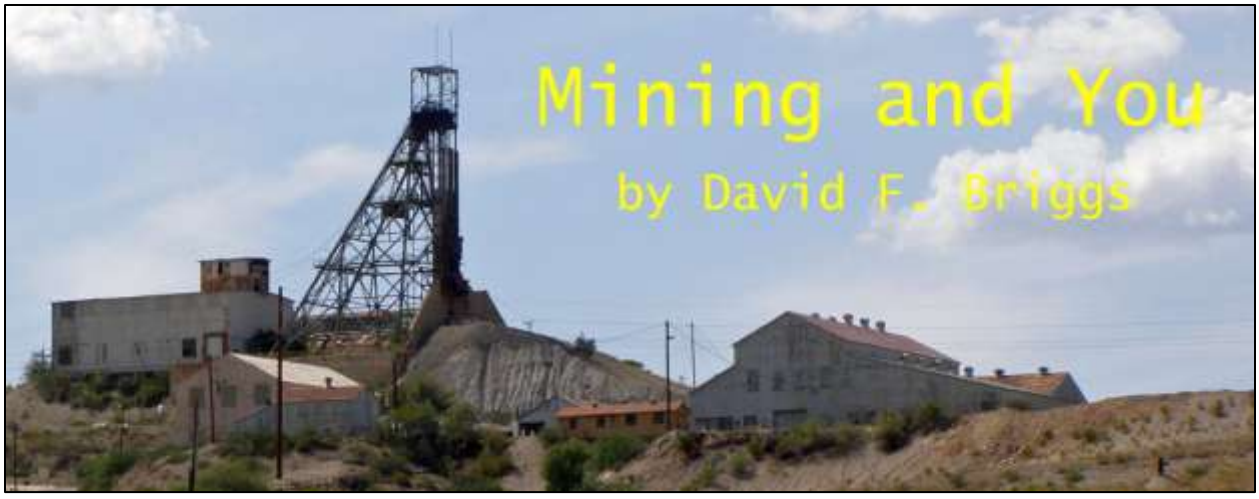


Advancements in Technology Enable Arizona's Mines to be Competitive in the Global Marketplace

by David F. Briggs

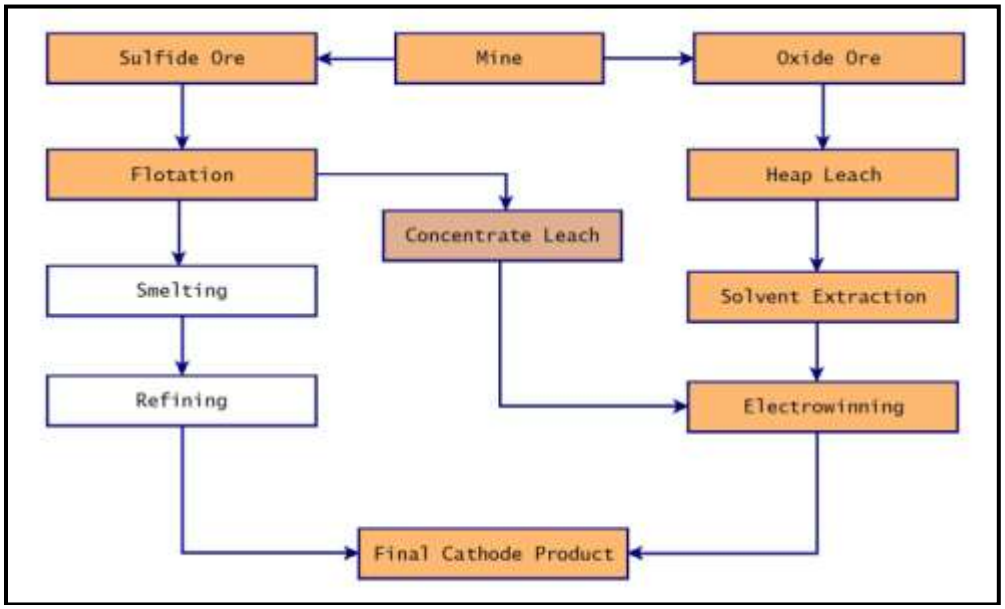
During the late 1970s, sixteen domestic copper smelters treated sulfide concentrates derived from our nation's mines. Today, only three remain in operation; Kennecott's Garfield smelter near Salt Lake City, Utah, ASARCO's Hayden smelter at Winkelman, Arizona and Freeport-McMoRan's Miami smelter near Globe, Arizona.

Freeport-McMoRan's Miami Smelter near Globe, Arizona (Photo by David Briggs)

Reasons for these closures are varied. Some of these facilities ceased operations as a result of the closure of the mines they served. The introduction of large-scale, heap leach and solvent extraction-electrowinning (SX-EW) facilities at some copper operations eliminated the need for the capacity provided by other smelters. However, the primary reason for their closure was the high cost of operating and maintaining these facilities in compliance with ever changing and more stringent environmental regulations, which made it impossible for them to compete with foreign operations.

These closures have resulted in a significant loss of our domestic smelter capacity, which has fallen to a point where America no longer has the ability to treat all of the copper concentrates produced at our nation's mines. Concentrates from many operations like Robinson, Pinto Valley and Butte are treated at foreign smelters. Even America's leading copper producer, Freeport-McMoRan shipped approximately 255,000 short tons of copper concentrates derived from their domestic mining operations to Atlantic Copper's (a wholly-subsidiary of Freeport-McMoRan) smelter in Huelva, Spain during 2014.

Interested in finding alternatives to conventional smelting and refining of copper concentrates, Phelps Dodge (now Freeport-McMoRan) began evaluating sulfate-based, pressure-leaching technology in 1998. Within a year, they had identified two potentially commercially viable processes that involved the use of autoclaves to pressure-leach copper concentrates; one at high temperature (225° C) and another at medium temperature (140 to 180° C).



Simplified Flow Diagram for Processing Copper Ores at Morenci

Application of autoclave technology to the treatment of copper concentrates evolved from their use in the gold mining industry, where they have been employed since the mid-1980s. In October 2001, Phelps Dodge decided to proceed with the design and construction of a $40 million concentrate

leaching pilot plant at its Bagdad mine, located about 50 miles northwest of Wickenburg, Arizona. This facility was commissioned in March 2003. Its successful operation led to a decision to develop a commercial concentrate pressure-leaching facility at Morenci, which was commissioned in October 2007 at a cost of $107 million. The collapse of copper prices during the fall of 2008 resulted in this facility being placed on care-and-maintenance status in early 2009, where it remained until operations were resumed during early 2015.

Conventional treatment of sulfide copper ores begins at the mine site, where the copper-bearing minerals are physically separated from the rest of the rock at a mill facility, which is known as a concentrator. Here the ore from the mine (grade averages 0.25% to 0.50% copper) is initially reduced to a consistency of a fine sand by crushing and grinding circuits. The finely ground ore is directed through a series of flotation tanks that produce a concentrate product, which generally averages about 30% copper. The copper concentrates are then shipped to a smelter and refinery that produce a final copper cathode product, containing 99.99% copper.

Under the medium temperature, pressure-leaching alternative employed at Freeport's Morenci operation, copper concentrates derived from the flotation section of the mill by-pass the smelting and refining stages and report directly to a concentrate leaching facility, where it is oxidized within autoclaves that operate at a temperature of 160° C and a pressure of 305 psi. This oxidation process produces a copper-bearing solution, which is treated by another newly developed technological process, known as direct electrowinning that produces a marketable copper cathode product.

Concentrate Leaching Facility at Morenci, Arizona (from Google Earth - 5/9/2014)

The successful application of sulfate-based, pressure-leaching technology offers many benefits:

- lower concentrate treatment costs compared with conventional smelting and refining.

- capital expenditures are significantly less than new smelting/refining projects. It also provides significant opportunities to reduce, or in certain circumstances eliminate capital expenditures related to concentrate handling systems (i.e. truck, rail, pipeline or ship).

- enables mining projects to deliver a value added copper cathode product to the market sooner, improving overall product stewardship and environmental performance by mining and processing ores, treating concentrates and management of waste materials at a single industrial site.

- keeps jobs here in America by increasing employment opportunities, strengthening local economies and generating tax revenue for local, state and federal governments.
- helps preserve jobs by maintaining existing SX-EW facilities throughout the life of the project as the mine transitions from oxide to sulfide-bearing ores.

- helps strengthen our economy and national security by reducing America's dependence on imported copper.

- provides an environmentally sound method to treat concentrates. Hazardous gaseous emissions or fugitive dusts are significantly less than observed at conventional smelting and refining facilities.

- eliminates freight and associated environmental costs resulting from the shipment of copper concentrates to off-site smelting and refining facilities. Also eliminates losses of product that occur during handling and transport of concentrates to off-site smelters.

- able to utilize existing solvent extraction and electrowinning capacity as well as existing site infrastructure.

- copper recoveries are slightly greater than conventional smelting and refining.

- reduces the need to purchase acid on the open market by generating by-product sulfuric acid that can used can be used to recover copper from oxide ores. A lower demand for acid from off-site sources also reduces freight and associated environmental costs related to acid deliveries to the mine site.

- precious metals can be recovered from oxidized residues.

Freeport-McMoRan's sulfate-based, pressure-leaching process is just one of the new and exciting technologies being developed at Arizona's mines. Advances in technology at Resolution Copper's project near Superior, Arizona

will allow Arizonans to safely mine copper ores from depths of 5,000 to 7,000 feet, where rock temperatures reach 175° F. ASARCO's participation in the Avalon Solar Project, located adjacent to their Mission mine south of Tucson, demonstrates their commitment to developing renewable energy projects on disturbed lands, including mine sites. Stand-alone, in-situ leaching technology employed at Florence Copper's proposed project will produce a marketable cathode product from a small, ephemeral, environmental footprint; allowing the land to be returned to productive use by the local community once mining activities have been completed. Dry stack tailings technology at Rosemont Copper's project near Tucson, helps conserve Arizona's water resources.

America's mining industry is working hard to remain competitive in the global marketplace, while responsibly producing the natural resources we consume every day. These kinds of technological innovations keep American jobs at home and provide a brighter future for the next generation.

Disclaimer: David F. Briggs is a resident of Pima county and a geologist, who has worked in the mining industry for more than 35 years.

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