner are partially cooled by mixing with exhaust air from point sources of fume. Conventional gas cooling frequently leads to condensation of fume on the cooling surfaces, and the coolers therefore need regular cleaning. Cooling by mixing with cool exhaust air causes fume to condense "in suspension", so that the condensate can be carried by the gases to the baghouse filters. The important point is to reduce the need for cleaning. Inside cleaning of flues and gas coolers is necessarily a dirty operation and its frequency must therefore be reduced as far as possible.

Flue Dust Agglomeration--
Rather conventional baghouses are used to clean the gas, but the flue dust or filter dust is never handled as such. By means of screw conveyors, it is taken in a closed system to a patented agglomeration furnace in which the dust is continuously fused and transformed into a liquid slag that subsequently solidifies into a solid mass.

The flue dust from a lead smelting operation has a high metal content and therefore has to be collected and fed back into the smelting furnace. The handling, transportation and mixing of flue dust into other charge materials has always been a hazardous operation with a marked contribution to the workplace pollution and usually also to the fugitive emissions from the plant. Both are eliminated by the use of the flash agglomeration method.

Flue and Filter Design--
The entire flue system and the fabric filters are designed to avoid deposition of dust. By using steep flues near the furnace where hardly any dust will deposit and by carefully engineering the whole flue duct, the exhaust velocities can be closely controlled and deposition even in horizontal ducts minimized. Again this reduces the need for or frequency of cleaning operations.

Baghouses are now available in which exchange of bags can take place from the "clean" side and under suction, so that this otherwise very dirty operation can be carried out with minimal exposure. More important is the selection of a baghouse and filter type in which the bags have a long life and only need to be exchanged infrequently. We have had very good results with a reversed type of filter in which suction is inside the bag so that dust collects on the outside. Cleaning simply takes place by allowing atmospheric pressure or a slight overpressure inside the bag that then bulges out and dislodges the dust "cake".

Solid Construction--
Copious ventilation is installed at all fume sources in workrooms and all such equipment is constructed from heavy gauge material. The use of solid construction throughout ensures that the equipment continues to function the way it was designed and that ventilation hoods and protective screening continue to be used at all times. Dented hoods that no longer fit, and sliding and swinging doors or screens that do not move freely rapidly fall into disuse. Solid construction also reduces the need for repair work that is another serious source of exposure.

"Clean" and "Dirty" Areas--
Raw materials in a secondary lead smelter are dusty and all such material is received and stored indoors in "dirty" rooms which are also used for charge preparation. The "dirty" rooms are effectively separated from ordinary workrooms where the furnaces are operated and where it is unnecessary to use respiratory protection in the daily routine.

The under-roof handling of raw materials is primarily an environmental control but the separation of "dirty" rooms from "clean" rooms is an important factor in the work hygiene design. In the case of the S-B furnace, all handling, storage, charge preparation, and actual charging of the furnace takes place outside the workrooms from which the furnace is operated, namely the control room and the tapping floor (Figure 1). Here lead in the atmosphere is controlled to below 100 $\mu g/m^3$ and, according to Danish regulations, the people can work an 8-hour day without respiratory protection. The rest of the plant is not controlled this low, but the only person working there for any length of time is the machine driver who is isolated in a cabin with a filtered air supply. In the tapping bay around the furnace, copious ventilation is installed at all point sources, e.g., the lead siphon and the four slag tapping holes. There is also a general ventilation of the room and the floor is frequently wetted.

In the case of the short rotary furnaces, a similar system is adopted (Figure 2). Reception, storage and handling of raw materials takes place in a "dirty" bay by means of a loading machine whose driver is isolated in a cabin ventilated with filtered air. The charging and tapping of the furnace, on the other hand, takes place in the furnace hall proper. To make this area acceptable from an occupational point of view, the furnace is well hooded, particularly at the front end where charging and tapping take place without fume escaping into the general background air. Furthermore, a system is used whereby skips are charged in an airlock between the "dirty" and "clean" rooms. Here they are first loaded from the "dirty" side, the airlock is then closed and exhaust is started before the airlock is opened from the "clean" side. On the "clean" side another truck with a tilting head feeds the skips one by one into the furnace, returning the empty skips to the same position again. A 20 ton charge is fed into the furnace in a matter of 12-15 minutes, virtually without polluting the atmosphere in the furnace hall.

A histogram of recent lead-in-blood measurements for all employees in the two smelting departments is presented in Figure 3. Most of these employees have a long history working with lead. Respirators are only used in emergency situations, and for repair and cleaning operations.

QUESTIONS, ANSWERS AND COMMENTARY

(Editor's note: The first question below was in regard to introductory remarks Mr. Gram made prior to delivering his paper. He said that a year or so ago East Germany had adopted a permissible exposure limit for lead, based on a time-weighted average of $5\mu g/m^3$, with a maximum allowable exposure of $10\mu g/m^3$. He said Russia, Poland and some other Eastern European countries had a similar standard).

Question (I. Tanenberg, R. Lavin & Sons, Inc.):

You made a remarkable statement about East Germany having such a low lead standard. Are they able to achieve it?

Answer (N. Gram):

I did say that East Germany has such a standard. I didn't say they had achieved this low level in their lead foundries or smelters.

I have visited one eastern smelter, the one that exists in East Germany. They don't meet the standard and they don't think at this time that they will ever be able to meet it. This very low standard for occupational hygiene was introduced in Russia some years ago, not only for lead but for all kinds of toxic substances.

Question (F. Boelter, OSHA):

Do you find that blood lead levels correlate at all with airborne lead exposures or do you find that the blood leads seem to be more related to personal hygiene?

Answer (N. Gram):

I can't say that we have found a correlation or seen a correlation. We have been doing blood leads for only three or four years. Before that we did basophillic testing, which was the screening method of those days in Denmark. And, during that period, we were always under the impression that personal hygiene and work practices were overriding.

I think it's true to say that there is an effect on blood lead levels by lowering the workplace lead in the air. But I can't say that we've found that that does the trick. I think it will be necessary to educate the workers (we have been doing that for some time), to do everything we can to reduce the workplace atmosphere's lead content, and to instruct and maintain good work practice and good housekeeping. The last two are very important and will remain so.

Question (F. Boelter):

What kind of locker room and showering facilities to you have?

Answer (N. Gram):

Our change room facilities have for many years been divided into "black" and "white" rooms. But our luncheon room facilities are not as good as they should be and they are now being revised. We can also improve on cleanliness of workclothes. We change people's clothes only weekly, except for very special jobs.

There is something else we could do that we don't want to do - we could give people respirators. This practice is not common or acceptable in Denmark. Our people work without personal protection, except for special jobs like relining or cleaning inside ducts and exchanging bags in dust collectors. All the daily routine jobs are done without respirators.

Question (D. Jackson, Chicago Inland Metals):

What effect, if any, would the introduction of the maintenance-free batteries have when they are comingled with the old batteries as regards wetting the floors?

Answer (N. Gram):

I'm afraid I can't answer shortly to that. I don't know whether we have time. I think there will be problems, and more so in the scrap trade than with the smelters. For details please refer to my article about arsine and stibine, published in "Lead Power News", No. 9 (Lead Development Assn., London, April, 1978).

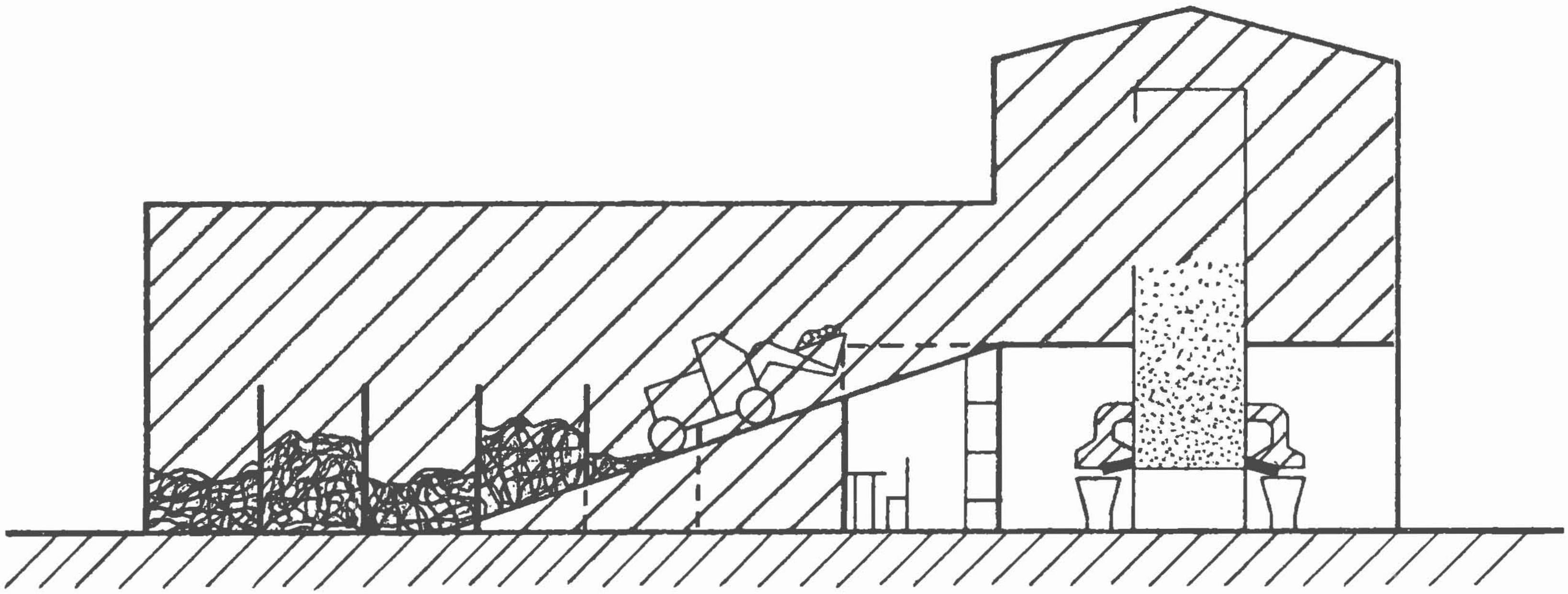
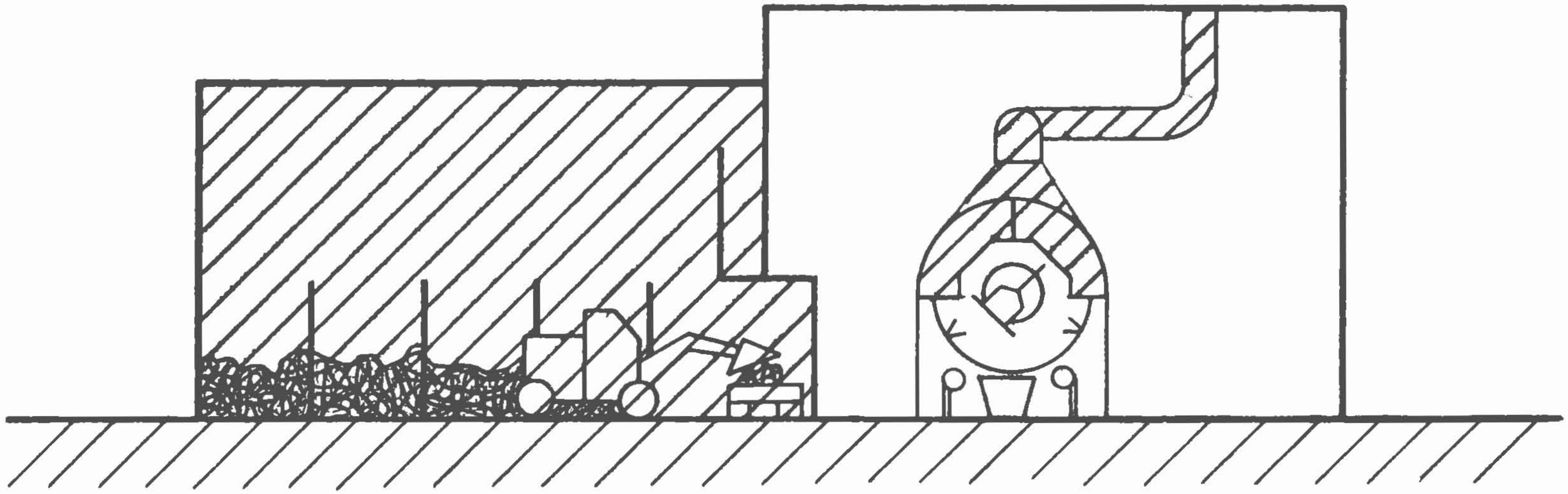


Figure 1. Clean and dirty rooms around the SB-furnace (in the tall building at right). The hatched areas indicate dirty rooms for reception and storage of raw material and for charging the furnace. Only the machine cabin is a "workroom". The tapping bay around the base of the furnace and the adjacent control room are controlled to low lead-in-air values.



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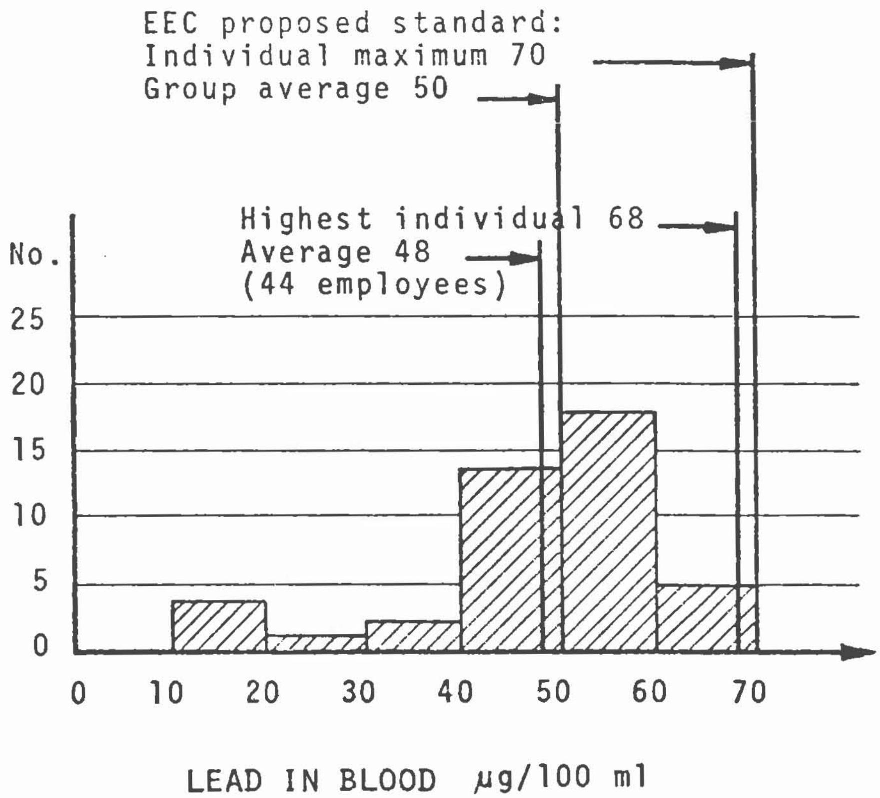

Figure 2. Clean and dirty rooms in the short rotary furnace department. The hatched area to the left is used for raw material storage and handling and the loading machine with its "clean" cabin is seen loading charge material into the charge skips in the airlock. Later another machine will take the skips from the clean side of the airlock and feed the contents into the rotary furnace under the hood (shown hatched to indicate the exhaust of fumes).

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NIOSH Project Officer: Dennis O'Brien
Project Manager: Robert C. Scholz

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