USE OF WATER IN THE U. S. COPPER INDUSTRY

Source: U. S. Geological Survey Water Supply Paper 1330-E
Arizona Department of Mineral Resources - Questionnaire to Principal Copper Companies.

In the U. S. Geological Survey Water-Supply Paper 1330-E, (by Mr. Orville D. Mussey), it is reported that more water is used to produce a ton of copper, on the average, than to produce a ton of any other major metal.

During the period under study (1955) the U. S. copper industry used about 330,000,000 gallons of water per day in the mining and manufacturing of primary copper - some 0.3 per cent of the total estimated withdrawals of industrial water in the United States for that year (1955). The report is limited to a study of water used in mining the ores and reducing domestic and imported ores and intermediates to refined copper. It does not include subsequent processing or fabrication.

It was found that a little more than 100,000 gallons of water was used in the production of a ton of copper from domestic ores. Of this amount, about 70,000 gallons per ton was used in mining and concentrating the ore, and about 30,000 gallons per ton was used to reduce the concentrate to refined copper. About 60,000,000 gallons per day or 18 percent of the water was used and not recovered. Nearly all the consumptive use occurred in the water-short areas of the West. Of the water used in mining and manufacturing primary copper (75 percent was surface water and 25 per cent ground water), 89 per cent was self-supplied by the copper companies and 11 per cent came from public supplies.

Based upon the U. S. Bureau of Mines' reported production of ore mined in 1955, namely 112,550,000 tons of copper ore, and 935,820 tons of copper recovered, and the survey's reported use of 70,000 gallons of water per ton of copper in mining and concentrating the ore, and about 30,000 gallons per ton used to reduce the concentrate to refined copper, we arrive at the following:

Year 1955	Tons Ore Mined	Tons Copper Produced	Gals. Water Per Ton Copper	Gallons Water		Tons Water	
				Total Thous. Gals.	Per Ton Ore	Total (Thous. Tons)	Per Ton Ore
Mining & Conc't'n.	112,550,000	935,820	70,000	65,507,400	582.0	271,815	2.415
Smelting & Refining	112,550,000	935,820	30,000	28,074,600	249.4	116,492	1.035
TOTAL	112,550,000	935,820	100,000	93,582,000	831.4	388,307	3.450

Based upon the total gallons of water used in 1955, namely 93,582,000,000, in mining, concentrating, smelting and refining all copper produced during the year, and the survey's reported consumption of 330,000,000 gallons of water per day, the plants were in operation a total of 283.6 operating days during the year.

SUMMARY OF SURVEY'S ANALYSIS OF OPERATING STEPS IN USE OF WATER IN PRODUCING REFINED COPPER *

Open-Pit Operations

Considerable water is used in controlling the silica dust from the gangue or from the country rock in the mines. Water is also used for dust control in coarse crushing which is done at many mines to facilitate handling of the ores en route to the ore-concentration plants.

Water is used for drilling, for sprinkling roads and piles of loose ore prior to handling, for steam locomotive boiler-feed, for sanitary and service, and for company housing. In extremely dry areas, considerable water is used for local irrigation and home and office air conditioning. Where no electric power is purchased, water is used for cooling and boiler-feed in producing thermo-electric power.

Underground Operations

Generally less water is used in underground than in open-pit operations, because less water is needed for dust control. For other purposes water uses in underground operations are similar to those listed for open-pit operations.

In addition, some water is needed for treating timber for mine use and, in one mine, for reducing temperatures.

Metallurgical Methods

Nearly all low-grade copper sulphide ores and some native copper ores are reduced to copper in three steps. The ore is first concentrated by flotation, then reduced to a metallic condition by smelting, and finally purified in a refinery using electrolytic methods. A small amount of copper ore is produced that is rich enough to go directly to the smelters.

Concentration By Flotation

Most of the copper ore mined consists of low-grade copper sulphides that are first concentrated by flotation. The ore is usually passed through primary and secondary crushers that use water only for dust control and bearing cooling. Water is added to the ore as it enters the rod mill, which consists of a revolving drum partly filled with round steel rods. The ore and water pass through the mill where the ore is crushed between the rods in the rotating drums. From the rod mill the ore passes through a classifier which separates the fine material from the coarse. The coarse material is passed in a closed circuit to the ball mills for further grinding, and the fine material from both the rod mills and the ball mills passes on in water suspension to the distributing boxes.

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* The description of the operating steps in converting copper ore into ingots of refined copper has been taken from Mr. Orville D. Mussey's Paper #1330-E.

At this point chemicals and possibly pine oil are added. The finely ground ore mixed with three or four times its weight in water is passed on to the flotation cells. Compressed air is either beaten into the pulp with agitators or introduced through the cell bottoms made of porous canvas. The air bubbles rise to form a froth containing the sulphides in the ore which overflow and are separated from the worthless gangue which passes out of the flotation cell with most of the water through an opening below the water surface. The sulphides (including the copper sulphide) rise in the flotation cell because the oil selectively coats the sulphides and the air bubbles cling to the oil coating, causing the sulphides to rise and remain at the surface....

The gangue or tailings pass on to thickeners where much of the water is reclaimed for reuse, and the thickened tailings are flushed to a tailings pond where the solid materials settle out. Excess water in the tailings pond may be returned to the concentration mill for reuse, or returned to the river from which it originally came.

Concentrates at a few mills are reground and passed through other flotation cells to increase the copper content of the concentrate, or maybe to recover molybdenum as a by-product.

In some dry areas, water is used for dust control on the tailings disposal areas.

In Michigan, the separation of native copper may be accomplished in part by hand sorting, in part by bumping tables that separate the heavy copper from the lighter rock by shaking the ground ore on tilted surfaces in the presence of a slowly moving sheet of water, and in part by flotation, using chemical additives differing from those that were used for concentrating sulphide ores.

Concentration By Leaching

Copper oxides cannot be separated by flotation; so the copper is usually separated from the ore by a leaching fluid that is mostly water. Ordinarily the ores are crushed to smaller than three=eighths of an inch and placed in leaching tanks containing perhaps 10,000 tons of ore. Water is used for bearing cooling and dust control during crushing, but the crushed ore is rather dry. The fine material may be agglomerated by the use of water sprays to permit free passage of the leaching fluids through the ore. Sulphuric acid is usually added to the leaching fluid, but some ores contain enough sulphates to make this unnecessary. Each batch of ores is leached several times. Leaching solutions containing little or no copper sulphates are passed through the lean ores that have already been leached several times and then through gradually richer ores until the leaching fluids are rich in copper sulphate.

From the leaching tanks the copper sulphate solution is passed to the iron launders. The launders consist of troughs containing sponge iron or iron scrap; usually shredded cans from which the tin has been melted and the paint or paper labels burned. The iron reacts with the copper sulphate solution, precipitating a black sand (called "cement copper") that contain about 90 percent copper. If, in addition to the oxides of copper, the sulphide occurs in the ore in amounts too small to make recovery by flotation profitable, some recovery of the sulphides may be made by using ferric sulphate and sulphuric acid in the leaching solution.

Some copper is leached from very low grade ores in place and some from waste materials of earlier mining operations.

At one plant, refined copper is obtained from the leaching solution by electrolysis.

Water is used for sanitary and service, for company housing, and at one plant for manufacturing sponge iron and sulphuric acid.

Smelting

The concentrates from flotation, together with suitable fluxing materials, make up the charge to a reverberatory furnace. This furnace consists of a chamber about 110 feet long and 30 feet wide, lined with firebrick, and fired with natural gas, oil, or powdered coal. High grade copper ores and copper sands from the leaching process may be added to the charge. Air and fuel are blown in at one end, and exhaust gases are removed at the other. Furnace temperatures reach about 1500°C. Because it contains considerable copper, the dust in the flue gases is recovered in waste heat boilers and used to produce electrical energy.

After the charge is melted, the slag is drawn off the top and discarded. The heavier matte-consisting chiefly of copper, sulphur, and iron-is placed in converters while it is still molten.

Water is used for cooling the reverberatory furnace and for boiler feed and condenser cooling in the generation of power from steam produced in the waste-heat boilers. Where water is plentiful it is sometimes used to granulate the slag and flush it to the slag dump.

A copper converter usually consists of a horizontal brick-lined steel cylinder with arrangements for introducing air through tuyeres in the cylinder wall. The charge of matte is introduced through an opening in the top, and the converter can be rotated on its axis so that the contents may be discharged through the same opening when the reactions are completed. After the matte is poured into the converter, a high-silica flux is added, and air blown in through the tuyeres. The sulphur is burned off; furnishing heat for the operation, and the iron is converted to iron oxide that combines with the silica to form a slag lighter than the copper. The slag, which usually contains 2 to 5 percent copper, is drawn off and routed back to the reverberatory furnace. The copper, including some copper oxide, is transferred to a holding furnace where copper oxides are reduced to a minimum by plunging green wooden poles into the melt.

Where there is a local demand for sulphuric acid, it may be manufactured by using the sulphur dioxide produced in the reverberatory furnace and the converter; considerable water is used in such a plant.

After the oxygen has been removed in the holding furnace, the copper is poured into casting molds, usually in the shape of copper anodes ready for electrolytic refining. For convenience these molds are mounted on the rim of a large-diameter wheel revolving about a vertical axle that brings each mold in position first for pouring and then to receive water sprays that cool the casting and form steam, which excludes air and prevents the formation of copper oxides. The castings continue to cool under the sprays, and after a half-turn on the wheel, are removed from the molds and are placed, hot and glowing, in a water tank called a bosh bath where they remain until they are cooled sufficiently to prevent oxidation. The empty molds are further cooled by spraying and then coated with powdered bone ash in water suspension to facilitate removal of the next casting.

Refining

The copper anodes produced at the smelters are over 98 percent copper and contain many kinds of impurities including most of the valuable metals contained in the concentrate. These anodes are placed in special tanks containing a water solution of copper sulphate and dilute sulphuric acid and are alternated between starting sheets made of refined copper. The temperature of the electrolyte is maintained between 130° and 150°F.

The copper is transferred from the anodes to the cathodes by electrolytic action. The impurities, including gold, silver, and other valuable material, either go into solution in the electrolyte, sink to the bottom of the tank, or adhere to the anodes from which they are washed in order to recover the valuable mud. Some impurities such as arsenic, iron, and nickel are dissolved in the electrolyte. Some of the electrolytic solution is continuously withdrawn and replaced by new or rejuvenated solution to maintain satisfactory quality in the electrolyte. Various methods, depending on the impurities and the local market for the by-products, are used to process the electrolyte that is withdrawn. Some of these methods involve evaporation of the water from the electrolyte that is withdrawn.

Most copper refineries treat the anode mud to recover the gold, silver, and other valuable by-products, but some refineries ship the mud elsewhere for processing.

The cathodes are washed with distilled water (or other water of high quality) and placed in a melting furnace from which the molten copper is cast in the form of wirebars, billets, cakes, ingots and ingot bars, in a procedure similar to that used in casting the anodes. Some electric arc furnaces are used for melting cathodes.

About 90 percent of the refined copper from domestic ores is electrolytically refined, and the remaining 10 percent is cast in commercial shapes after only fire refining.

Water is used for boiler-feed to produce steam for maintaining the temperature of the electrolyte. The condensate from the steam used for heating is reused to wash the cathodes and to incorporate into the replacement electrolyte. Water is used for boiler-feed and for cooling at some refineries making their own electric power. It is also used for cooling the melting furnace and the casting wheel and in the bosh bath. Water is used for general and sanitary purposes, for company housing and for irrigation. In one plant, the potential energy contained in city water under pressure is used to operate hydraulic elevators before it enters the cooling water system. Some saline water is used for cooling through heat exchangers.

ARIZONA'S MINING INDUSTRY AND THE DEVELOPMENT

AND USE OF WATER

Compiled By The Arizona Department of Mineral Resources
F. P. Knight, Director - F. J. Tuck, Statistical Engineer
Fairgrounds, Phoenix, Arizona

During the year 1957, the Arizona mining industry used 15.9 billion gallons of fresh water equivalent to 48,788 acre-feet; nine percent of it for domestic purposes, and the balance for mining, milling, smelting and steam power generation.

Almost ninety percent of Arizona's mining industry is operated in individual communities which are wholly integrated as to mining, milling, smelting and townsite operations. Their history, therefore, gives a very good indication of the important part water plays in their operations. The availability of a good supply of water is a prime essential of a successful operation. Mill concentration of low-grade ores calls for the use of enormous quantities of water to effect the separation of metal contents from the enclosing rock minerals.

In nearly all operations the water has to be pumped long distances and is therefore expensive. Hence most concentrators provide for the re-use of mill-water by the installation of settling tanks and pumps. In such cases, the reclaimed water amounts to about two or three times the original fresh water needed.

The principal use of water in concentrators is in the wet grinding required for freeing the mineral sulphides for flotation. Classifiers employing large quantities of water, are used in conjunction with the grinding.

A summary of the more important developments of a water supply for the major mining areas in Arizona follows:

Development of a Water Supply for the Hayden Concentrator and Ray Mine Operations

Because the proposed concentrator would need a good source of water, it was decided to locate the mill near the junction of the Gila and San Pedro Rivers.

At first the water level in the vicinity of the junction of both rivers was relatively close to the surface, and the excavation of a large ditch was sufficient to furnish a large enough reservoir for pumping the water to a 5-million gallon mill-reservoir located above the mill, a mile away from the river and 250-feet higher. A half-million gallon reservoir was used for domestic supply. When the water-level later dropped, a series of holes was driven alongside the big ditch, and the water was air-lifted to a pumping reservoir for transfer to the domestic and mill reservoirs.

Until the recent expansion of production at Ray and Hayden, there was always a plentiful supply of water for all operations at Hayden, and the only water reclaimed was that from the concentrate dewatering plant. The tailings water had been allowed to return to the Gila River, after settling the tailings in a 1100-acre storage area in the river valley. In this connection, it may be well to note that although the Hayden concentrator used tremendous quantities of new water, probably two-thirds of it got back into the Gila River bed, and traveled some distance down the river to the irrigation projects at Florence and Coolidge. The real consumption, therefore, was probably about the same as other concentrators which reclaim their tailings water and re-use it.

Early in 1960, a thickener, 325-feet in diameter, became the main element in the water reclamation program. The recovery and re-use of water is vital to the operations of the expanded plant. The tailings from the sulphide circuits are fed into the thickener from the flotation plant; the thickened pulp is discharged to the tailings pond, and about 3,300 gallons of water per minute overflows to be returned to the concentrator.

In this connection, it might be noted that the return of this water to the mill circuit results in the saving of considerable lime needed to keep the flotation curcuit at the proper alkalinity. Sulphide flotation requires an alkalinity of at least 9pH, and fresh water uses up considerable lime in order to accomplish this. Hence the return of treated water from the tailings reduces the amount of lime required.

The clear water from the tailings pond flows as usual to the Gila River. It amounts to approximately 1 ton of water per ton of tailings.

Water supply at Ray has not been so plentiful, and the operations and townsite both have been handicapped by a chronic shortage. However, the fact is that the mine and the towns of Ray and Sonora have been in successful operation for fifty years, and the Company has succeeded in providing the necessary water. Mineral Creek has been the chief source of this water, though it has been dry many times during the years.

Development of a Water Supply for Miami and Inspiration

A water supply for the Inspiration concentrator was developed at Wheatfields, about 12 miles from the mill site, and, later, wells were sunk on the flat below the tailing storage site. The best location was determined to be about 2½ miles from the mill, at the junction of two fair-sized drainage channels receiving their supply from the Pinal Mountains about 10 miles away, and 4,000 feet higher.

To provide the necessary water for the Castle Dome operation, a 16" combination steel and wood-stave pipe was laid a distance of over 11 miles from the Old Dominion mine at Globe to Castle Dome, and a 3,563,000-gallon reservoir was built.

Fresh water for the Copper Cities project is supplied from two sources, one of which is the Old Dominion Mine near Globe. Water is pumped from the mine shaft to the Copper Cities pumping plant at Burch. The second source comes from a water development across the Miami Wash at Burch. An 8 x 8-foot shaft was sunk 190 feet to solid conglomerate below the water-bearing sands, and a drift was driven westerly under the dry wash. Churn drill holes were drilled through the sands into the drift, and were cased with perforated stainless steel pipe. Water is collected in the drift and pumped with three deep well pumps from the shaft to a water-treatment plant.

Development of a Water Supply for Ajo

An ample supply of water for the New Cornelia operations was obtained by sinking a two-compartment shaft 650 feet deep at a place six miles distant, where the water-table of the region was tapped originally by two underground pumps, with a combined capacity of 1,500 gallons per minute, and ultimately by five pumps with a combined capacity of 5,500 gallons per minute. The water is delivered to a reservoir at the mine against a total head of 1,375 feet. Recently the underground pumps were replaced by submersible pumps on surface.

Development of a Water Supply for Morenci and Clifton

When the present Morenci operation began in 1942, at the beginning of World War II, the Phelps Dodge Company was permitted to draw on the water of the Black River which flowed into the Salt River System. The Company agreed to replace it over the subsequent years by contributing to the development of the Horseshoe and Bartlett Dams on the Salt River Project. The Company was granted the use of 250,000 acre-feet, to be drawn on during the life of the Morenci project. The construction of a Dam near Show Low by the Company has also contributed to this replacement.

The water from the Black River is pumped into Willow Creek and thence flows to Eagle Creek where the Morenci pumping plant is located. The total lift is about 1,400 feet, and the maximum distance the water travels before it is used at Morenci is some 75 miles.

Development of a Water Supply for San Manuel

The water supply for San Manuel Copper Corporation and townsite is provided for by a series of artesian wells along the San Pedro Valley below the plant site. The well water is pumped to a central gathering station from which it is pumped to the town supply tanks and plant supply tanks for distribution. In addition to the wells, the mine makes about 3,000 g.p.m. which supplies the mine requirements, and the excess is pumped to the plant for concentrator needs, through an 18-inch pipe line.

Development of a Water Supply for Silver Bell

Water for the camp and plant use is obtained from three wells 500 feet deep, sunk in the valley about 9 miles southeast of the concentrator.

Development of a Water Supply for Phelps Dodge's Lavender Pit

Water pumped from the Bisbee underground mine workings is used in the Lavender Pit Concentrator.

Development of a Water Supply for the Esperanza Operations

A water supply for Duval Sulphur & Potash Company's Esperanza property was developed on the western edge of the Santa Cruz River Valley about 6 miles east of the mill site. Three 16 inch wells, located about 1,500 feet apart, were sunk to depths ranging from 650 feet to 900 feet. Water is pumped from these from a depth of 350 feet to a gathering tank, thence through a 16 inch steel pipe line for 30,000 feet to the mill system. The total lift from water table to the mill storage tanks is about 1,150 feet.

WATER CONSUMPTION

Based upon the reported consumption of water, in 1957 and 1960, by eight principal mining areas of Arizona, a typical mining community would use new water in the following approximate amounts, in tons of water per ton of ore mined:

	Tons Water Per Ton Ore Mined	Gals. Water Per Ton Ore Mined	Per Cent
Total new water used -	1.31	314	100.0
Distribution:			
Milling plant use	1.00	240	76.2
Mining plant use	.04	9	3.2
Smelting plant use	.07	17	5.4
Power plant use	.10	24	7.6
Domestic use	.10	24	7.6
Total reclaimed water used	2.50 tons per ton ore		

Estimated cost of new water per 1,000 gals. 17 cents (Varies from 6 to 35 cents).

Estimated cost of reclaimed water per 1,000 gals. 3.5 cents.

Applying the 1.31 tons and 314 gallons of water per ton of ore against the total tons of copper ore treated in the year 1960, namely 66,032,439 tons, we arrive at a total of 86,502,495 tons of water used in the Arizona copper industry, or 20,734,186,000 gallons, or 63,630 acre feet.

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