Capsule Report

Control of Acidic Air Pollutants by Coated Baghouses

January 1979

This report was developed by the
Industrial Environmental Research Laboratory
Cincinnati, OH 45268

Baghouse and exhaust stack controlling secondary aluminum smelter (80,000 ft^3/min)

1. Significance

Emissions from the aluminum, glass, phosphate fertilizer, and sulfuric acid industries and from waste incineration have exhaust gas emission characteristics unique to their sources because of process variations. However, they also share common problems: combined particulate, corrosive acid vapor, and acid mist emissions. The uncontrolled pollution characteristics of these sources are shown in Table 1. Unless controlled, these pollutants form a dense plume that can damage property and animals and may be harmful to human health.

In sufficient quantities, fluorides from aluminum and phosphate emissions can cause severe bone malformations (called fluorosis) in grazing animals. Acids can etch glass, damage paint, and corrode metal. Particulate matter and acid mist reduce visibility and can adversely affect human health.

These combinations of pollutants also cause problems in operation of the more common air pollution control systems. Dry electrostatic precipitators, cyclones, and ordinary fabric filters (baghouses) do not remove gases and are subject to rapid deterioration from the acids. Mist eliminators are effective only on liquids; acid gases pass through unaffected. Scrubbers and wet precipitators introduce a wastewater source that often requires treatment

To avoid potential water pollution problems, a dry control system is desirable. To avoid corrosion problems, neutralization of the acid is desired. For environmental reasons, efficient removal of particulate matter, acid mist, and acid gases is necessary. This capsule report presents an approach that accomplishes all these requirements through the use of a dry scrubbing agent to neutralize and capture the acids, followed by removal of particulates and captured acids in a baghouse filter.

Table 1.

Characteristics of Uncontrolled Emissions from Acid-Emitting Industries

2. The Process

The key element in the dry scrubbing process is the intimate contact between the exhaust stream constituents and the dry sorbent. This contact ensures both capture of particulates and neutralization of acid gases by the sorbent. There are currently three techniques for achieving contact:

- Fluidized bed system
- Injection system
- Batch-charge system

A fluidized bed contact system is illustrated in Figure 1. Sorbent is fed from the crude sorbent tank to a screened plate under the baghouse. Process gases pass up through the screened plate and fluidize the sorbent granules, providing good contact. The gases then pass through the baghouse before being released. Abraded fines from the process are caught in the baghouse, where they assist in capturing the acid gases.
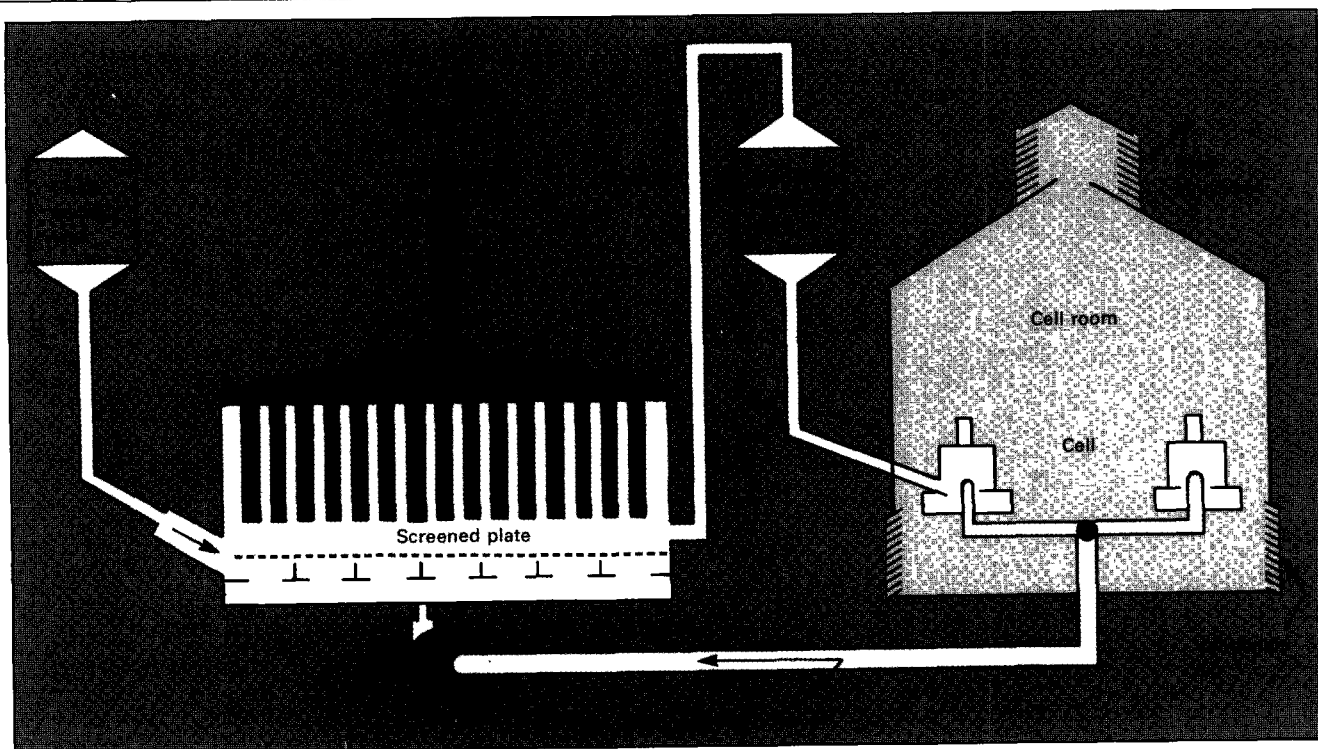
Limestone feed supply tower

Figure 1.

Fluidized Bed System for Emissions from Primary Aluminum Production

Figure 2 is a diagram of an injected sorbent contact system. In this process a powdered sorbent is blown into the gas stream before it enters the baghouse. The sorbent can then react with acids both in the duct and in the baghouse. A quench chamber may be placed upstream of the injection point, as shown in the figure, to reduce temperature and raise humidity to improve sorption.

The third method, the batch-charge process, is actually a variation of the injection process. In the batch-charge process, sorbent is blown directly into the bags and retained until its ability to remove acids is near exhaustion; it is then replaced.

Details of the design of these control systems vary somewhat with the industry; however, all rely on some form of dry sorbent to coat the inside of the baghouse filter and scrub exhaust gases.

Sorbents commonly used include alumina, limestone, and nepheline syenite (a silicate). Industries using dry sorbents often demonstrate a preference for a particular system for reasons that will be discussed. It is perhaps best, then, that each system be discussed in the context of the industry that uses it.

Primary Aluminum

Fluidized bed contact systems have been used in the primary aluminum industry for several years; typically these systems use alumina as the sorbent.

Primary aluminum is produced almost solely from alumina (Al_2O_3) in shallow, rectangular cells (Figure 3) called pots, by use of carbon electrodes. These electrodes may be prebaked or may be baked in situ (Soderberg process). Cryolite (Na_3AlF_6) serves as both a solvent and an electrolytic material for alumina. During the production process, solid and gaseous fluorides are evolved.
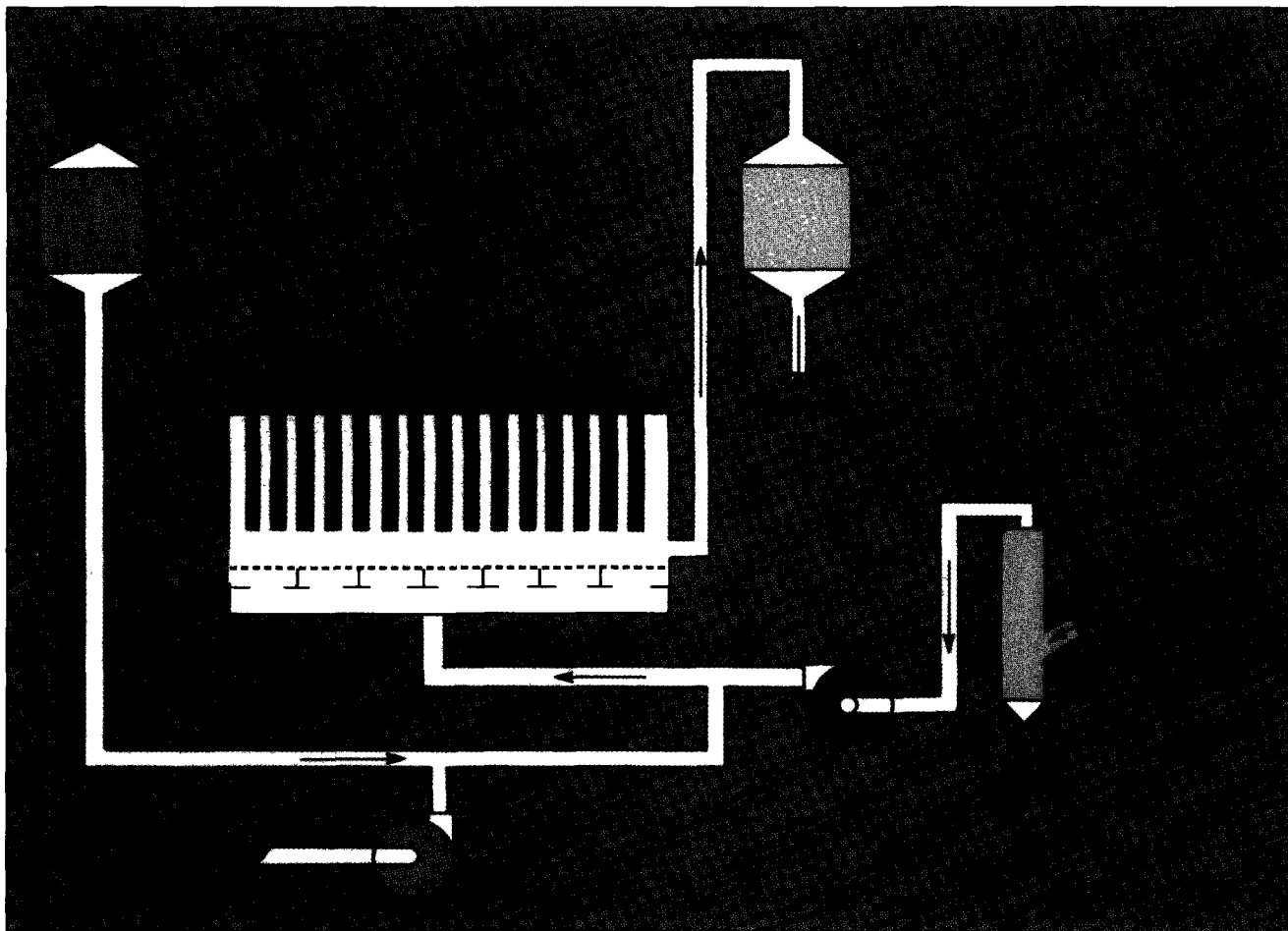
Figure 2.

Injected Sorbent System

Both the fluidized bed and injected sorbent techniques have been used for prebake potlines and Soderberg potlines. These processes appeal to the primary aluminum industry because of the lack of heavy oils in the exhaust, the use of alumina as a feed for the process, and the usability of the captured fluorine to replace makeup fluorine in the process. The amount of alumina used in production and the amount of fluorine in the exhaust are such that a large quantity of alumina can be used without economic penalty.

Unfortunately, because other industries use sorbent inefficiently in the fluidized bed process and cannot use the spent sorbent, this system is applicable only to the primary aluminum

industry. It is also more difficult to use the system for Soderberg potlines because of the presence of high molecular weight organics from the baking of the anode. Moreover, the accumulation of unwanted acid gases in the cell gases may necessitate supplemental treatment of some of the gas stream.
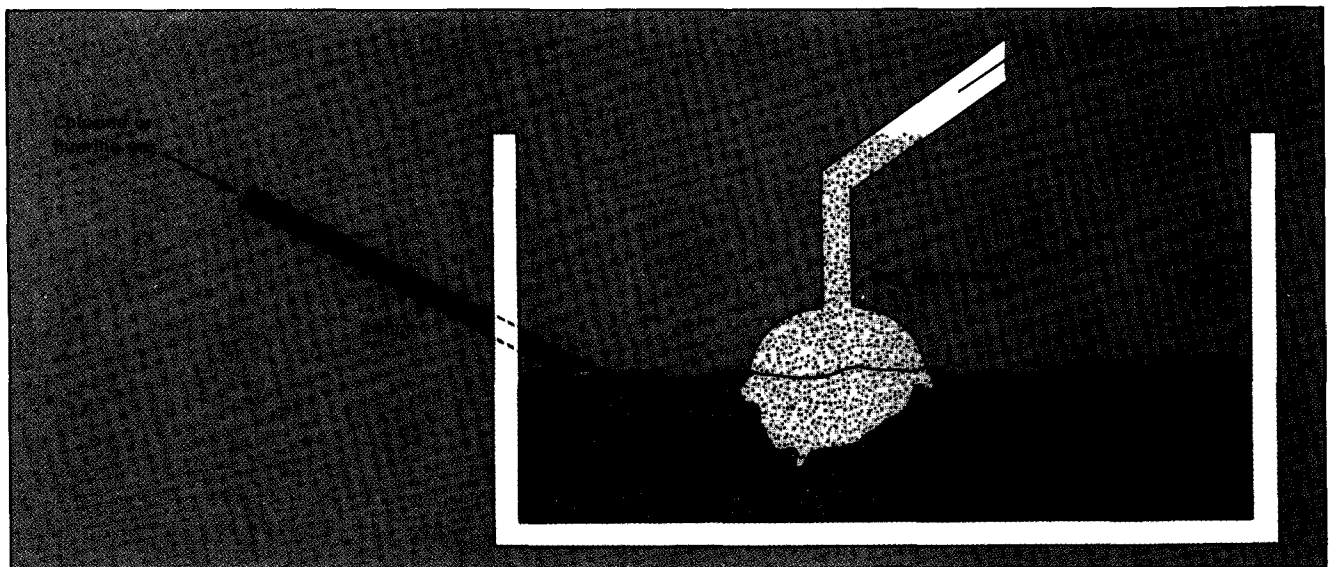
Secondary Aluminum

The secondary aluminum industry recycles aluminum scrap of varying quality from a multitude of sources

(Figure 4). Troublesome impurities found in scrap include magnesium and oils. Fluorine and chlorine are used to react with and remove the magnesium in a process known as demagging. Sparks and fluorine or chlorine, as well as oils and solids, are emitted from the process. The oils blind uncoated baghouses, and sparks tend to cause burnthrough of the filters. Batch-charge seems to be the favorite sorbent contact method for this industry because the relatively low acid gas concentrations allow a reasonable cycle time (3 to 10 days). Before the exhaust enters the baghouse it is usually quenched with water to cool it and to extinguish sparks from the process.
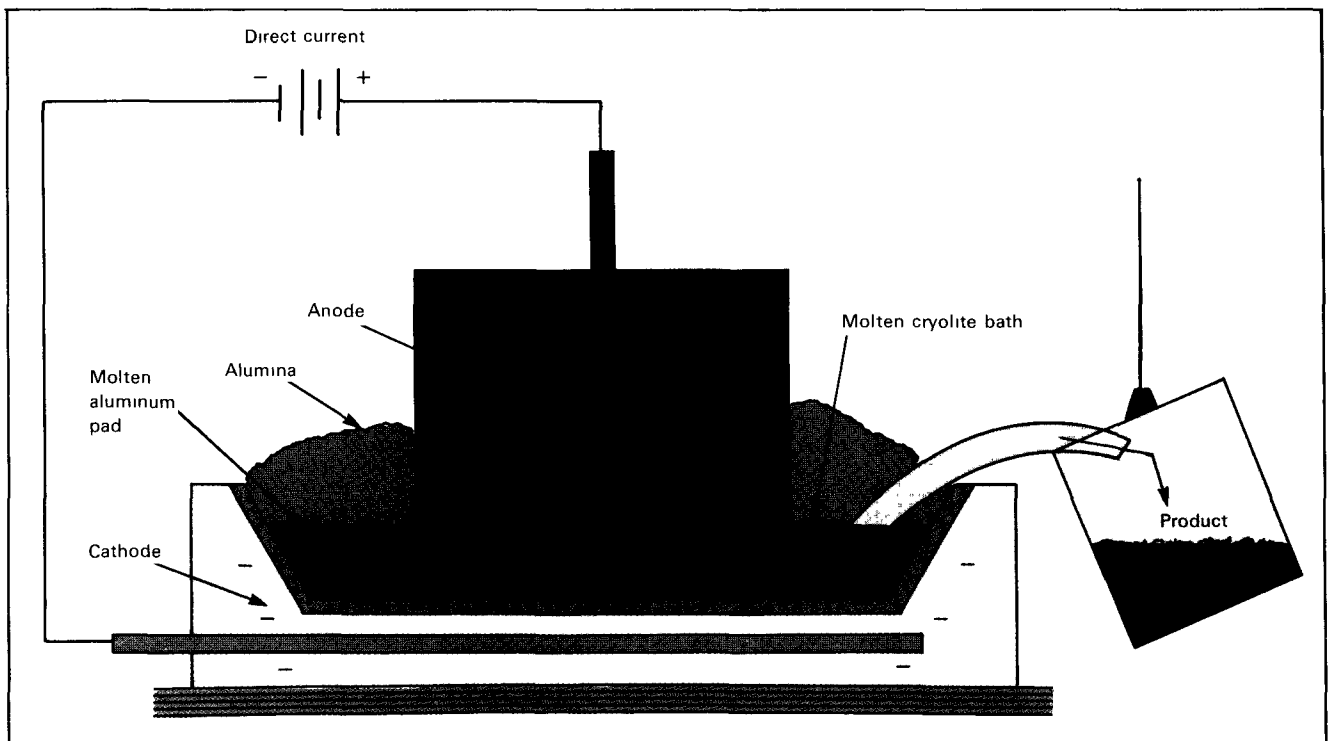
Figure 3.

Aluminum Reduction Cell

Figure 4.

Secondary Aluminum Magnesium Reduction Process

Charging of secondary aluminum furnace

Settling chamber upstream of baghouse to capture sparks and large debris

3. Performance

Emissions on which dry sorbent systems have been demonstrated to be effective include acid gases such as HF and HCl, sulfur oxides (SO_3 and, to a lesser extent, SO_2), particulates (both carbonaceous and inorganic), and resulting visible stack plumes.

In the three dry sorbent systems the acid gas outlet concentrations depend only on the gaseous stream and the sorbent type, provided that sufficient contact between the two occurs and that the sorbent is not depleted. The control system, therefore, will exhibit a constant outlet concentration independent of inlet loading; a conventional system, on the other hand, will exhibit constant efficiency irrespective of the inlet concentration. This point is illustrated in Figure 5, where acid gas concentrations for the aluminum industry are shown along with outlet concentrations of acid gases for a dry sorbent system. For example, inlet concentrations of 1,000 ppm would be reduced by over 99.9 percent while an inlet concentration of 2 ppm would only be reduced by about 50 percent.

The particulate collection efficiency of dry sorbent systems depends primarily on particle size. Collection efficiency will be almost 100 percent for large particles; very small particles will pass through the baghouse at significantly less efficiency. A given process stream from a primary aluminum plant will have a particle size distribution very similar to that of a process stream from a secondary aluminum plant. This similarity makes it possible to compare particulate outlet concentrations. Figure 6 shows the inlet and outlet particulate concentrations and the effect of dry sorption control. Coated baghouses will increase efficiency in capturing very small particles as compared to conventional, uncoated baghouses.
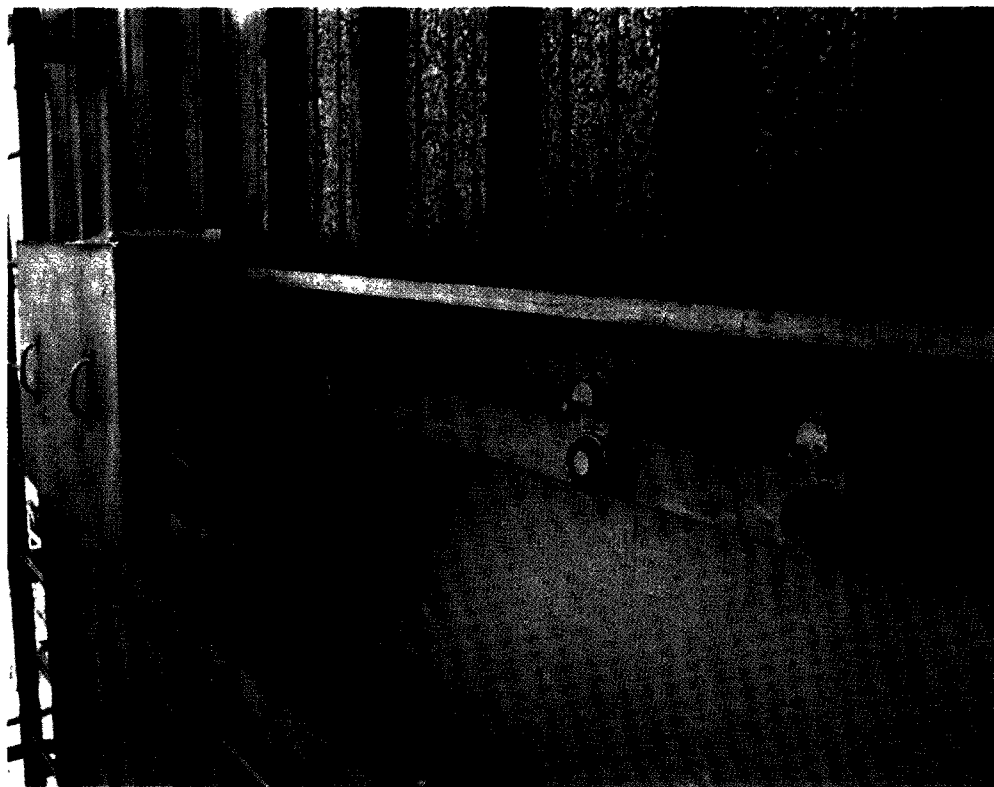

Emergency cooling damper linkage in baghouse
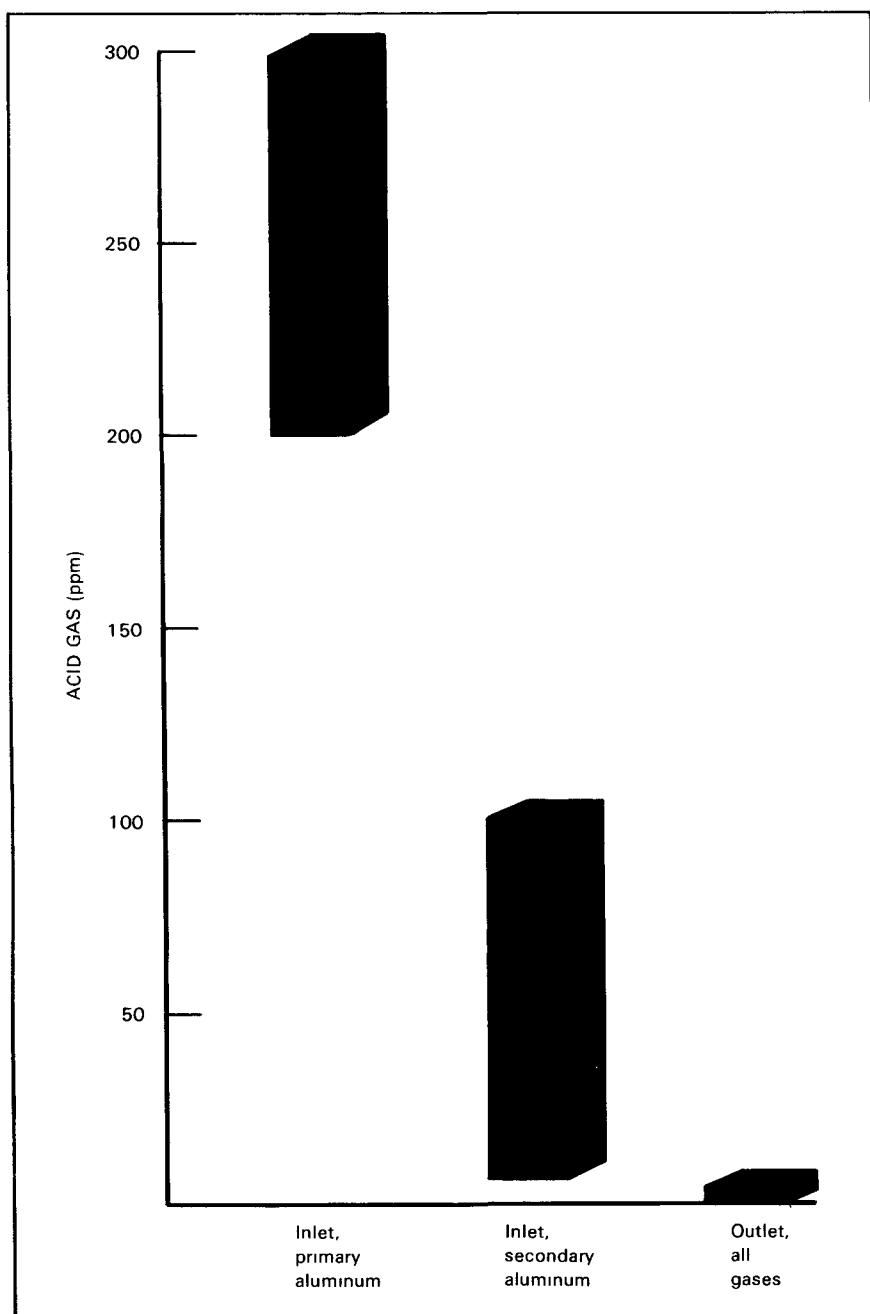
Figure 5.

Inlet Gas Concentrations Compared to Outlet Concentrations from Sorbent System

Dry sorption baghouse systems are, therefore, particularly effective in reducing the opacity of the stack plume. The opacity is determined by a complex relationship of particle concentration, total particle surface area, particle size, shape and distribution, optical properties, acid gas concentrations, and climatic conditions. The dry sorbent system is capable of eliminating the visible plume from the stack. Figure 7 shows controlled and uncontrolled opacities from the aluminum industry using dry sorbents.

Figure 6.

Inlet and Outlet Particulate Concentration and the Effect of Dry
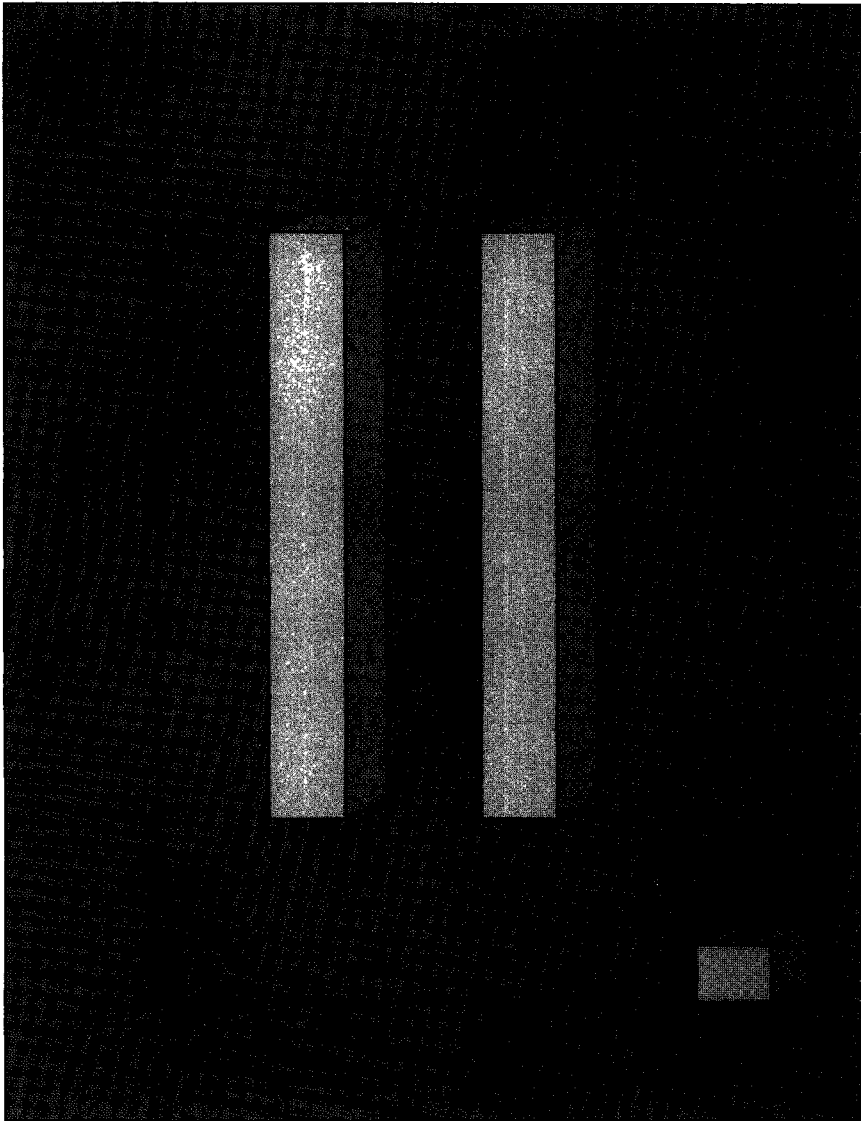Sorbent Control
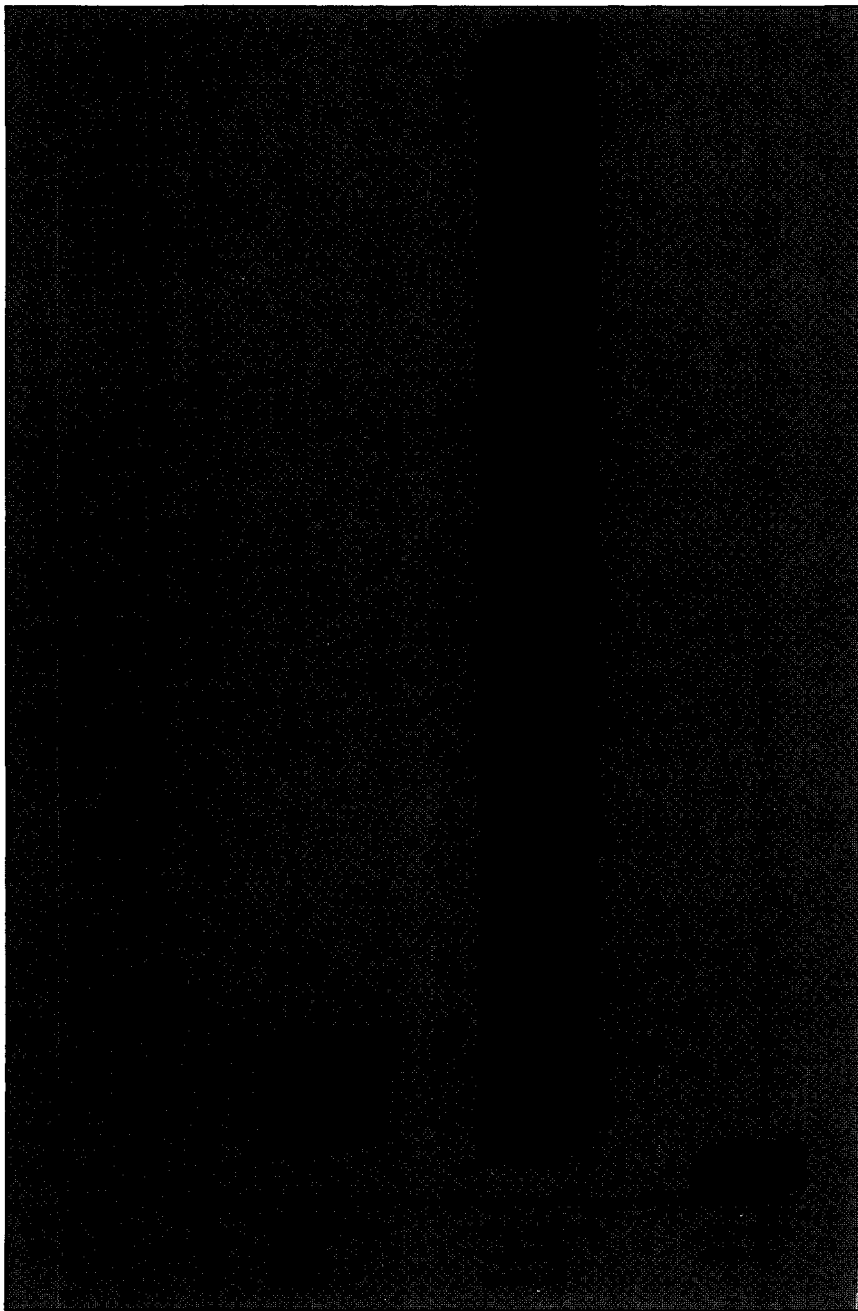
Dry sorbents also influence baghouse operation. Earlier in the discussion, major problems in baghouse control were identified as the corrosiveness of the gaseous stream, the oiliness of the particulate, and the presence of sparks. Thus, there is often a high rate of failure owing to bag corrosion, blinding, and perforation.

Dry sorption systems, however, act as a precoat to protect the filter bags from both blinding and burning, while they absorb and neutralize acid gases. Once applied, the coating is effective for several (3 to 7) days. In this manner, the dry sorbent increases the life of the bags.

Figure 7.

Comparison of Uncontrolled and Controlled Opacities Using
Sorbent Systems

4. Economics

Costs for a primary aluminum plant producing 300 tons per day of aluminum, and for a secondary aluminum plant producing 200 tons per day of aluminum, are given in Tables 2 and 3, respectively. These costs are intended to represent typical retrofit situations for each industry, and assumptions are identified to enable conversion to different values. Operating costs are in proportion to volume of gas handled rather than to amount of pollutant removed.
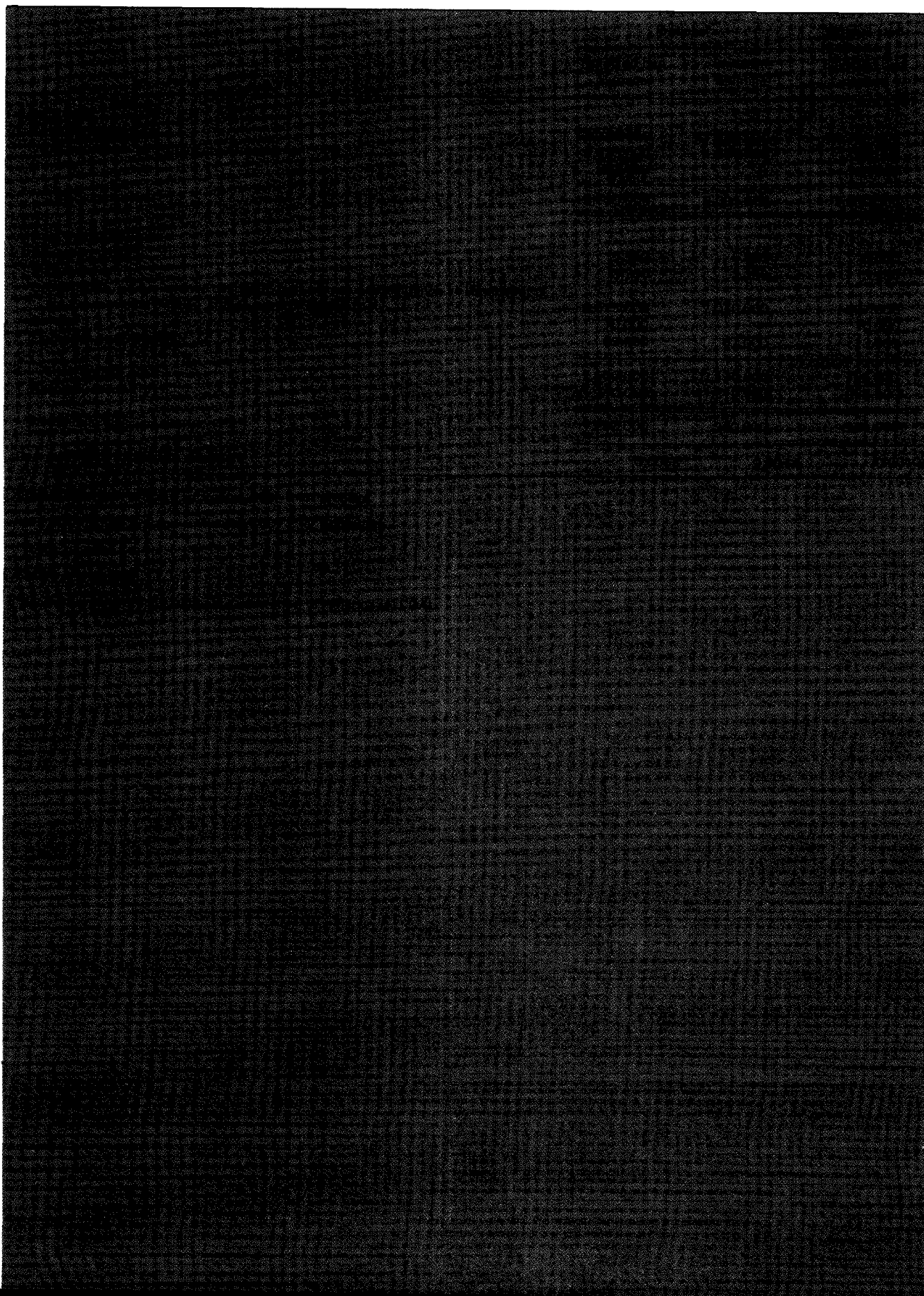
Costs for these systems will, of course, vary widely with the exact ducting configuration, with the size of the flow volume, and with differing values of the cost components covered in the tables.

View of baghouse and limestone tower (foreground)

Table 2.

Cost of Air Pollution Controls for 300-ton/d Primary Aluminum Plant (Pot Vents Only)

Table 3.

Cost of Air Pollution Controls for 200-ton/d Secondary Aluminum Smelter[a]

Item	Injected or batch Tesisorb®
Capital cost·	
Equipment, total installed cost at $9/actual ft³/min	$540,000
Working capital at 20 percent of equipment cost	108,000
Royalty	45,000
Total capital cost	693,000
Annual operating cost.	
Operating labor[b]	$3,800
Maintenance[b].	2,200
Depreciation, administrative overhead, property tax, and insurance at 15 percent of capital cost and interest at 8 percent of capital cost	159,000
Utilities:	
Electricity at $0.03/kWh	4,300
Sorbent	4,800
Disposal for recovered material at $10/ton	9,000
Total annual cost	183,100
Cost per pound of product	0.0028

[a]60,000 ft³/min average air flow at 200° F.
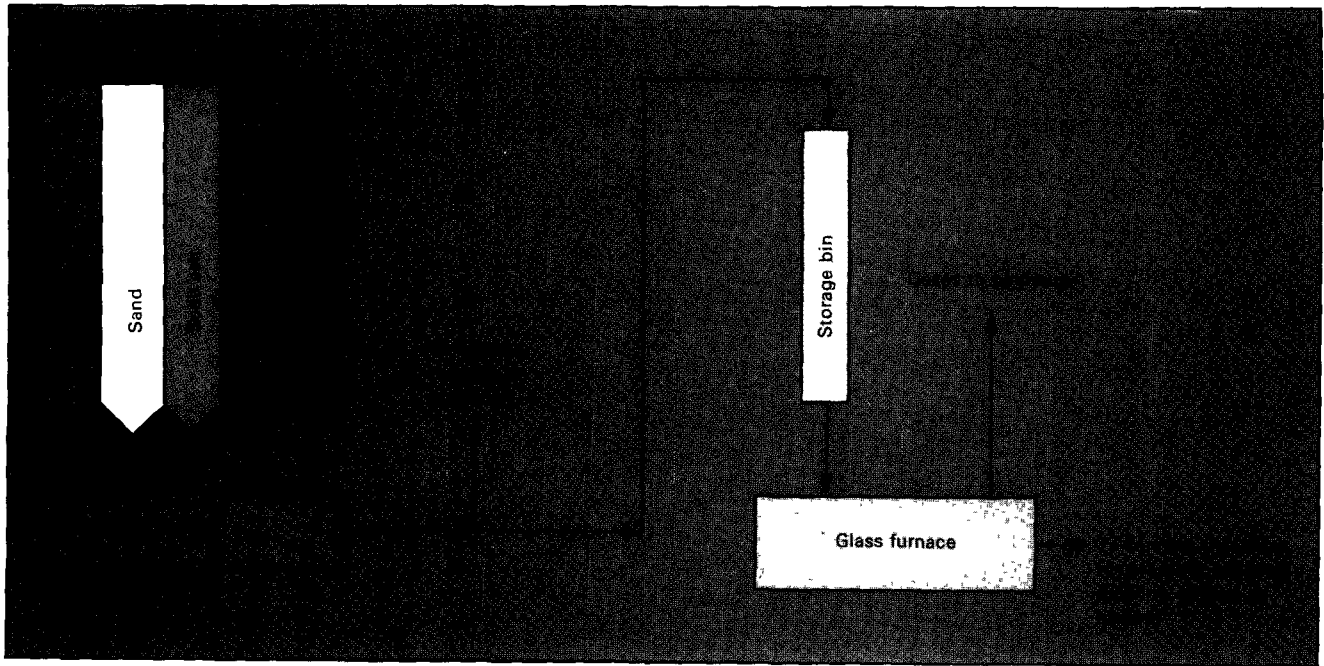
[b]750 h/yr at $8/h.

5. Areas of Application

In light of the information presented in Table 1, the glass industry and industrial or municipal incineration can appropriately be considered potential areas for the use of the described dry sorption systems. Only a few glass plants now use dry sorbent in baghouses. At least one municipal incinerator plans to use a dry sorption system.

Figure 8 illustrates the glass manufacturing process. Glass is formed by melting and mixing sand, soda ash, cullet, and limestone or lime, along with numerous other materials added to give the glass its special characteristics.

Typical emissions from glass manufacture include very fine particulates, NO_x, and SO_x (especially SO_3), which are difficult to remove by scrubbers, wet precipitators, or conventional baghouses.

The preferred scheme for using dry sorption in the glass industry is injection of the sorbent some time after quenching. In the case of fiberglass and opal glass, lime may be used in the quench to reduce the consumption of sorbent and to preclude formation of extremely fine boron fumes that are very difficult to remove. In some cases, the recovered materials can be reused in the glass process. Nepheline syenite is the only sorbent known to have been used, to date, for the glass industry.

Industrial or municipal incineration is another possible area of application. Waste incinerators can emit large quantities of particulates and varying amounts of acid gases, depending on the material incinerated. Acid gases may result from the incineration of materials containing sulfur, chlorine, or fluorine.

Figure 8.

Glass Manufacturing Process