How Copper Ore is Transformed into Products You Use Everyday

by David F. Briggs

There are generally two types of copper ores, sulfide ores and oxide ores. Sulfide ores contain copper-bearing sulfide minerals such as chalcopyrite, bornite and chalcocite, while oxide ores are composed of a variety of copper-bearing silicate, carbonate, sulfate or chloride minerals, including chrysocolla, malachite, azurite, brochantite and atacamite.

Chalcopyrite-Bornite-Quartz Vein from Freeport's Dos Pobres mine near Safford, Arizona (Photo taken by David Briggs)

Azurite from Freeport's Morenci Copper Mine (Photo taken by David Briggs)

A different treatment process is employed to recover the copper from each of these ore types.

Sulfide Copper Ores

The process used to treat sulfide copper ores (see Figure 1) begins at the mine site, where the copper-bearing minerals are physically separated from the rest of the rock.

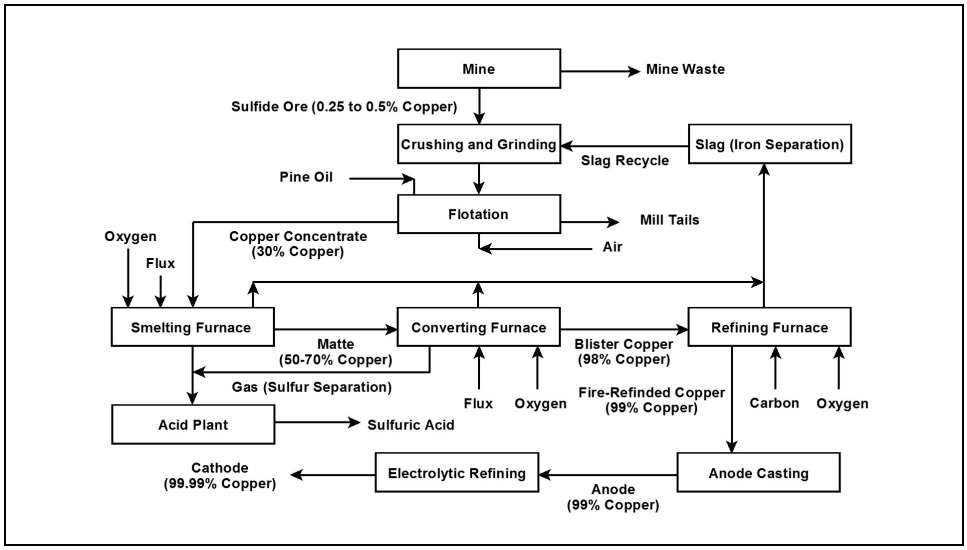


Figure 1: Flow Chart for Treatment of Sulfide Copper Ores (Modified from Goonan 2009)

This occurs at a mill facility, which is known as a concentrator. The ore from the mine (averages 0.25% to 0.50% copper) is initially reduced in size to about 10 to 0.5-inches by a one or more stages of crushing. The crushed ore reports to a grinding circuit, where steel balls are used to further reduce it to a consistency of a fine beach sand.

Ball Mill Grinding Circuit at Freeport's Sierrita Concentrator
(Photo taken by David Briggs, June 2002)

The ground ore then proceeds to a series of froth flotation tanks, where organic compounds, such as pine oil, are used to attract the sulfide grains.

Flotation Circuit at Freeport's Sierrita Concentrator
(Photo taken by David Briggs, June 2002)

Air is injected from the base of the flotation tanks to make bubbles that the copper sulfides stick to and float to the surface, where it is skimmed off.

Sulfide Coated Bubbles Collected from Flotation Tank at ASARCO's Mission Concentrator (Photo Provided Courtesy of Jan Rasmussen)

The percentage of copper contained within these concentrates depends on the minerals present in the ore, but generally averages around 30%. The copper concentrates are dewatered by filter presses and shipped to an off-site smelting facility.

Copper Matte is Tapped from Bottom of Smelting Furnace at ASARCO's Hayden Facility (Photo Provided Courtesy of Jan Rasmussen)

The smelting process takes place in three stages with each stage successively upgrading the copper content of its final product. The initial stage includes a smelting furnace, which produces a matte product (50 to 70% copper) that is upgraded in a converting furnace to produce blister copper (98% copper).

During the first two stages initial copper concentrate and matte products are mixed with fluxing agents (silica) and melted in the presence of oxygen. The fluxing agents bind with iron, silica and other impurities to produce slag, which floats to the surface and is skimmed off for disposal. The sulfur combines with the oxygen to form sulfur dioxide gas, which is captured and sent to an acid plant, where it is converted into sulfuric acid that is either sold on the commercial market or used to leach copper from oxide copper ores. The final smelting stage occurs in a refining furnace, where the blister copper is melted with carbon in the presence of oxygen to produce fire-refined copper (99% copper), which is cast into anodes that are shipped to a copper refinery.

During the electrolytic refining process the copper anodes are placed in large acid-filled tanks with stainless steel cathode starter sheets.

Electro-refining Tank House at the ASARCO'S Amarillo Refinery
(Photo Provided Courtesy of Jan Rasmussen)

An electric current is passed through the tank, moving the copper from the copper anodes at the positive pole to a stainless steel starter sheet called a cathode at the negative pole. Any impurities contained within the copper anodes fall to bottom of the tank and are periodically collected to recover any precious metals that may be present. After approximately ten days, the copper is 3/8 of an inch thick on the starter sheets. At this point, they are pulled from the tank and rinsed. The final copper cathode product (99.99% copper) is stripped from the starter sheets and shipped to a rod plant, where it is melted and cast into copper rod or copper cakes that are sold to manufacturers, who use it to produce a wide variety of consumer goods.

Oxide Copper Ores

The process used to treat oxidized copper ores (see Figure 2) begins at the mine site, where the ores are either dumped directly onto lined leach pads or in some cases are crushed prior to being placed on the leach pads.

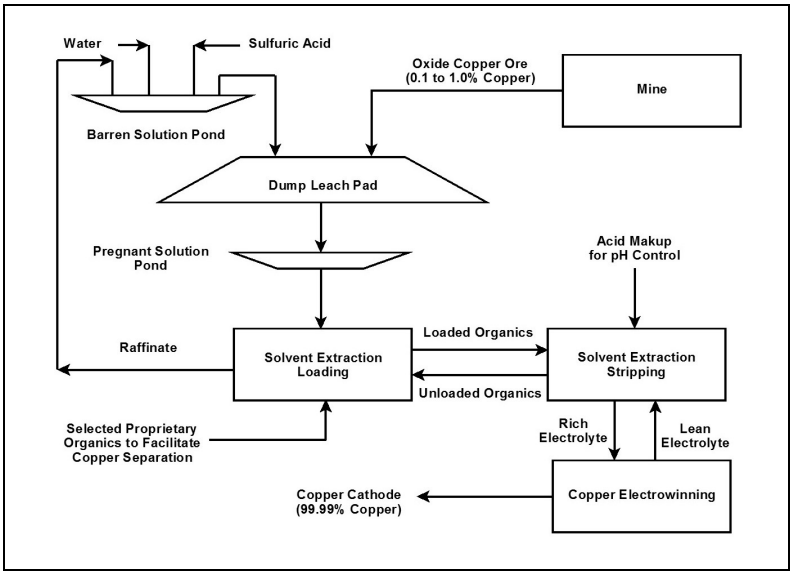


Figure 2. Flow Chart for Treatment of Oxide Copper Ores (Modified from Goonan 2009)

A weak sulfuric acid solution is applied to the leach pad by a drip irrigation system, which is similar to that used by farmers to irrigate their fields.

Large Dump Leach Pad at Freeport's Morenci Mine (Photo taken by David Briggs)

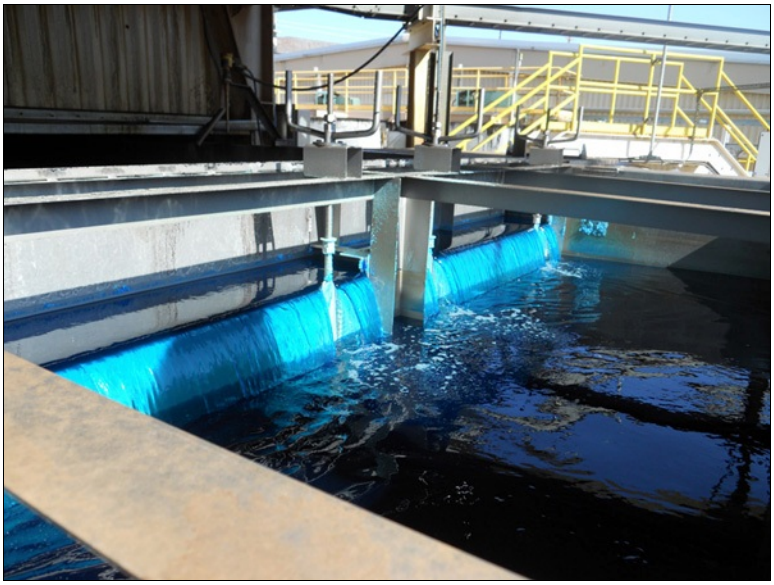
As this weak acidic solution percolates down through the rock it dissolves the soluble copper contained within the ore.

Drip Irrigation Lines on Leach Pad at Freeport's Bagdad Mine
(Photo Provided Courtesy of Jan Rasmussen)

These copper-bearing solutions are collected from the bottom of the leach pad and directed to the pregnant solution leach pond before reporting to the solvent extraction plant.

Solvent Extraction Plant at Nord Resources' Johnson Camp Mine
(Photo Provided Courtesy of Jan Rasmussen)

The solvent extraction phase of treatment occurs in two stages. During the initial phase an organic solvent is used to recover copper ions contained in the pregnant leach solution, exchanging them with hydrogen ions in the acid. The final phase of the solvent extraction process employs a strong acid to strip the copper from the organic solution, producing a blue, enriched copper-bearing solution that is treated at an electrowinning plant.



Blue Copper Enriched Solution from Solvent Extraction Facility at Freeport's Safford Mine (Photo Provided Courtesy Jan Rasmussen)

Bundles of Copper Cathode Ready for Shipment at Freeport's Bagdad Mine (Photo Provided Courtesy of Jan Rasmussen)

The electrowinning plant consists of a number of large tanks, which contain the enriched copper-bearing solutions derived from the solvent extraction circuit, stainless steel starter sheets and inert anodes made from a lead alloy. As an electric current is passed through the circuit, the copper ions contained in the solution precipitate onto the cathode starter sheets. When the copper is 3/8-inch thick on the starter sheets, they are removed from the tank and rinsed. The final copper cathode product (99.9% copper) is stripped from the starter sheets and bundled for shipment.

References

Goonan, T. G., 2009, Copper Recycling in the United States; Chapter 10, of Sibley, S. R., Flow Studies for Recycling Metal Commodities in the United States: U. S. Geological Survey Circular 1196-X, 30 p.

Rasmussen, J. C., 2013, From Mine to Me How Copper Ore Becomes Copper Wire: 122 p.

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