METALS FROM ORES: A LOOK TO THE FUTURE

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METALS FROM ORES: A LOOK TO THE FUTURE

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ABSTRACT

In the past centuries pyrometallurgy was the only route to extract metals from ores and this was for a good reason - no other technology was available. Today metallurgists have the option to use other technology in particular the hydrometallurgical route. For example, the recovery of zinc, copper, and nickel have switched over from pyro- to hydrometallurgical technology. Another example is the recovery of alumina from bauxite - an essential step in the production of aluminum.

1. INTRODUCTION

Extracting metals from ores requires a number of operations: some mechanical, physical, and physicochemical known as mineral beneficiation and some chemical known as extractive metallurgy (Figure 1). The chemical processes can be divided for convenience as pyro-, hydro-, and electrometallurgy. Pyrometallurgy is the most ancient technology, while hydrometallurgy is about four centuries old. On the other hand electrometallurgy is the most recent and came into existence only after the invention of the large-scale electrical generators in the mid nineteenth century. No wonder then that, in some cases, these last two new technologies are displacing the older ones gradually, either because of improved efficiency and better economics or to comply with environmental regulations. Here are some examples.

2. PRODUCTION OF ZINC

For centuries, metallic zinc was produced by roasting its main mineral sphalerite to get zinc oxide, which was reduced at high temperature to get the metal (Figure 2). Although many modifications were made to improve this technology it was only during World War I that hydro- and electrometallurgical concepts were applied to develop a new process that competed with the old technology and finally displaced it in the 1970s (Figure 3). However, the new process introduced other problems that have to be solved, such as treatment of side products and disposal of waste residues (Figure 4).
Finally, in the 1980s, a new process was invented that leached directly the sulfide concentrate and electrolyzed the solution to get the metal (Figure 5).

3. PRODUCTION OF COPPER

Copper is an ancient metal and was produced over the centuries by smelting the ore to get a matte that was then treated by a number of thermal methods until the metal is liberated in a pure form. Beside the extensive fuel needed for the process, the emission of sulfur dioxide and other toxic material obliged metallurgists to seek other routes. The major improvement that took place was in the 1940s when flash smelting was introduced to displace the reverberatory furnace thus decreasing sharply the fuel consumption, but SO₂ was still a problem (Figure 6 and 7). It must be carefully collected, purified and transformed into sulfuric acid for which a nearby market must be available. At the beginning of the 21th century it was realized that the same technology recently applied for zinc sulfide concentrates can be as well applied for copper. Hence the pressure leaching of chalcopyrite was introduced for the first time in the copper industry.

![Zinc from sulfide concentrates, the old pyrometallurgical route](image1)

![Zinc from sulfide concentrates, the pyro-, hydro-, electrometallurgical route](image2)
Figure 4 – Improved zinc production in 1970s

ZnS concentrate → Oxidation → Acid plant → H_2SO_4

O_2 → Zinc oxide calcine → Leaching → Filtration → Concentrated Residue

Dilute H_2SO_4 recycle → Leaching 95°C → Filtration → Iron precipitation → Iron-containing residue

H_2SO_4 → Filtration → Purification → Electrolysis → Pure zinc

Figure 5 – Hydrometallurgy of zinc in 1980s

Make up H_2SO_4 → Sulfide concentrate → O_2

Leaching → Filtration → Purification → Electrolysis → Metal

Gangue, S, PbSO_4 FeOOH

Spent electrolyte
4. PRODUCTON OF NICKEL

Nickel occurs in nature as a low grade oxide [the laterite deposits] and as high grade sulfide deposits. The laterites are treated by a variety of processes the most important are the pressure leaching operations in Moa, Cuba. Until recently all nickel sulfides were treated by a smelting process not much different from that of copper. With the recent discovery of the Voisey Bay sulfide deposits in the Canadian North it was decided to use a pressure leaching process similar to that used for zinc and copper sulfides shown in Figure 5 to produce elemental sulfur instead of SO₂.

5. PRODUCTION OF ALUMINA

Bauxite is the major raw material for producing alumina needed for producing the metal. It was first sintered with sodium carbonate at high temperature then leached with water to obtain a solution from which aluminum hydroxide was precipitated, filtered, and calcined to get pure Al₂O₃ (Figure 8). Towards the end of the nineteenth century a new pressure leaching process for bauxite was invented that displaced the sintering process because it was more economical (Figure 9). The process has been applied ever since without any major changes except improving its engineering aspects.
6. PRESSURE LEACHING

A pressure leaching plant (Figure 10) is essentially composed of a high pressure pump that continuously forces the concentrate or ore slurry into an autoclave heated at a temperature of 150 – 200°C and operating at high pressure. The slurry leaving the autoclave is then introduced in flash tanks where sudden expansion takes place thus releasing low-pressure steam that is used for pre-heating the feed slurry and at the same time decreasing the pressure to permit filtration at ambient pressure. In such system heat economy is maximum. A typical autoclave is shown in Figure 11.

![Figure 10](image)

Figure 10 – A pressure leaching plant is composed of [from left to right] a slurry preparation tank, a slurry pre-heater, high pressure piston pump, an autoclave, flash tank, agitated tank to supply the slurry to the filtration system.
7. EPILOGUE

Historically, the production of alumina from bauxite in 1888 by the hydrometallurgical route was the turning point in introducing pressure leaching technology and to replace the pyrometallurgical process then in use. The production of zinc and copper from their sulfide ores has been shifted from a pyrometallurgical route to a completely hydrometallurgical. Nickel production from the recently discovered sulfide deposits at Voisey Bay in Canada are now also treated by pressure leaching technology which shows that this technology is the technology of the future and should be considered for other metals like tin and lead that are still smelting operations.

8. SUGGESTED READINGS