

Copper Smelting

Industry Description and Practices

Copper can be produced either pyrometallurgically or hydrometallurgically. The hydrometallurgical route is used only for a very limited amount of the world's copper production and normally only considered in connection to in-situ leaching of copper ores; from an environmental point of view this is a questionable production route. Several different processes can be used for copper production. The old traditional process is based on roasting, smelting in reverberatory furnaces or electric furnaces for more complex ores, producing matte and converting for production of blister copper which is further refined to cathode copper. This route for production of cathode copper requires large amounts of energy per ton of copper (30-40 million Btu per ton cathode copper). It also produces furnace gases with low sulfur dioxide concentrations from which the production of sulfuric acid or other products is less efficient. The sulfur dioxide concentration in the exhaust gas from a reverberatory furnace is about 0.5-1.5% and from an electric furnace is about 2-4%. So called flash smelting techniques have therefore been developed which utilize the energy released during oxidation of the sulfur in the ore. The flash techniques reduce the energy demand to about 20 million Btu/ton of produced cathode copper. The sulfur dioxide concentration in the off gases from flash furnaces is also higher, over 30%, and less expensive to convert to sulfuric acid (note: the INCO process results in 80% sulfur dioxide in the off gas). Flash processes have been in use since the 1950s.

In addition to the above processes there are a number of newer processes such as the Noranda, Mitsubishi, and Contop which replaces or was intended to replace roasting, smelting and converting, or processes such as ISA-SMELT and KIVCET which replaces roasting and smelting. For converting the Pierce-Smith and Hoboken converters are the most common processes.

The matte (copper-iron sulfide) from the furnace is charged to converters where the molten material is oxidized in the presence of air to remove the iron and sulfur impurities (as converter slag) and to form blister copper.

Blister copper is further refined as either fire-refined copper or anode copper (99.5% pure copper), which is used in subsequent electrolytic refining. In fire-refining, molten blister copper is placed in a fire-refining furnace, a flux may be added and air is blown through the molten mixture to remove residual sulfur. Air blowing results in residual oxygen which is removed by the addition of natural gas, propane, ammonia or wood. The fire-refined copper is cast into anodes for further refining by electrolytic processes or is cast into shapes for sale.

In the most common hydrometallurgical process the ore is leached with ammonia or sulfuric acid to extract the copper. These processes can operate at atmospheric pressure or as pressure leach circuits. Copper is recovered from solution by electrowinning – a process similar to electrolytic refining. The process is most commonly used for leaching low grade deposits in situ or as heaps.

Recovery of copper metal and alloys from copper bearing scrap metal and smelting

residues requires preparation of the scrap (such as removal of insulation, etc.) prior to feeding into the primary process. Electric arc furnaces using scrap as feed are also common.

Waste Characteristics

Principal air pollutants emitted are sulfur dioxide (SO₂) and particulate matter from the processes. The amount of sulfur dioxide released from the process will depend on the characteristics of the ore – complex ores may contain lead, zinc, nickel and other metals – and whether facilities are in place for capturing and converting the SO₂. Sulfur dioxide emissions may range from less than 4 kilograms per metric ton (kg/t) copper to 2,000 kg/t copper. Particulate emissions can range from 0.1 kg/t copper to as high as 20 kg/t copper.

Fugitive emissions occur at furnace openings, from launders, casting molds, and ladles carrying molten materials. Additional fugitive particulate emissions occur from materials handling and transportation of ores and concentrates.

Some vapors, as arsine, are produced in hydrometallurgy and various refining processes. Dioxins can be formed from plastic and other organic material during melting of scrap. The principal constituents of the particulate matter are copper and iron oxides. Other copper and iron compounds as well as sulfides, sulfates, oxides, chlorides and/or fluorides of arsenic, antimony, cadmium, lead, mercury and zinc may also be present. Mercury can also be present in metallic form. At higher temperatures, mercury and arsenic could be present in vapor form. Leaching processes will generate acid vapors while fire-refining processes result in copper and sulfur dioxide emissions. Emissions of arsine, hydrogen vapors and acid mists are associated with electrorefining.

Wastewater from primary copper production contains dissolved and suspended solids that may include: concentrations of copper, lead, cadmium, zinc, arsenic and mercury, and residues from mold release agents (lime or aluminum oxides). Fluoride may also be present and the effluent may have a low pH. Normally there is no liquid effluent from the

smelter other than cooling water; waste waters do originate in scrubbers (if used), wet electrostatic precipitators, cooling of copper cathodes, etc. In the electrolytic refining process, by-products such as gold and silver are collected as slimes which are subsequently recovered. Sources of wastewater include spent electrolytic baths, slimes recovery, spent acid from hydrometallurgy processes, cooling water, air scrubbers, washdowns, stormwater and sludges from wastewater treatment processes that require reuse/recovery or appropriate disposal.

The major portion of the solid waste is discarded slag from the smelter. Discard slag may contain 0.5-0.7% copper and is frequently used as construction material or for sandblasting. Leaching processes produce residues while effluent treatment results in sludges which can be sent for metals recovery. The smelting process typically produces less than three tons of solid waste per ton of copper produced.

Pollution Prevention and Control

Process gas streams containing SO₂ are processed to produce sulfuric acid, liquid sulfur dioxide, or sulfur. The smelting furnace will generate process gas streams with SO₂ concentrations ranging 0.5-80% percent depending on the process used. It is important, therefore, that a process be selected which uses oxygen enriched air (or pure oxygen) to raise the sulfur dioxide content of the process gas stream and reduce the total volume of the stream, thus permitting efficient fixation of sulfur dioxide. Processes should be operated to maximize the concentration of the SO₂. An added benefit is the reduction of nitrogen oxides (NO_x).

Closed loop electrolysis plants will contribute to prevention of pollution.

Continuous casting machines should be used for cathode production to avoid the need for mold release agents.

Furnaces should be enclosed to reduce fugitive emissions, and dust from dust control equipment should be returned to the process.

Use energy efficiency measures (such as waste heat recovery from process gasses) to reduce fuel usage and associated emissions.

Recycle cooling waters, condensates, rainwater, and excess process water for washing, for dust control, for gas scrubbing, and for other process applications where water quality is not of concern.

Good housekeeping practices are key to minimizing losses and preventing fugitive emissions. Such losses and emissions are minimized by enclosed buildings, covered or enclosed conveyors and transfer points, and dust collection equipment. Yards are paved and run-off water is routed to settling ponds. Regular sweeping of yards, and indoor storage or coverage of concentrates and other raw materials also reduce material losses and emissions.

Treatment Technologies

Fabric filters are used to control particulate emissions. Dust that is captured but not recycled will need to be disposed in a secure landfill or other acceptable manner.

Vapors of arsenic and mercury present at high gas temperatures are condensed by gas cooling removed. Additional scrubbing may be required.

Effluent treatment by precipitation, filtration, etc. of process bleed streams, filter backwash waters, boiler blowdown, and other streams may be required to reduce suspended and dissolved solids and heavy metals. Residues that result from treatment are either sent for metals recovery or sent to sedimentation basins. Storm waters should be treated for suspended solids and heavy metals reductions.

Slag should be landfilled or granulated and sold.

Modern plants using good industrial practices should target on meeting releases for total dust of 0.5-1.0 kg/t copper and a discharge for SO₂ of 25 kg/t copper.

The double contact double absorption plant should emit no more than 0.2 kg of sulfur dioxide per ton of sulfuric acid produced (based on a conversion efficiency of 99.7%).

Emission Guidelines

Emission levels for the design and operation of each project must be established through the Environmental Assessment (EA) process, based on country legislation and the *Pollution Prevention and Abatement Handbook* as applied to local conditions. The emission levels selected must be justified in the EA and acceptable to MIGA.

The following guidelines present emission levels normally acceptable to the World Bank Group in making decisions regarding provision of World Bank Group assistance, including MIGA guarantees; any deviations from these levels must be described in the World Bank Group project documentation.

The guidelines are expressed as concentrations to facilitate monitoring. Dilution of air emissions or effluents to achieve these guidelines is unacceptable.

All of the maximum levels should be achieved for at least 95% of the time that the plant or unit is operating, to be calculated as a proportion of annual operating hours.

Air Emissions

For copper smelters the following air emissions levels should be achieved:

Emissions from Copper Smelting

<i>Parameter</i>	<i>Maximum value milligrams per normal cubic meter (mg/Nm³)</i>
SO ₂	1,000
Arsenic	0.5
Cadmium	0.05
Copper	1
Lead	0.2
Mercury	0.05
Particulates - smelter	20
Particulates - other sources	50

The environmental assessment should address the build-up of heavy metals from

particulate fall-out in the vicinity of the plant over its projected life.

Liquid Effluents

For copper smelters the following effluent emissions levels should be achieved:

Effluents from Copper Smelting

<i>Parameter</i>	<i>Maximum value milligrams per liter (mg/L)</i>
pH	6-9
Total suspended solids	50
Arsenic	0.1
Cadmium	0.1
Copper	0.5
Iron	3.5
Lead	0.1
Mercury (total)	0.01
Zinc	1.0
Total metals	10
Temperature increase	less than or equal to 3°C ¹

¹The effluent should result in a temperature increase of no more than 3 degrees Celsius at the edge of the zone where initial mixing and dilution take place. Where the zone is not defined, use 100 meters from the point of discharge.

Note: Effluent requirements are for direct discharge to surface waters.

Ambient Noise

Noise abatement measures should achieve either the following levels or a maximum increase in background levels of 3 dB(A). Measurements are to be taken at noise receptors located outside the project property boundary.

Ambient Noise

Receptor	Maximum Allowable L _{eq} (hourly), in dB(A)	
	Daytime 07:00 - 22:00	Nighttime 22:00 - 07:00

Residential; institutional; educational	55	45
Industrial; commercial	70	70

The emission requirements given here can be consistently achieved by well-designed, well-operated and well-maintained pollution control systems.

Monitoring and Reporting

Frequent sampling may be required during start-up and upset conditions. Once a record of consistent performance has been established, sampling for the parameters listed above should be as detailed below.

Air emissions should be monitored continuously for SO₂ and particulate matter. Other air emission parameters should be monitored annually.

Liquid effluents should be monitored daily for pH and total suspended solids and at least monthly for all other parameters.

Monitoring data should be analyzed and reviewed at regular intervals and compared with the operating standards so that any necessary corrective actions can be taken. Records of monitoring results should be kept in an acceptable format. These should be reported to the responsible authorities and relevant parties, as required, and provided to MIGA if requested.

Key Issues

The following box summarizes the key production and control practices that will lead to compliance with emissions requirements:

- Give preference to processes that are energy efficient and which produce high SO₂ concentrations (e.g., flash smelting).
- Use oxygen for enrichment of SO₂.
- Use the double contact double absorption process for sulfuric acid production.
- Reduce effluent discharge by maximizing wastewater recycling.
- Maximize the recovery of dust and sludges.

- Minimize fugitive emissions by encapsulation of process equipment and use of covered or enclosed conveyors.
- Give preference to dry dust collectors over wet scrubbers.

Further Information

The following are suggested as sources of additional information (these sources are provided for guidance and are not intended to be comprehensive):

Bounicore, A.J. and W.T. Davis. 1992. *Air Pollution Engineering Manual*. New York: Van Nostrand Reinhold.

Environment Canada. April 1980. "A Study of Sulphur Containment Technology in the Non-Ferrous Metallurgical Industries." Report EPS 3-AP-79-8.

World Bank, Environment Department. 1996. "Pollution Prevention and Abatement: Copper Smelting." Technical Background Document.

Technical Note on Best Available Technologies Not Entailing Excessive Costs for Heavy Metal Emissions from Non-Ferrous Industrial Plants, May 1991, European Commission

Study on the Technical and Economical Aspects of Measures to Reduce the Pollution of Water and Other Environmental Areas from the Non-Ferrous Metal Industry, August 1993, European Commission..