The Hidalgo Smelter

Ibrahim H. Gundiler

2000, pp. 263-266. https://doi.org/10.56577/FFC-51.263

in:

Southwest Passage: A trip through the Phanerozoic, Lawton, T. F.; McMillan, N. J.; McLemore, V. T.; [eds.], New Mexico Geological Society 51 st Annual Fall Field Conference Guidebook, 282 p. https://doi.org/10.56577/FFC-51

This page is intentionally left blank to maintain order of facing pages.

THE HIDALGO SMELTER

IBRAHIM H. GUNDILER
New Mexico Bureau of Mines and Mineral Resources, New Mexico Institute of Mining and Technology, 801 Leroy Pl. Socorro, NM 87801;gundiler@gis.nmt.edu

Abstract—When U.S. Congress passed the 1970 Clean Air Act Amendment, the Environmental Protection Agency established discharge limits for point sources of pollution that were universally adopted by the states. Among the regulations that mainly concerned the copper mining states in the Southwest was the requirement for recovery of 90% of the sulfur input at the copper smelters. The existing reverberatory-furnace smelters were able to capture only 50–60% of sulfur if they were also equipped with an acid plant. Most smelters were not. In 1976, Phelps Dodge Corporation built the first flash furnace smelter in the U.S. in Hidalgo County, New Mexico. The Hidalgo smelter, equipped with two acid plants, was also the first smelter able to meet the new air quality standards in the nation. This energy-efficient flash smelter was capable of smelting 2400 short tons of copper concentrate a day while capturing 96% of sulfur input and producing sulfuric acid. The smelter was closed and mothballed in September 1999.

INTRODUCTION

The Phelps Dodge Corporation holds the distinction of building the first flash-furnace copper smelter in the United States. The Hidalgo smelter, built in 1976 in Hidalgo County, New Mexico, was also the first smelter in the nation capable of meeting the air quality standards mandated by the 1970 Clean Air Act Amendments (CAA). When Congress passed the CAA, it set a deadline of five years for states to meet the new standards. The U.S. Environmental Protection Agency (EPA) required the removal of 90% of the sulfur at copper smelters and 99.5% of the sulfur input in acid plants. In addition, the maximum permissible SO_2 emission for copper smelters was limited to 650 parts per million (ppm), and ambient air (ground level) annual mean concentration of SO_2 to 0.03 ppm (White, 1971).

Smelters with conventional reverberatory furnaces and acid plants were able to recover only 50–60% of the sulfur. Those without an acid plant released approximately 2 short tons (st) of SO_2 to the atmosphere for every ton of copper produced.

In the 1970s, Phelps Dodge Corporation owned several mines and operated three reverberatory furnace copper smelters in Arizona, Ajo, Douglas, and Morenci, and also developed the Tyrone open-pit copper mine in New Mexico. The Tyrone mill was brought on line late in 1969 and began shipping flotation concentrates to the Morenci smelter, which was already under pressure to reduce throughput to curtail SO_2 emissions. In 1974, Phelps Dodge Corporation began construction of a flash-furnace copper smelter using Outokumpu technology, in Hidalgo County, New Mexico. The company had purchased a large cattle ranch and acquired control of adjacent lands in the Playas Valley in 1960s (Anon., 1980). The new smelter was commissioned in July 1976 and concentrates from Tyrone were processed at the Hidalgo smelter (Fig. 1) approximately 40 mi south of Lordsburg.

COPPER SMELTING AND CONVERTING

The reverberatory furnaces (reverbs) were very versatile reactors and there are many reverbs still operating all over the world. A typical reverb furnace is a refractory brick-lined rectangular hearth, covered with an arched brick roof. The heat for smelting is provided by combustion of fuel oil, natural gas, or pulverized coal in burners situated at one end of the furnace (Fig. 2). The combustion gases leave the furnace through the waste-heat boilers (WHB) for energy recovery. The SO_2 concentration in the reverb gas is usually too dilute (0.5–2%) to be recovered economically.

Copper flotation concentrates contain mainly chalcopyrite ($CuFeS_2$)

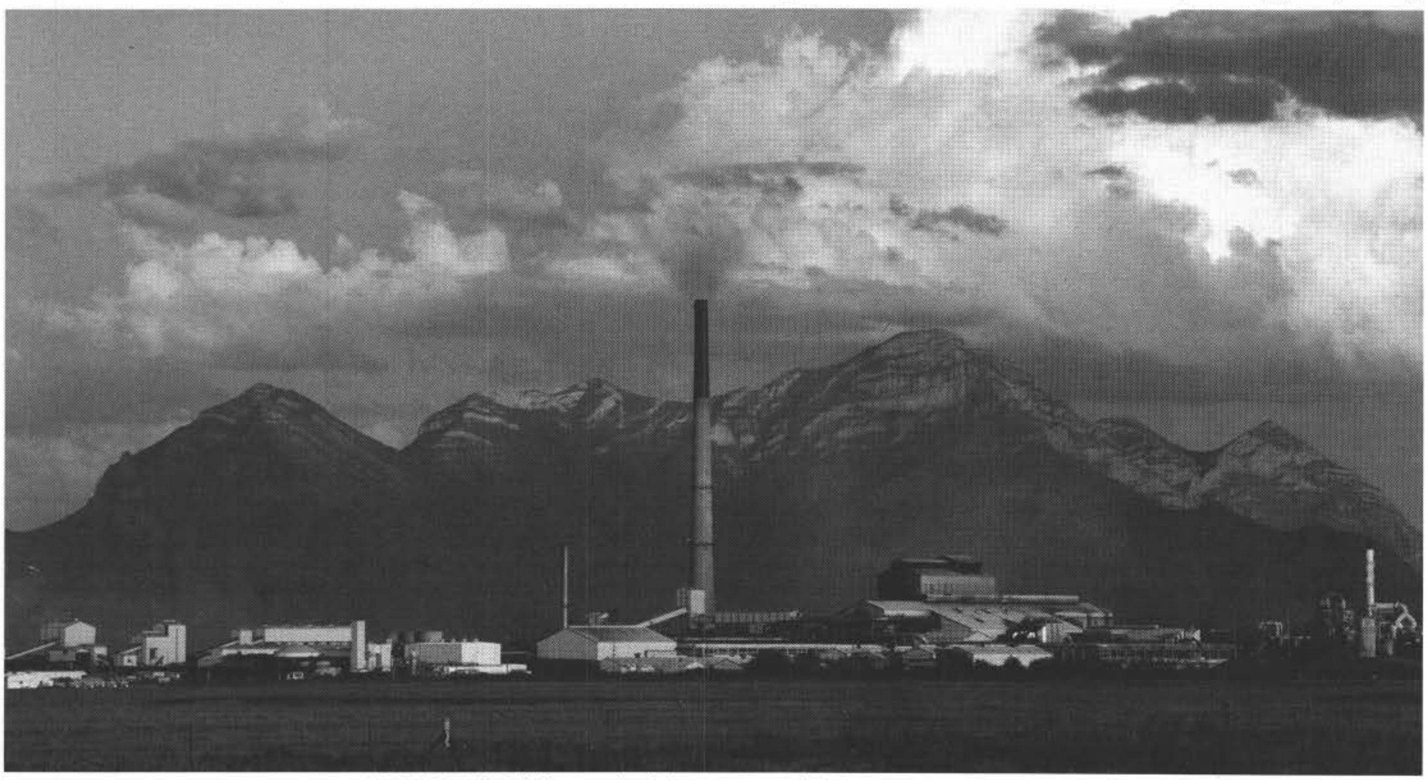

FIGURE 1. The Hidalgo smelter (photo courtesy of Phelps Dodge Hidalgo, Inc.).

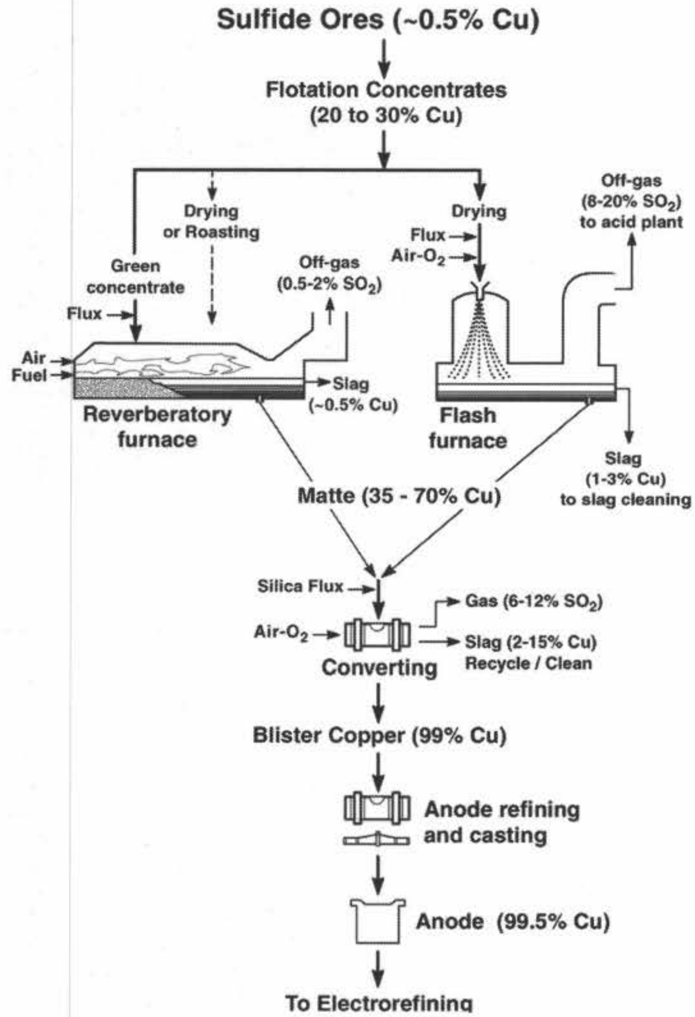

FIGURE 2. Schematic flow diagram for reverberatory and flash-furnace copper smelting (adapted from Biswas and Davenport, 1994).

and pyrite (FeS_2), some bornite (Cu_5FeS_4) and chalcocite (Cu_2S), and typically contain 20–30% Cu, 20–30% Fe, 25–35% S, 0–10% SiO_2, CaO, and Al_2O_3. During smelting, excess sulfur and a portion of the iron sulfides are oxidized to SO_2 and FeO. Oxide minerals react with flux components to form the slag phase; the sulfide melt, called matte, separates and settles to the bottom. Slag and matte layers are allowed to build up and are partially drained through the tap holes placed towards the opposite end of the furnace. The reverberatory slag (~0.5% Cu) is discarded. The slags, typically containing 30–40% FeO, 35–40% SiO_2, up to 10% CaO and Al_2O_3, are hard, inert, and resistant to weathering. At some locations, the slags are crushed and used for railroad ballast in coarse sizes, and the fines are used as aggregate, for road fill, or for sandblasting.

The matte (25–40% Cu in a solution of Cu_2S and FeS) is collected in 20–25-st buckets (ladles) and transferred into the converters (Fig. 3). Matte is also a very good solvent and collects virtually 100% of the gold, silver, nickel, cobalt, and platinum-group metals present in the charge (Biswas and Davenport, 1994).

Converting is a batch process carried out in two stages in refractory brick-lined cylindrical reactors mounted horizontally on a gear-driven rotation mechanism. In the first stage, FeS in the matte is oxidized until the melt composition approaches that of pure Cu_2S (~80% Cu), called "white metal." Air- or oxygen-enriched air is injected into the matte layer through 2-in. holes (tuyeres) in the refractory.

Iron oxides react with silica flux to form a fluid slag of fayalite composition ($2FeO{\cdot}SiO_2$), which includes 2–15% entrained Cu. The converter slag is skimmed off by rotating the vessel and returned to the smelting furnace. At that point the "copper-making" stage begins. Air is blown into the white metal and remaining sulfur is oxidized to obtain "blister copper." The converter gases are collected through retractable hoods and send to the acid plant for sulfur recovery.

FLASH-FURNACE SMELTING

Matte-converting reactions generate enough heat to keep the charge and slag in liquid form. Flash-furnace-smelting processes take advantage of the heat generated by the oxidation of copper- and iron-sulfides, reducing overall energy requirements by 1/3–1/2 (Parmeswaran et al., 1987). Furthermore, by reducing the volume of effluent gases using oxygen-enriched air (Outokumpu process) or commercially pure oxygen (INCO process), a steady stream of concentrated SO_2 gas is provided to the acid plants. They are also highly energy efficient; INCO is fully self-sufficient, and the Outokumpu furnace requires some fossil fuel to make up for the heat deficit.

THE HIDALGO SMELTER AND ACID PLANTS

The Outokumpu flash smelting furnace (FSF) was developed in Finland in 1949 (Habashi, 1993). The FSF consists of three sections: the reaction shaft, the settler, and the uptake shaft (Fig. 2). Dried flotation concentrates, silica flux, recycled flue dust, and coal or coke breeze are blended and injected into the hot reaction shaft through four concentrate burners that consist of two concentric pipes. The concentrate flows through the central pipe, and preheated air (at 500°F) and industrial oxygen is injected through the annulus. As the sulfide minerals are swirled in the hot reaction shaft, combustion occurs almost instantaneously and sulfide minerals burn in a flash. Molten sulfides and silica particles rain down on the pool in the settling chamber and separate into slag and matte layers. Matte grade is adjusted by controlling FeS–oxygen ratio, hence the degree of oxidation.

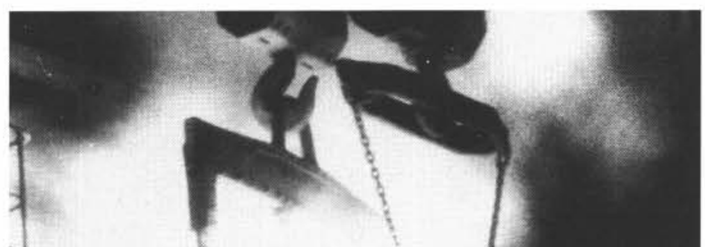

FIGURE 3. Pouring copper matte into a converter.

At Hidalgo, the FSF matte containing 62–65% Cu was tapped into 25-st ladles and transferred into one of three 13 x 30 ft Pierce-Smith type converters (Pannell, 1987). Flash-furnace slags (1–3% Cu) were treated in a slag-cleaning furnace for copper recovery.

Typically the FSF gases contain up to 20% SO_2. As the gases pass through the settler, the majority of the molten particles settle in the chamber. The gasses are cooled in the WHB, and dust is captured in electrostatic precipitators and recycled back to the furnace. Steam generated at the WHB is used at the power plant to generate a significant portion of the plant's electrical power requirements.

The Hidalgo smelter was originally designed to treat 1400 short ton per day (stpd) concentrates without an oxygen plant. The capital investment for the smelter, including the townsite, rail link, concentrate and acid-handling facilities, and 600-ft smokestack was $320 million ($1 billion in today's dollars). Capacity was increased to 1900 stpd concentrates during the construction phase (Anon, 1981), and in 1986 an oxygen plant that was salvaged from the Morenci smelter was installed at Hidalgo increasing capacity to well over 2400 stpd (Dillard, 1992). After the closure of the Morenci smelter, the concentrates from Morenci and Metcalf mines were also smelted at Hidalgo. During the 1990s, typical furnace feed consisted of 110 st concentrates per hour (stph), 8 stph silica flux, 1 stph petroleum coke, and 9 stph recycled flue dust.

The Hidalgo smelter has two acid plants (total capacity of 3000 stpd) and produced approximately one ton of acid for every ton of concentrate smelted (Walenga, 1990). The FSF gas was cleaned by quenching with water, dried, and SO_2 was oxidized to SO_3 in a fixed bed reactor over vanadium oxide catalysts. The SO_3 gas was then absorbed in sulfuric acid and captured in two-stages in absorption towers (Muller, 1997). Effluents from gas cleaning scrubbers are neutralized at the water treatment plant and empounded in lined ponds.

The company used a leased fleet of 500 tank-cars to transport acid. As many as 3000 rail cars of acid per month were shipped to phosphate fertilizer producers in Florida and Texas (Epler, 1993). The remainder of the acid was mostly consumed by the company's New Mexico and Arizona operations. In 1995, of the 1.2 million st of acid produced from the Hidalgo and Chino smelters combined, all but 550,000 st were consumed in company's operations (Dillard, 1996).

All of Phelps Dodge's Arizona smelters closed during the mid-1980s, and the Tyrone concentrator closed in 1992. As the heap-leach operations at Morenci and Tyrone were expanded, truck shipments of acid from the Hidalgo smelter also increased. In 1997, the company built a new facility at Tyrone for unloading acid from the rail cars, eliminating 48 truck-loads of acid shipments per day going through Silver City (Gary, 1997).

FIRE-REFINING AND ANODE CASTING

The blister copper produced in converters was further refined in two 13 x 30-ft anode furnaces to remove traces of sulfur and excess oxygen (Anon., 1983). Fire-refined copper (99.7% Cu) was then cast in a 40-ft diameter, 26-mold, computer-controlled casting wheel into characteristic shapes (Fig. 4). On average, 1700 anodes were cast every day, each weighing 810 lbs, which were shipped to the El Paso (Texas) refinery to produce 99.99% Cu and to recover precious metals (Epler, 1994).

DEVELOPMENTS IN FLASH-FURNACE SMELTING

The International Nickel Company (INCO) of Canada developed the Oxygen Flash Smelting process and installed the first commercial furnace at its Copper Cliff unit (Inco Staff, 1955). Asarco Inc. (American Smelting and Refining Co.) chose the INCO technology (which became available for licensing in 1978) to replace its reverberatory furnaces at the Hayden plant in Arizona (Clisby, 1983). The Kennecott Copper Corporation also chose the INCO flash furnace for its Hurley smelter during its $400 million modernization program at the Chino Mines division in New Mexico. Of that amount, $120 million was allocated for the construction of a new INCO flash furnace, 625-ft stack, and 450-stpd oxygen plant. The new smelter, designed to process 1400 stpd concentrates, started production in 1984 (Russell, 1984). Phelps Dodge Corporation acquired the Chino Mines Company and closed its Douglas smelter in early 1987.

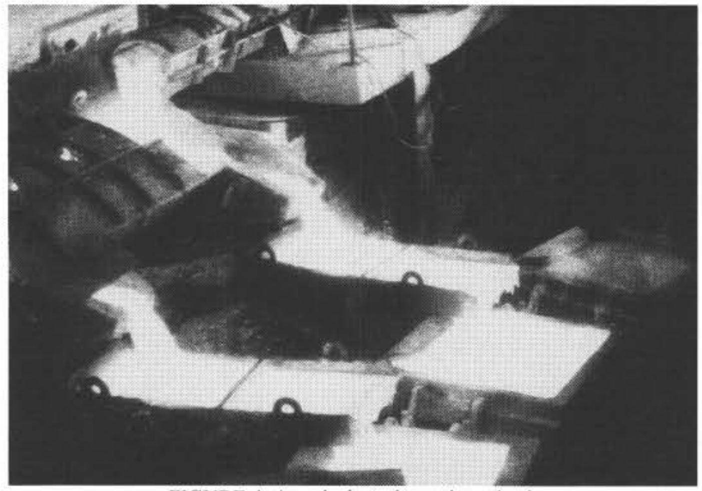

FIGURE 4. A typical anode casting wheel.

Magma Copper Company in San Manuel, Arizona, and Kennecott Utah Copper Company (KUCC) at Salt Lake City, Utah, both installed Outokumpu flash furnaces during respective modernization and expansion projects in 1988 and 1995. In addition, Kennecott and Outokumpu jointly developed and installed the first Flash Converting Furnace (FCF) at KUCC. The FSF matte is granulated by water quenching, dried, ground, and injected into the FCF, which is similar to FSF but smaller in size. Continuous matte-converting process provides a uniform gas stream to the acid plant and eliminates fugitive SO_2 emissions generated during matte transfers and batch-converting. Secondary emissions throughout the plant are collected and particulate emissions are captured in the baghouse. The tail gases are then scrubbed in sodium hydroxide (NaOH) solution and vented through the 1200-ft main smelter smokestack (Newman et al., 1999). The KUCC smelter claims 99.9% sulfur capture rates, thus, sets a new standard for future copper smelters.

The Hidalgo smelter was closed and mothballed September 10, 1999. During its last years of operation, this smelter was able to capture 96.8% of the sulfur input (Hayostek, 1998). Currently there are five smelters operating in the Southwest, all capable of capturing better than 96% of the sulfur input. All other copper smelters in the nation were closed in the 1980s and early 1990s.

Phelps Dodge Corporation also announced late in 1999 that the company would convert its Morenci mine into a mine-for-leach operation as in Tyrone. The conversion will be completed by the year 2001 and the flotation concentrators will be put on stand-by. The $220 million project is expected to reduce the unit costs by 10%, approximately 9 cents per lb of copper produced at Morenci (company press release, September 1, 1999).

ACKNOWLEDGMENTS

Robert E. Eveleth, Lynn A. Brandvold, and Vigil W. Lueth, New Mexico Bureau of Mines and Mineral Resources, and Carol A. Hjellming read earlier versions of this manuscript and made valuable suggestions for improvements. Leo O. Gabaldon drafted the flowchart.

REFERENCES

Anon., 1980, Copper, cattle and crops are good neighbors in New Mexico: Pay Dirt, July, p. 3.

Anon., 1981, Phelps Dodge, a copper centennial 1881–1981: Supplement to Arizona Pay Dirt, 192 p.

Anon., 1983, Hidalgo smelter may set record for continuous operation: Pay Dirt, August, p. 7A

Biswas, A. K. and Davenport, W. G., 1994, Extractive metallurgy of copper: Pergamon, New York, 500 p.

Clisby, H., 1983, Asarco's new flash furnace at Hayden: Pay Dirt, November, p. 18A.

Dillard, G., 1992, PD completes Hidalgo turnaround after 8-year campaign: Pay Dirt, July, p. 3A.

Dillard, G., 1996, More leaching means use for more acid: Pay Dirt, March, p. 29.

Epler, B., 1993, A curious Pay Dirt follows copper trail east: Pay dirt, December, p. 4A–8A.

Epler, B., 1994, El Paso refinery: Pay Dirt, January, p.4A–13A

Gary, E., 1997, New acid unloading facility commissioned: Pay Dirt, September, p. 8.

Habashi, F., 1993, History of metallurgy in Finland: the Outokumpu story: Canadian Institute of Mining and Metallurgy Bulletin, v. 86 (975), p. 57–63.

Hayostek, C., 1998, The Hidalgo hog: mighty mover of converters: Pay Dirt, July, p. 8–10.

Inco Staff, 1955, The oxygen flash furnace smelting process of the International Nickel Company: Canadian Institute of Mining and Metallurgy Bulletin, v. 48 (517), p. 292–300.

Muller, T. L., 1997, Sulfuric acid and sulfur trioxide; *in* Encyclopedia of chemical technology: John Wiley, New York, v. 23, p. 363–408.

Newman, C. L., Probert, T. I. and Weddick, A. J., 1999, Kennecott Utah copper smelter modernization: Mining Engineering, July, p. 39–45.

Pannell, D. G., 1987, A survey of world copper smelters; *in* Traulsen, H. R. and Taylor, J. C., eds., World survey of nonferrous smelters: The Metallurgical Society, Inc., Warrendale, Pennsylvania, p. 79–83.

Parameswaran, K., Nankardi, R. M., Pitt, C. H. and Wadsworth, M. E., 1982, Energy requirements in copper extractive metallurgy; *in* George, D. B. and Taylor, J. C., eds., Copper smelting—an update, The Metallurgical Society of AIME, Warrendale, Pennsylvania, p. 265–321.

Russell, W, 1984, Chino starting up Inco furnace to complete modernization: Pay Dirt, November, p. 5.

Walenga, K., 1990, Unwanted smelter product is now more viable: Pay Dirt, p. 4A–7A.

White, L., 1971, SO_2 laws force U.S copper smelters: Engineering and Mining Journal, July, p. 61–71.