35 MINERAL PROCESSING PLANTS

Introduction

The following is a brief overview of the processes involved in mineral production in Ontario.

During extraction and refining, the valuable metals are separated from the worthless materials by a series of physical and chemical operations. In Ontario the primary metals extracted using these methods are nickel, copper, zinc, cobalt, and lead. Other metals such as gold, tin, silver, and indium are usually extracted as byproducts. Sulphide ores are most common and there are various health and environmental hazards associated with them.

Chemical metallurgical extraction processes are usually divided into two types:

1) pyrometallurgical methods (requiring high temperatures), and
2) hydrometallurgical methods (leaching).

This chapter focuses primarily on the pyrometallurgical methods.

Processes

The sequence of processes used in extracting and refining metals from ores varies according to a number of factors: the metal being extracted, the ore type, the mineral content, and the mineral concentrations.

Because the metal concentration is usually quite low in nonferrous ores, the first stage in mineral production at the mine is ore beneficiation, usually consisting of the processes of **milling** (crushing and grinding) and **concentrating** (usually consisting of a series of steps including flotation and dewatering by thickening and filtering).

The concentrate goes to the thermal pre-treatment or pyrometallurgical processes. These require very high temperatures and include the following procedures.

Sintering

Often used in lead production to reduce the sulphur content of the concentrate, sintering involves feeding a mix of moistened concentrate, flux, and fuel (coke) to an endless belt. The charge is ignited and burns below the metal melting point to become a fused mass (sinter) which drops off the end of the machine and goes to crushers. The ventilation and production gases go to baghouses or electrostatic precipitators for dust recovery.

Roasting

This is usually the initial step in the smelting process. The ore concentrate is roasted at about 550°C to dry it and remove much of contaminants such as sulphur. Roasting is typically used in the production of copper, nickel, cobalt, and zinc, although some smelters bypass this step and add the charge directly to the smelting furnace. The material produced is calcine.

Smelting

The extraction of metals from their ores is usually accomplished by the chemical reduction of the oxides of the metal with carbon in a furnace. The purpose of smelting sulphide ores is to produce a valuable metal concentrate, called **matte**.

In **copper** and **nickel** production, this is a mixture of metallics with sulphide compounds. The cold concentrate or hot calcine charge is melted at above 1000°C by burning fossil fuels, or in an electric furnace or, in the case of flash smelting, by oxidizing the sulphur in the concentrate.

In **lead** production, sinter and coke are charged to a blast furnace for smelting and the lead is reduced to metallic lead and cast as bullion.The bullion is further purified by adding sulphur to form a copper sulphide matte from which copper is recovered.

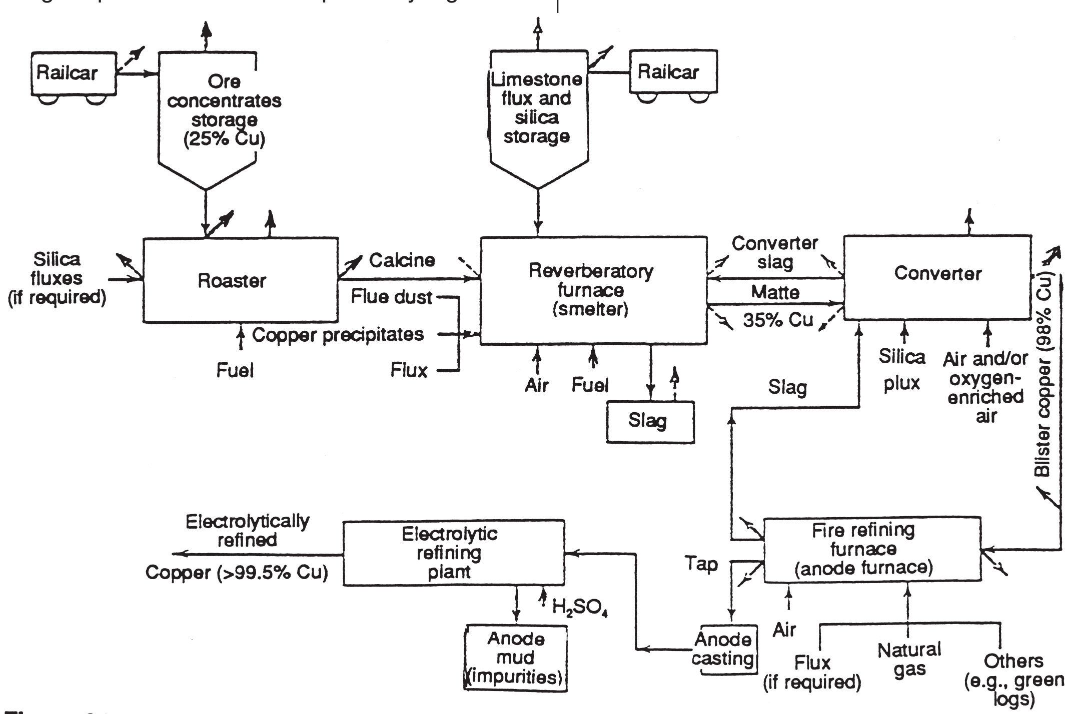

Figure 24.1 – Flow diagram for typical copper smelting operation

Converting

The matte from the smelting furnace in copper production usually goes to a converter, where iron and sulphur are removed by oxidation with the addition of a flux and low pressure air (sometimes oxygen). In copper production, this process produces blister copper, usually about 98% copper.

Anode production/fire refining

Blister copper is further refined in a gas-fired furnace where oxidation removes remaining sulphur and soda ash is added to the molten bath to remove arsenic and antimony in a slag which is skimmed off. The blister copper is now cast into shapes called anodes which are about 99.5% copper.

Refining

Lead - Lead bullion is from 95% to 99% pure but contains valuable impurities such as gold, silver, tin, and antimony. These are removed by treating molten lead bullion in kettles with various reagents.

Copper - After casting, the blister copper anode (positive electrode) is refined by electrolysis in an aqueous solution of copper sulphate and sulphuric acid using a pure copper cathode. The copper from the anode is deposited during electrolysis on the cathode. Impurities such as gold, silver, and selenium drop to the bottom of the tank as a black mud called slimes. Other impurities, such as arsenic and nickel, remain in solution and are treated separately.

Nickel - Matte is refined by electrolysis or by the Mond process, in which the matte is ground, calcined, and treated with carbon monoxide at 50°C to form gaseous nickel carbonyl ($Ni(CO)_4$), which is then decomposed above 60°C to deposit pure nickel powder.

Figure 24.1 shows a flow diagram for a typical copper smelting operation.

Health Hazards – Copper and Lead Production

The tables below indicate hazardous exposure potentials for copper smelting and lead production.

Other Health Hazards in Mineral Processing

Many hazards can be encountered during construction or maintenance in mineral processing plants. Industry and plant orientation and training programs must be identified and planned for at the time of contract bidding so that they can be delivered to the necessary personnel on time.

The contents of all storage and piping systems should be determined. MSDSs should be obtained and reviewed in advance. Information should be readily available from the client/mill operators.

Plant operating practices and procedures must be followed at all times. Confirm with operating personnel potential problems in your working area such as the following:

1) potential sources of air contaminants needing isolation
2) areas where sudden unexpected exposures might occur
3) pinch points and moving equipment. Several categories of equipment can present these kinds of hazards, such as transportation equipment, bulk loading equipment, overhead cranes, and operating equipment.
4) explosion and burn hazards — spatters or spills of molten material are an obvious source of burns and fires. Contact between molten metal or slag and moisture will result in violent explosions and spattering of molten material. A network of piping transports fuel gases and oxygen around the plant – all of which have a potential for explosion and fire. Sparks and fires around oxygen lines are especially hazardous.
5) health and hygiene hazards – acids, carbon monoxide (CO), sulphur dioxide (SO_2), matte fume, and dusts such as arsenic (As), lead (Pb), and silica (SiO_2).

COPPER SMELTING		
Operation	**Purpose**	**Potential Exposures**
Roasting	Dries ore concentrate Controls silica content Produces calcine	Ore dust, SO_2, CO, lead & arsenic, heat, and particulate
Smelting	Produces Cu-Fe sulfide matte and silaceous slag. Charge is concentrate or calcine, recycled precipitates, converter slag, flux dust, limestone, and silica flux	Lead-containing dust, flux dust, CO, matte dust & fume, SO_2, noise
Converting	Produces blister copper (95.8%). Charge is matte and silica flux.	Lead-containing dust, flux dust, SO_2, noise, metal dust/fume
Refining	Produces domestic copper (>99.5%)	H_2SO_4 mist, noise. Arsine gas can occur without precautions

LEAD PRODUCTION		
Operation	**Purpose**	**Potential Exposures**
Sintering	Convert sulphides to oxides and sulphates	SO_2, lead-containing dust
Smelting	Removes impurities, reduces compounds to lead (bullion) containing 94-98% lead and slag.	CO, SO_2, silaceous dust, lead dust, other metallic oxides
Drossing	Remove copper, silica, arsenic, antimony and nickel from solution	CO, SO_2, lead dust