Metallurgical Dust. Evaluation and Recovery

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Introduction
Fine particles of material treated in furnaces are partially carried out of the unit in the exit gas. For example the blast furnace gas may contain up to 170 kg of dust per tonne of pig iron produced. This dust must be captured for two reasons: to recover its valuable metal content and to prevent pollution of the environment. Methods of dust removal depend mainly on the particle size of the dust, and temperature and moisture content of the gas. The equipment used can be broadly classified as either dry or wet collectors.
• The dry collectors include the gravity and baffle chambers, cyclones, filters, and electrostatic precipitators;
• In the wet collectors dust particles are made to collide with water which then makes their removal as a slurry possible.

Wet cleaning is preferred to dry cleaning because of the excessive wear and the difficulty in handling the fine dust removed in the dry methods. Wet methods must be followed by filtration, drying of filter cake, and recycle of water. Equipment used for wet methods are known as scrubbers. Usually two or three sets of equipment are connected in a series to remove first the large and then the small dust particles. The range of application for each type of equipment is shown in Figures 1 and 2, from which it can be seen that gravity chambers and cyclones are only suited for separating the large particles while the filters, scrubbers, and electrostatic precipitators are most suited for separating the small particles.
In gravity and baffle chambers the gas is allowed to pass through a large chamber or a long tunnel to reduce its velocity and cause the dust to drop out by gravity. To enhance separation, the gas flow is deflected by baffles or its direction of flow is reversed.

Cyclones are more efficient than the previous type and occupies less space. The centrifugal force causes the dust particles to travel outward to the wall of the chamber, where they collide and fall downward to a receiver at the bottom, while the gas escapes from an opening at the top. Filters are units in which the dust-laden gas is passed through woven cloth that filters the dust particles. The filtering devices are vertically mounted cloth bags suspended in metal enclosures. A shaking mechanism or a pulse of air periodically loosens the layer of adhering dust so that it falls into a hopper below.

Electrostatic precipitations are expensive but efficient equipment. They are also capable of removing droplets of liquid constituting a mist. The method was invented by F. G. Cottrell (1877–1948) (Figure 3) in 1905.
Figure 3 - Frederick G. Cottrell (1877-1948) graduated from the University of Berkeley in 1896, studied in Berlin under van't Hoff and in Leipzig, receiving a doctorate from the latter institution in 1902. He then returned to Berkeley where he developed the electrostatic precipitator. In 1911 he entered the service of the US Bureau of Mines and in 1912 he founded the non-profit organization The Research Corporation for the Advancement of Science. In 1920, he became Director of the Bureau of Mines.

Wet Methods
Equipment for the wet methods consists of a contact zone where the dust laden gas and the water are brought together, followed by a separation zone where the gas is separated from the wetted slurry. In the contact zone the particles increase their weight and size and adhere together when they are moistened thus making their separation easy.

Dust, fumes, and smoke
Dusts are particles or aggregates of particles 1 to 150 microns in diameter, fumes 0.2 to 1, and smokes are less than 0.2 microns. Dust is usually formed as a result of mechanical attrition but fumes and smoke are formed as a result of chemical reaction. The production of aluminum in Søderberg cells produced intense fumes of organic compounds in the working place (Figure 4).

Figure 4. Aluminum plant using Søderberg cells
As a consequence, the new technology displaced these cells by pre-baked electrodes which resulted in improved working conditions (Figure 5). Fumes of fluorine and its compounds that are emitted during operating these cells are captured by the alumina before its introduction in the cells thus eliminating pollution and recovering otherwise lost fluorine compounds (Figure 6).

![Figure 5. Aluminum plant using pre-baked electrodes](image)

![Figure 6. Capturing of fumes of fluorine and its compounds by alumina](image)
Fumes and smoke are more dangerous because of their small particle size and the ease with which they can enter the respiratory system. Dust particles susceptible to oxidation, e.g., aluminum or iron powders may catch fire or explode due to violent oxidation. Figure 7 shows an explosion at a plant manufacturing cast aluminum automotive wheels that killed one worker, injured others, and damaged the facility.

![Figure 7. Explosion at a plant manufacturing cast aluminum automotive wheels](image)

**Steel industry**

During the early manufacture of steel by oxygen top blowing (LD Process) in the 1950s thick brown fumes of iron oxide were formed that was environmentally unacceptable. Because of their extremely fine particle size they were difficult to remove from the stack gases and thus they cause nuisance to the inhabitants of the neighborhood. The problem was solved not only by efficient capturing the dust but also by recovering the carbon monoxide generated during converting (Figure 8).
Processes for steel and stainless steel manufacture in electric furnaces produce fine dust (\(< 0.5 \, \mu m\)) that is enriched in zinc, cadmium, and lead. This dust represents 1–2\% of the changes. It cannot be recycled because of its nonferrous metals content. It is usually disposed of at landfill sites. This practice, however, became environmentally unacceptable because a part of the nonferrous metals may be leached by surface water and cause contamination problems. As a result, legislation has been introduced to prohibit this practice. Solutions to this problem were developed based mainly on the recovery of zinc and other nonferrous metals. For example, leaching with NaOH and electrowinning of zinc from the leach solution, or leaching by H2SO4 at high temperature and pressure followed by electrowinning, or by reduction in a plasma-heated furnace.

**Ferroalloys**

Ferroalloys are used as additives to steel. They are manufactured by the reduction of a mixture of an iron ore and another oxide ore. For example, ferrosilicon is produced by the reduction of Fe2O3 and SiO2 mixture. During the manufacture this ferroalloy in an electric furnace a part of the silica sand used in the feed is reduced by the carbon and volatilized as silicon monoxide, SiO. This is then oxidized by the air to form finely divided silica dust which is collected in the dust recovery system. The reactions taking place are the following:


\[ \text{SiO}_2 + \text{C} \rightarrow \text{SiO} + \text{CO} \]
\[ \text{SiO} + \frac{1}{2}\text{O}_2 \rightarrow \text{SiO}_2 \]

This dust cannot be disposed of at landfill sites because it contains traces of soluble zinc compounds. A solution to this problem was found when it was discovered that this dust can be used with advantage in concrete as a substitute for some of the sand.

**Recovery of metals from metallurgical dust**

- *Vanadium from fuel oil* Fuel oil contains on the average 100 ppm vanadium. During burning in boilers to generate steam, the dust collected in the gas treatment section is rich in vanadium and is recovered in some plants (Figure 9).

  ![Figure 9. Vanadium from fuel oil](image)

**Figure 10. Rhenium from porphyry copper ores**

Chalcopyrite ore

- Crushing and grinding
- Bulk flotation
- Steaming
- Selective flotation
- Chalcopyrite concentrate

- Purification, e.g., leaching
- Roasting
- Dust collector

\[ \text{Cu}^+ \]
\[ \text{MoS}_2 \rightarrow \text{MoO}_3 \]
\[ \text{Re}_2\text{O}_7 \]
\[ \text{SO}_2 \]
Rhenium from porphyry copper ores  Chalcopyrite concentrate from porphyry copper ores contains on the average 0.05% molybdenite. This is usually separated by selective flotation. The molybdenite concentrate obtained contains about 700 ppm rhenium, which is enriched in the dust fraction during oxidation and is recovered by scrubbing (Figure 10). This is the principal source of rhenium.

- Cadmium from lead-zinc concentrates  Cadmium is usually associated with lead-zinc ores. While it is recovered from the zinc leach solution, it is volatilized during the sintering of lead concentrates (Figure 11). The reason is that roasting of zinc sulfide takes place at about 900 °C while that of lead sulfide at a higher temperature of about 1400 °C.

- Arsenic, antimony, and bismuth  These metals are usually associated with copper sulfide ores and are volatilized during roasting and smelting operations. They are captured in the dust recovery system for recovery or disposal.

![](image)

Figure 11. Recovery of cadmium during the processing of lead – zinc ores

Summary and conclusions
Dust in metallurgical plants is no longer a problem since the technology has advanced greatly permitting the capture of extremely fine dust particles (Figure 12).
Figure 12. A metallurgical plant before and after installation of an efficient dust recovery system
Suggested Readings

1. F. Habashi, *Pollution Problems in the Mineral and Metallurgical Industries*, Métallurgie Extractive Québec, Québec City, Canada 1996. Distributed by Laval University Bookstore


