New copper technology is winning the ore

Metal recovery from low-grade and hitherto worthless stocks is near. And as for the copper industry's bread-and-butter ores, a competitive new hydrometallurgical process does not generate air-polluting sulfur dioxide.

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The copper industry is entering the nuclear age. If a recent proposal by Kennecott Copper Corp. is approved by the Atomic Energy Commission, a 20-kiloton nuclear device will be detonated some 1,200 ft. below ground-level at a site near Safford, Ariz. The blast would crush a deposit of low-grade ore, now uneconomic to mine, creating a chimney through which it is hoped that copper can be recovered by inplace leaching with sulfuric acid.

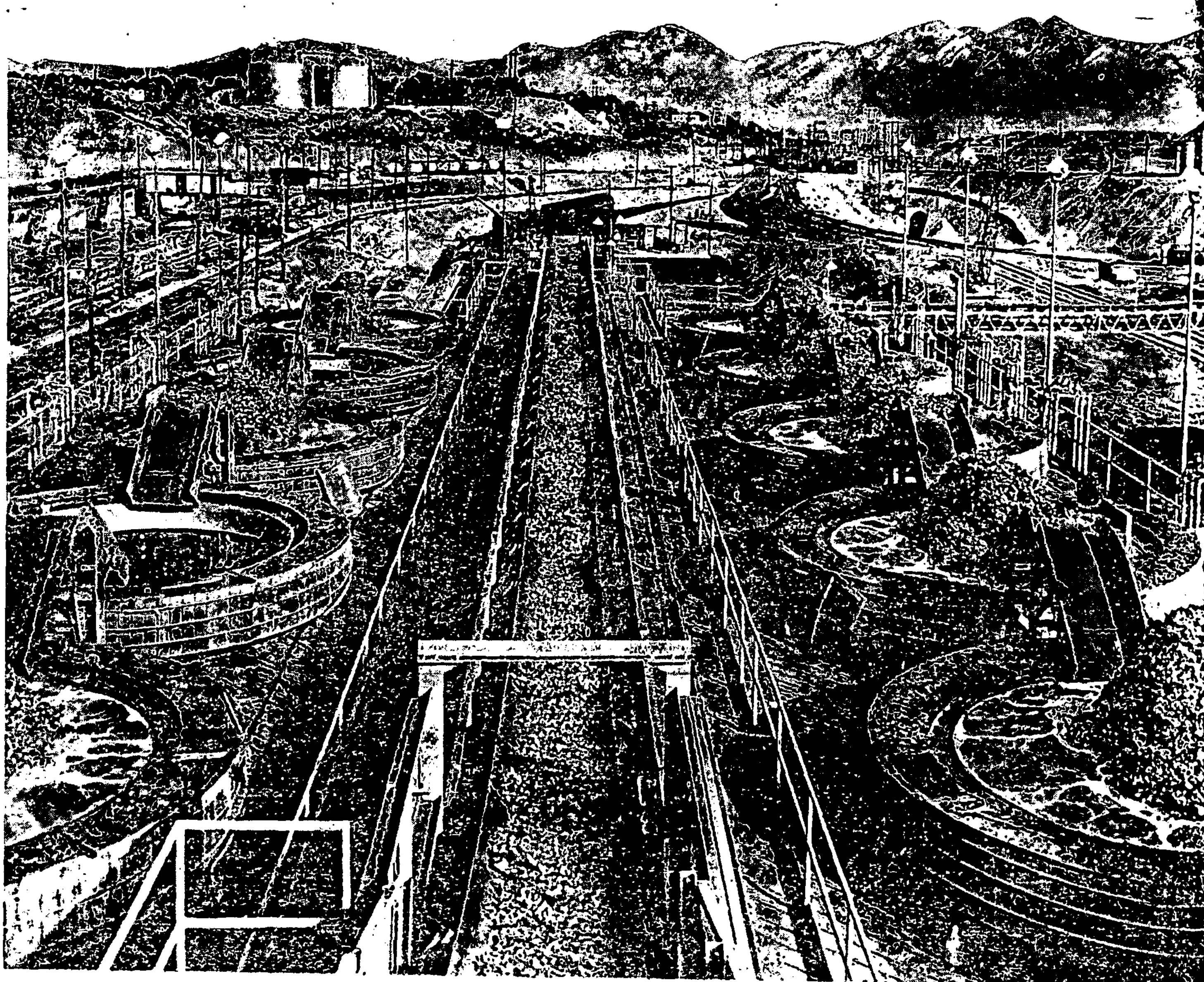
And there are other important, though not earth-shattering, developments. Indeed, the copper industry is in the midst of intense technological activity. Some conventional operations are being improved and new techniques are emerging.

▶ **Active Duo**—There are presently two widely used commercial techniques to recover copper from ore. One is for the plentiful sulfide ores, the other for the deposits of oxide, mixed oxide-sulfide and native (unfettered copper) ores.

Smelting Sulfides—Sulfide ores are generally floated and smelted, then electrorefined. Deposits usually are low grade, containing from a fraction to several percent copper. For economic processing, the metal content of the ore is concentrated.

After being crushed, ore is ground to loosen mineral particles from the gangue. This mass is then carried to a cell where most of the minerals are removed from the worthless rock by froth flotation, then dewatered to form a concentrate assaying 15 to 30% copper.

Fed to the smelting circuit, this



concentrate normally is first roasted: enough sulfur is oxidized and driven out to leave a desired balance of copper, iron and sulfur. In a reverberatory smelter, iron oxides in the ore combine with siliceous flux to produce a slag. Copper sulfide, iron and some sulfur are left as matte, which is then reduced to copper in two stages of air-blowing in a converter.

The resultant more-than-95% pure metal is known as blister copper. Used as anodes in an electrolytic cell, along with pure copper starting-sheet cathodes, the blister ebbs away as copper ions migrate to the cathodes. The pregnant, high-purity-copper cathodes are then melted down and cast into ingots, wirebars or other shapes.

Loaded Liquor — Hydrometallurgical treatment is the prime means used to recover copper metal from oxide, mixed oxide and sulfide, and native ores. It is also used, in some instances, to process sulfide tailings and overburden.

Ores first are leached with an appropriate solvent. For sulfides, this is generally water or dilute sulfuric acid. (In some cases, natural bacterial action converts the sulfides to oxides, forming sulfuric acid. The acid then extracts copper to produce the metal sulfate.) Dilute sulfuric is also favored for the leaching of oxide and mixed ores. The scarce native ores are usually treated with a solution of ammonia and ammonium carbonate.

The leach liquor can be handled by either of two methods:

Classically, it is contacted with iron scrap. Iron goes into solution. Copper precipitates. Once dewatered, this finely divided "cement" copper, seldom over 90% pure, is shipped to a smelter for further processing, or is sold.

The other method handles the leach liquor, after some purification, in an electrowinning cell. Except for insoluble anodes and about four times greater electrical energy requirements, the unit is similar to that used for electrorefining of blister. Heavy, pure-copper cathodes are grown. Again, they are melted and cast.

▶Busy Cones—Important developments in copper-ore leaching processes have been coming to light at a fast clip.

Researchers at Kennecott's Western Mining Division, Salt Lake City, have devised a cone precipitator that is said to make cement copper with much greater efficiency than the conventional method of passing liquor through troughs filled with scrap iron.

In one installation, cone precipitators more than doubled metal production, from 150,000 lb./day to 400,000 lb./day.

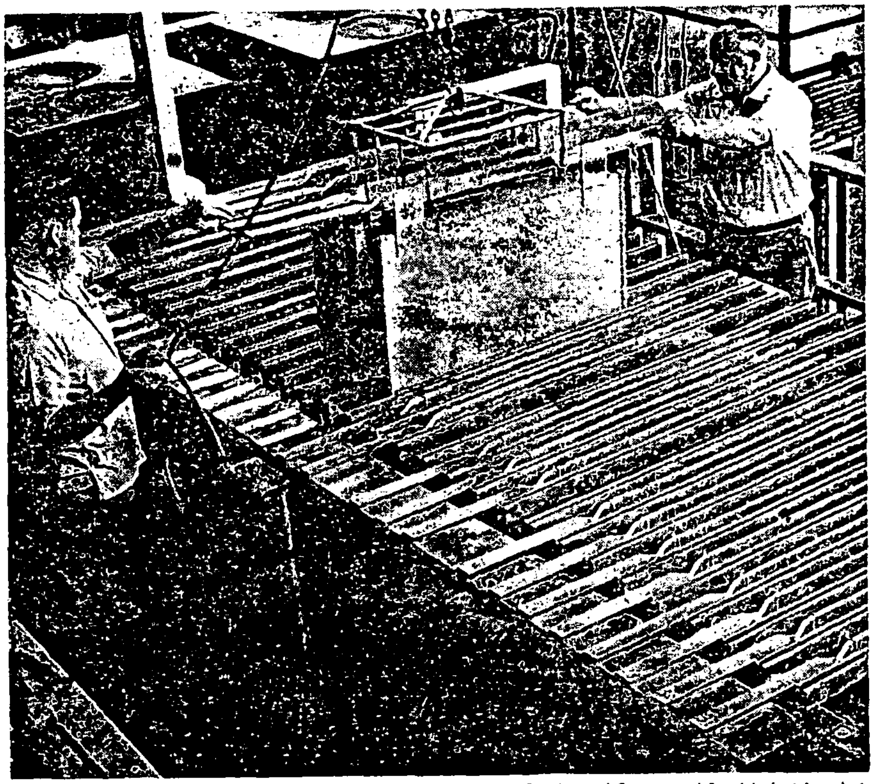
Each precipitator can reclaim 20 to 30 lb. of red metal a minute, depending on copper content and the flow rate of solution through the cone. And, according to the company, the units lend themselves to a higher degree of instrument control than do troughs.

▶Selective Solvent—But boosters of high-purity-copper recovery by hydrometallurgy have been active, too. Fundamental to all of their plans is the need for, or advantage of, using refined copper-rich solution.

The Chemical Div. of General Mills, Kankakee, Ill., has developed a water-insoluble organic reagent, called LIX 64, that can be used to purify leach liquor through solvent extraction.

Already in use at several pilot plants, the liquid ion-exchange reagent will be applied commercially for the first time at the Ranchers Exploration and Development Corp. plant being built in Miami, Ariz., to eliminate cementation and let liquid go into electrowinning.

In use, a 7 to 10% solution of LIX 64 in a carrier such as kerosene gives up two hydrogen ions in exchange for each copper ion in the acidic leach liquor. Then, in a second step, the copper is stripped



Continental Copper and Steel Industries photo

ELECTROWINNING CELL of new design can tolerate higher levels of impurities in its feed. And it operates at 2 to 3 times present cells' current densities.

...S **OF CONE PRECIPITATORS** at Utah ...have upped cement-copper production ...st threefold. Each unit can process ...0 gpm. of copper-rich leach solution.

...ott Research Center Photo by Don Green from the reagent by an acidic electrolyte in exchange for hydrogen ions.

▶ **Unexcelled Cell**—Just as ion-exchange may make pure copper-rich solution readily and economically available, Continental Copper and Steel Industries of New York has devised a cell that is said to be less sensitive to solution impurities than present electrowinning units. Of course, it functions best with a pure solution.

This unusual cell, called the CCS. deposits red metal smoothly at the cathodes. In conventional units, by comparison, metal is unevenly distributed on the sides of the cathodes facing away from the direction of solution flow. Dendrites of copper build up, sometimes to the point where they short-circuit against an anode.

While present commercial cells operate at a current density of 11 to 20 amp./sq. ft. of cathode surface, the CCS unit has optimum performance in the range of 30 to 45 amp./sq.ft. and has run as high as 60 amp./sq.ft. However, at this higher value, copper is produced as powder. (Harlan Metals Corp., Phoenix, Ariz., is piloting a cell that works at a "significantly higher" current density to make copper powder). Power efficiency is between 90 and 92%.

Increases in current density decrease the cathode surface necessary for a given copper recovery, and reduce the number of electrolytic tanks needed. As a consequence, CCS cell installations would allow lower capital expenditures.

Another plus claimed for the CCS cell is that lower copper concentrations in solution can be used economically. And as much as four times more copper is taken out of solution than in conventional cells.

▶ **Gas Task**—Phoenix-based Arizona Chemcopper Co., a joint venture of Bagdad Copper Corp. and Chemetals Corp., has demonstrated a hydrogen reduction process for producing highly refined copper from leach liquor. The company has had a plant in Bagdad, Ariz., onstream for more than a year.

Feed material for this plant is impure "cement" copper. Sulfuric acid leaches out copper in the form of copper sulfate. Once insolubles are filtered out, the acid solution is sent to agitated autoclaves where it contacts hydrogen gas at about 300 F. and 425 psi. The product is copper powder and dilute sulfuric acid. An acrylic-based dispersing agent prevents agglomeration of the metal particles.

The copper slurry is washed and dewatered, with the acid recycled back for reuse in leaching. The powder, either loose or compressed into briquettes, is sintered to remove traces of sulfur, oxygen and other impurities. This plant caters to the metal-powder market, but its high-purity copper could just as well be melted down and cast into the regular shapes.

There is no doubt, notes a Chemetals spokesman, that the present cement-copper step could be eliminated. Leach liquor, extracted with a reagent such as LIX 64, would provide a sulfate solution pure enough to go directly to hydrogen reduction. This would put the hydrogen reduction process squarely in competition with electrowinning in conventional tank houses or in cells using the CCS development.

Chemetals' estimates indicate that hydrogen reduction followed by powder melting and casting is slightly cheaper than electrowinning where cathodes are cast. However, the savings are not significant enough to create a major switchover. The relative advantages of the two processes vary, in fact, from location to location, depending on individual circumstances.

▶ **Cyanide's Side**—To further complicate matters, another technique may eventually provide a third alternative.

Though its process is still under development (a pilot plant has not yet been built), Treadwell Corp., New York, intends to take refined copper-sulfate solution and react it below 212 F. with hydrocyanic acid and sulfur dioxide. Copper cyanide and sulfuric acid form. The cyanide, insoluble in the acid, precipitates and is separated from the barren liquor by conventional means.

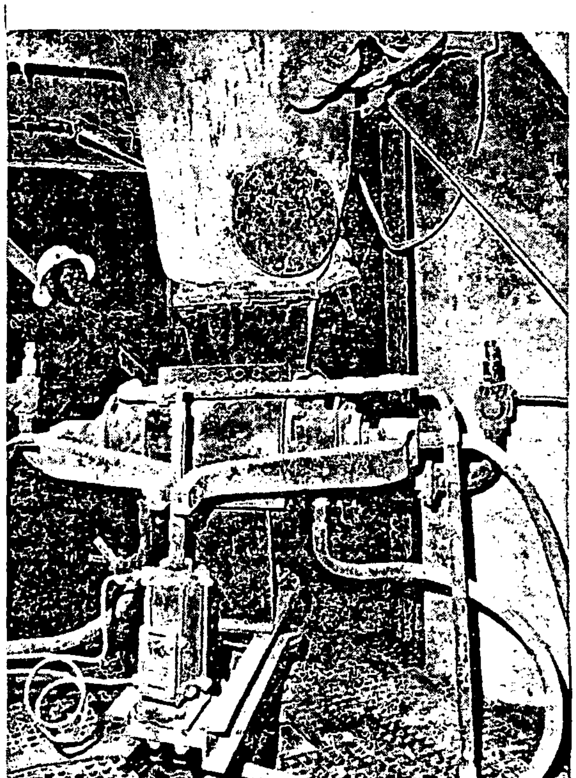
The copper cyanide is contacted with hydrogen gas at 570 to 750 F. to produce pure copper powder and hydrocyanic acid for recycle.

According to the inventor, the process should yield copper more cheaply than electrowinning or hydrogen reduction of copper sulfate, and at less cost than for smelting and electrorefining.

▶ **Refractory Recovery** — While much work has been done to improve the processing of ores from which copper already can be recovered, means for winning metal from hitherto worthless refractory deposits also have been developed.

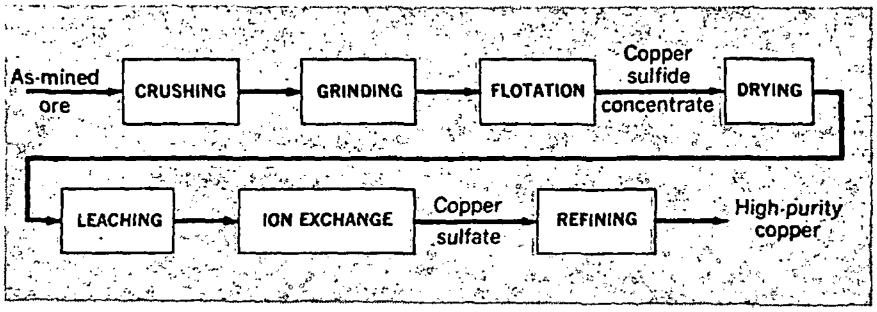
Refractory ores are so completely tied to the worthless gangue that crushing, grinding and flotation cannot free the mineral value. Nor can presently used solvents leach these ores profitably.

Anglo American Corp. of South Africa (Johannesburg) has devised a method to recover metal from such ores at a cost said to compare favorably with that of conventional production. A plant will be completed in Mauritania in about two



Anglo American Corp. of South Africa photo

COPPER FROM REFRACTORY ORE is isolated from gangue in chamber at African plant. Metal then passes on for concentration and refining operations.



NEW ROUTE FOR SULFIDE ORES is being investigated. Chemical process, unlike conventional hot-smelting operations, would win metal without venting harmful sulfur dioxide into the air. And it may require only half the capital.

years. Similar ones may be started shortly in Zambia and Italy.

In Anglo-American's Torco (treatment of refractory copper ores) process, dried ores are sent to a vessel to react with a secret ingredient at a high temperature. (Other investigators, in previous ill-fated attempts, tried sodium chloride and carbon; and in one case, salt and llama dung.) Copper is released as metal particles. The mixture is then cooled in water, and a 55% or higher copper concentrate is extracted by flotation.

Leaching with alkaline cyanide solution is being mentioned by several companies as a way to recover copper from refractory ores in tailings, overburden and other low-grade material.

Copper Range Co. of New York, for one, is planning a plant around such a process. Its pilot tests indicate that much normally lost metal can be recovered profitably by alkaline cyanide leaching.

▶**Smokeless Smelting**—About 88% of U.S. copper production involves hot-smelting of sulfide ores. However, as a byproduct of the process, enormous quantities of noxious sulfur dioxide fumes are spewed into the air (although some is recovered as sulfuric acid). As an outcome, hydrometallurgical techniques that cause little or no air pollution are being groomed to challenge hot-smelting.

Leaching would do away with the large amounts of fuel, and the fluxes for slagging gangue, as well as the dust and fumes of smelting. In many steps, liquids would be handled instead of more-bothersome solids. And such a process probably would not have a cement-copper production step—this would eliminate the problem of getting rid of the water-polluting ferrous sulfate made along with the precipitate.

On the other hand, the liquids would be corrosive, so that efficient washing of treated ores would be difficult. Moreover, no such leaching system has proved economical.

Yet, today's materials, equipment and technology can surmount the drawbacks—at least judging from what is being piloted and proposed.

In one plan, copper-sulfate concentrate from a flotation circuit would undergo a controlled roasting. Off-gas would be rich enough in sulfur dioxide so that it could be used directly in the manufacture of sulfuric acid. Not only would this cut down on the amount of baneful gas vented to the atmosphere, but the sulfuric acid would then be used to leach the sulfide-oxide mix produced by the roasting.

The resulting copper-sulfate solution would be purified and then refined by electrowinning or other means to yield pure metal.

Arizona Chemcopper has already run a pilot plant using a completely smokeless method. With a special solvent, ore is leached directly at a low temperature and pressure and under essentially noncorrosive conditions. Then the solution is purified by ion exchange. Copper is recovered by hydrogen reduction or electrowinning.

Sulfur is recovered as sulfuric acid. This could serve to leach oxide ores, if any, or could be converted to gypsum (calcium sulfate) and sold. It also could be used to treat phosphate ores for making phosphate fertilizers.

For large plants, the cost of operating such a process is estimated to be about the same as for hot-smelting. Capitalization is only about one half as much.

So, for plants either just being planned or now without a smelter, the technique is considered worthwhile. Its adoption at other locations is precluded by existing investments in smelting facilities.

However, with tightening pollution regulations, such a chemical means for winning copper may win industrywide acceptance.

New Relief for the Thirsty: Fresh Water from Wet Air

Fresh water from the air may solve the water-supply shortages for many islands and coastal regions of the world, and at a lower cost than from seawater desalting.

The method as proposed by Robert D. Gerard and J. Lamar Worzel, Columbia University oceanographers, requires a coastal location in the regular path of humid, maritime winds, with cold ocean water offshore. These conditions are met in most of the Caribbean islands, and in numerous other coastal regions of the world. An estimated 300 million gal. of water vapor in the lower atmosphere sweep across every mile of island shoreline exposed to the humid trade winds, according to the two scientists.

Cold ocean water from a depth of approximately 3,000 ft. would be piped to a condenser set up on shore to intercept the humid winds. Resultant cooling of the water-laden air would produce liquid condensate to be drawn off and stored as a fresh-water supply.

Calculations show that a 3-ft.-dia. pipe running 1 mi. from deep water in the Virgin Island Basin to an onshore condenser could produce 1-million gal. of fresh water a day. The cost could be kept low by using wind-driven generators to pump the ocean water.