Ore Concentration and Milling

Morenci Plant of Phelps Dodge Notable—Alloy Cast-Iron Liners and Balls Increasingly Used—Sink-Float Processes Attracting Attention

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LARGEST and most important of the milling plants under construction during the year is the Morenci plant of the Phelps Dodge Corp., in Arizona, where plans are being rushed for production in 1942. Grate mills will be used for fine-grinding, and in the pilot plant, classifiers of the spiral type have the preference for the closed-circuit work. The flotation units will be chiefly of the pneumatic type, with some mechanical units as auxiliaries. The Fagergren, Pan American, and Agitair machines were left in the competition as the year closed.

Possibly quite as important but for obvious reasons not so publicized have been the extensions and improvements made in the International Nickel Company's mill at Copper Cliff, Ont. Here plans call for installation of Marcy open-end rod mills, 84 in. diameter, discharge opening 52 in. diameter. The MacIntosh flotation machines may be supplemented or partly replaced with mechanical flotation apparatus. Also in Canada, the Hudson Bay Mining & Smelting Co. at Flin Flon is increasing its capacity for both copper and zinc output. Production has been increased 20 per cent and another 10 per cent is in prospect.

If the absence of European markets for finished products has dislocated the mining industry, fortunately the lack of raw materials required in the beneficitation of ores has not been serious, except possibly as to the inability to import flint grinding pebbles. Some of the less important gold mines still use pebbles for grinding as is also the practice in the comminution of nonmetallics used in various industries.

At the Calumet & Hecla in the Lake Superior copper district pebbles have been used exclusively in open-circuit grinding in the Hardinge mills treating the hard conglomerate ore, whereas on the softer amygdaloid, steel or cast-iron balls are used in closed circuit. Although a two years' supply of pebbles was on hand when all exports from Denmark and France ceased it has become necessary to change to ball-grinding. The inability to obtain foreign pebbles has led to exploitation of domestic sources. Pebbles from Newfoundland, although not the equal of imported flint, are proving fairly satisfactory for grinding certain materials. Manufactured cubes produced from various quartzite beds in Tennessee, Alabama, and Minnesota are finding limited markets.

An interesting development has been the use of cast-iron balls instead of forged steel. Apparently all the larger companies, particularly those with foundry facilities of their own, are tending toward use of the cast product. Marked improvement in the use of alloy-hardening material, more particularly the nickel and chrome compounds of which the best known is Ni-Hard, has resulted in a tremendous improvement in the wearing qualities of the cast balls.

In the Lake Superior area, where the white-iron chilled stamp shoes and other white-iron products have for many years shown abrasion-resistant qualities equal to the best of the manganese and other steels, the substitution of locally made, hard, cast-iron balls for the forged steel product has resulted in an increased life of at least 25 per cent and at a delivered cost of about one-third that of the purchased forged balls. Use of Ni-Hard in grinding balls is too recent to give exact figures of wear but it would appear that the life of a Ni-Hard ball containing about 4.5 per cent nickel and 1.5 per cent chromium is 2 1/2 to 3 times that of the white-iron ball but at about three times the cost per ball.

Use of Ni-Hard castings for wearing parts subject to severe abrasion is one of the most striking and encouraging developments of the year so far as reduction in costs is concerned. Sponsored and developed by the International Nickel Co., this product is now finding new uses in much standard equipment. Particularly in pumps handling coarse sand, where there is little impact but much abrasion, use of this material has produced startling increases in life of the shells, shell liners, and impellers. Compared to chilled white iron, an increase of 300 to 500 per cent in the life of the parts subjected to greatest wear is now assured and although the Ni-Hard liners may cost two or three times as much as the white iron the saving in final cost is marked wherever the labor and time involved in changing wearing parts is considerable.

Other advantages result. At Lake Shore Mines, for instance, use of Ni-Hard liners in tube mills, by increasing the effective diameter of the mill because of the ability to use thinner metal liners, has resulted in marked increase in capacity. Because of the lesser wear, too, it is possible to start out with a grooved or step liner and to be assured of the continuation of the desired shape throughout the life of the liner. The grooved liner (Malcolm Black patent), according to Lake Shore metallurgists, appears to have a decided advantage over a smooth liner not only as regards capacity but in saving of ball wear. Other operators have found that the smooth type becomes grooved with wear, the spacing depending upon the average ball diameter, and prefer to let nature take its course.

Ball grinding finds application on ma-
terial as coarse as 13/2 in. (Gunnar Gold in Canada) and as fine as 85 per cent minus 325 mesh (Cline Lake Gold). An excellent discussion of fine-grinding data at Lake Shore Mines will be found in the July 1940 issue of the Bulletin of the Canadian Institute of Mining and Metallurgy.

Flotation of Fluorspar

One of the important developments of 1940 in the nonmetallic field has been the continued expansion in the fluorspar industry which became notable first in 1939 with the demand for this product following the outbreak of the war. Flotation had been applied as early as 1924 to separate the zinc and lead from the fluorspar and in 1929 the spar itself was successfully floated commercially at Rosiclare, though fluorspar had been commercially floated in 1921 at Trail, B. C. The Mahoning Mining Co. has erected a modern mill and is making a successful separation by differential flotation of zinc sulphide, lead, and fluorspar. The uses of fluorspar are being expanded with the production of the purer and cheaper product, the Illinois Geological Survey being active in this research.

Improvements in metallurgy are of economic importance not only because of increased recoveries, but because of another fact not so easily recognized but just as important—a decided increase in ore reserves. Thus we find Miami mining sulphide ore assaying 0.6 per cent copper. This is reflected also in developments in the Lake Superior copper district where the mines are low-grade, deep, and becoming exhausted. The largest and most extensive tailing reclamation plant in existence, handling tailing from the now exhausted Calumet conglomerate mine, has been operating for 25 years with possibly 4 more years to run. Extensive deposits of low-grade amygdaloid tailings (5 to 8 lb. per ton) exist in this same district and attention is now directed to them. The Copper Range Co. has been treating material of this grade at its Champion property intermittently for 3 years and is making a profit with copper at the current price of 12c. The Quincy Mining Co. is doing preliminary work of a similar nature. A high percentage of recovery and extreme economy of operation, including cheap power, is necessary to make treatment of these low-grade sands profitable. Such installations have not been particularly attractive at copper prices prevailing in the last decade.

The Cotopaxi Exploration Co. started its 300-ton mill at Macuchi, Ecuador, last February and is treating successfully by selective flotation a copper-gold ore high in pyrite. The principal flotation reagent is American Cyanamid Company's 208.

The Cia. Minera Aguilar, a subsidiary of St. Joseph Lead operating in Argentina, is treating 800 tons daily of a lead-zinc-silver ore by selective flotation. The lead concentrate is kiln-dried before freight shipment to a smelter at Buenos Aires. Also in Argentina is the Soc. Minera Pirquitas, which is floating a silver chloride and has made a concentrate running over 90 per cent silver, probably a record.

Bolivian tin is certainly in the spotlight because of the Far Eastern situation and there are many interesting developments. The Bolivian International Mining Corp. by dredging is making a gravity concentration of cassiterite, magnetite, hematite, and other iron oxides. Former practice from this point on was to remove iron minerals by means of a single Dings-Wetherill magnetic separator; a second machine was used as a cleaner with return of its magnetic product to the head of the first machine yields both a higher-grade concentrate and lower tailing.

Other South American Mills

At Potosi, also on tin, 20-deck round tables, like those used at Anaconda just before the adoption of flotation, treat the minus-200-mesh pyritic tin ore. Concentrate from these tables assays 5 to 15 per cent tin and is treated by flotation to bring it to a shipping grade. Many of the mills still use the old Cornish hand-operated buddles of two generations ago.

Heavy-liquid separation is being tried experimentally on tin ore. At Colquiri a 25-ton experimental unit is operating with promising results. No classification is used beyond screening out the minus—2mm. fines. Concentration by volatilization of the tin of high-pyrite tin ores is also under experimentation.

At Braden Copper Co. in Chile, a small unit was completed for recovery of molybdenum sulphide from copper concentrate, the treatment being similar to that at Utah Copper. At the Utah Copper plant the molybdenum concentrate is further freed of its small amount of copper and "insoluble" by roasting in a hearth furnace at a temperature which oxidizes the copper but not the molybdenum sulphide. The "insoluble" is then floated off, and finally the molybdenum sulphide.

At Miami which sulphide concentrate containing molybdenum is thickened, conditioned with lime, and steamed for two hours to remove reagents. It is then filtered and the molybdenite floated with fuel oil and reclamed six times in a Fahrenwald machine. The small amount of copper remaining is still further removed by leaching with sulphuric acid so that the final concentrate assays about 92 per cent molybdenum sulphide.

Float-and-sink Processes

The optimistic faith of the backers of this type of concentration is apparently bearing fruit in large and successful operations. The process was put forth seriously some four years ago by Victor Rakowsky of Joplin as a means for separating, particularly in coarse sizes, the zinc-lead ores of the Tri-State district, using a finely ground galena suspension as medium. The process is now in successful operation on a large scale at Mascot, Tenn., at Picher, Okla., and on the Mesabi Range. At Mascot, according to the metallurgical staff of the American Zinc, Lead & Smelting Co. who control the Differential Density Concentration Process, the procedure consists of the continuous rejection of a large proportion of the mill feed as a barren tailing by passing coarsely ground ore through a cone filled with the separating medium of high specific gravity—in that case a suspension of finely ground galena. The same process is used by the Eagle-Picher Mining & Smelting Co. and the two plants are treating approximately 10,000 tons per day. In these plants the feed is delivered continuously to the cone. The tailing overflows and is rejected after being freed of the adhering medium. The concentrate sinks to the bottom of the cone, is removed, drained, and washed free of galena. At Mascot the material treated in the cone is plus 3/8 in., the undersize going to the jigging plant. The density of the medium at the top of the cone is 2.80 sp. gr. and at the bottom 2.95, that of the rejected tailing being just under 2.80. The loss of galena at Mascot is given as 0.14 lb. per ton of mill feed. The cost is as low as 11c. per ton milled without credit for returned galena which reduces this cost by 3c. per ton.

A Problem on Iron Ore

When a high-density medium composed of galena was tried for concentration of iron ores difficulty was experienced in cleaning the medium from the reject and in turn cleaning the medium itself. The loss of galena due to its reduction by grinding and thus becoming unsuitable for suspension was also serious. Many materials were tried including even finely ground native copper and success was finally obtained with the use of ferrosilicon, a magnetic sub-
can be crushed in ball or rod mills. to 7.0, a Moh hardness of 5 to 6, and can be crushed in ball or rod mills.

Maximum practical specific gravity obtainable in a solid-water medium is approximately 50 per cent that of the gravity of the solid, and the medium should be about 70 per cent solids by weight as below this it is difficult to keep the solids in suspension.

The big advantage of a magnetic medium is the ease of cleaning. If non-magnetic, either gravity or flotation must be used and this is difficult with the fineness of particle size demanded. With magnetic separation on the other hand the particles tend to adhere to each other as all are small magnets after passing through a magnetizing coil or between permanent magnet blocks. In this cleaning circuit the pipe lines containing the solids discharge through nozzles between blocks so arranged for polarity that the flow of material penetrates two magnetic fields. This causes a polarity in each ferrosilicon particle and aids flocculation and rapid settling.

The present high-density plant treats ore between 3/4 in. and 1 3/4 in. in size. The minus-1/4-in. material is treated in jigs. The heavy-density method is positive in its action and the sole factor in its success or failure is in the structure of the ore. Over 1,000,000 long tons was treated in 1940 so that the present status is that of a commercial process.

Flotation Progress

MORE and more this process becomes the recurrent wonder of this remarkable metallurgical age. As its field is being extended laterally to oxidized ores and nonmetals so also is its efficiency being increased with improvements in both reagents and mechanical application. Use of mahogany soap has been of particular value in increasing recovery from oxidized ores. The deep-air-cell machines as developed at Britannia Beach and elsewhere have decided advantages in increasing the grade of concentrates and in providing higher capacities. Fagergren and Agitair cells have been introduced in many mills and the Fahrenwald promises to displace Macintosh cells at International Nickel to some extent.

An interesting and unique flotation improvement has been developed in Canada at the Lake Shore and Little Long Lac. At Lake Shore the cyanide tailing containing sulphide mineral is floated with the aid of sulphur dioxide which creates a slightly acid circuit. These sulphide minerals thus floated are calcined, yielding sulphur dioxide for the flotation circuit, and the calcine in turn is cyanided. This process is supposed to yield a profit on a 30c. tailing.

With the removal of restrictions on arsenical roasting by the Dominion Government there have been decided extensions in the treatment of this type of ores by cyaniding following flotation. Now Beattie, in northwestern Quebec, and small mines in the Little Long Lac district in Ontario are operating roasting plants. Their concentrates are self-roasting and the calcines are cyanided. This results in a decided saving in freight and treatment costs.

New Apparatus

THE gap between screening to 6-10 mesh and coarse classification at 28-35 mesh has this year been filled by a new type of Dorr classifier operating in the 4-28-mesh range. It resembles the standard Dorr classifier so far as raking mechanism, head motion, and tank are concerned. It differs in that the lower end of the tank is decked over and surmounted by a small pool in which the separation takes place, rather than in the tank proper.

The Dorrco sand wheel, introduced this year, is a device for elevating mill discharge to classifiers in closed-circuit operations where the classifiers are so wide, 8 ft. and up, as to make it difficult to obtain an all-gravity circuit. The sand wheels are directly connected to the discharge trunnions of the rotary mills and are totally enclosed and splash-proof.

A new type of diaphragm sludge pump, used for controlling the discharge of thickeners, is unique in that the stroke of the plungers and hence the rate of discharge may be varied at will by a handwheel while the pump is in motion. It has two pumping chambers, cast in a V shape, and occupies only about half the space of former diaphragm pumps of the same capacity.

Density controllers of various types and for various uses are being installed in many plants. The Massco density controller finds its greatest application for maintaining a constant density in closed-circuit grinding units as well as to regulate the density of the medium used in the sink-and-float processes.

Flotation machines are being continually improved, the tendency toward deeper cells continuing. Fagergren, Agitair, and Fahrenwald machines have
Metallurgy of Copper

Additional Equipment Being Installed at Many Smelters as Capacity Operation is Reached

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EARLY 1940 found the copper industry in an optimistic mood. Demand both for domestic consumptions and for export was high, and the industry was operating at a production rate of about 90,000 tons per month. However, with adverse war developments and the fall of France consumption declined during the spring months to around 62,000 tons per month. By late summer, exports of U. S. copper had virtually ceased. As the national defense program got under way, demand again rapidly increased, and sales in September reached record-breaking figures. During the first nine months of the year the industry kept well in step with requirements, and was producing at around 80 per cent of capacity. In the last quarter, to meet steadily increasing demand, production was further increased; and as the year drew to a close the industry was operating well up to capacity and lined up to assume the full burden of responsibility imposed upon it by the requirements of national defense.

Throughout the year many of the larger producers report a rather unusual record of expansion and modernization in smelting operations.

At the Douglas plant of the Phelps Dodge Corp. a new reinforced concrete chimney was constructed to dispose of converter gases. This chimney is 565 ft. high with an inside diameter of 18 ft. at the top. The concrete shell is lined with solid 8-in. radial, hard-burned clay brick for 94 ft. above its base. Above this point the lining, reduced to 4 in. in thickness, extends to the top of the stack, being supported on corbels. Between the lining and the stack proper, upward for a distance of 341 ft., is an insulating layer of glass wool installed in blanket form. Before installing the lining the interior of the stack received two coats of paint. On the outside, the top 160 ft. of stack also is painted.

Together with the stack, a new converter-dust collection system was installed. Converter gases from the main balloon flue are passed through a battery of cyclone-type dust-collecting units to the chimney. The efficiency of the new dust-collecting system is higher than that of the former dust chamber, and the smoky condition in the converter aisle has been eliminated. It is also reported that a new reverberatory furnace and waste-heat boiler installation is planned at this plant in the near future.

At the Morenci plant of this corporation the work of mine development and stripping is proceeding apace. Construction of concentrator, smelter, and power plant is under way, and the entire plant should be ready for operation by Jan. 1, 1942.

The Hurley smelter of the Nevada Consolidated Copper Corp., newest of all copper smelters, continues to operate most satisfactorily. A third 13 by 30-ft. Peirce-Smith converter has been installed and put into service.

The McGill plant of the Nevada Consolidated continues to smelt a high tonnage in their raw-charge smelting operation. The charge treated runs between 9 and 10 per cent moisture, and the rate of operation approaches 1000 dry tons per furnace day. This type of operation obviously calls for a high rate of fuel consumption, so combustion control and waste-heat recovery are important. The reverberatory furnace is fired by pulverized coal, and to meet requirements of increased capacity an additional ball mill for coal pulverizing was necessary. With two mills operating, coal is delivered to the furnace at the rate of 225 tons per day. Smelting requires a heat input of 6,376,000 B.T.U. per ton of dry solid charge, and a waste-heat recovery of 55.1 per cent is obtained.

At the Garfield plant of the American Smelting and Refining Co. two new Peirce-Smith converters have been installed. A special feature of this new installation is an improvement in hood design which considerably reduces air infiltration and leakage.

The great Anaconda plant, one of the old-timers, is also in the throes of a construction campaign. Here, an entirely new converter plant is being built adjacent to the reverberatory plant. This change in location eliminates the trimming of matte and converter slag between reverberatories and converters. The new plant will contain four large Peirce-Smith converters together with new tilting anode furnaces and casting equipment.

War conditions prevent the reporting of much in the way of activity from the Canadian or African smelters. We do, however, note that at Noranda, in Quebec, the demand for ever-increasing capacity has required the installation of additional coal-pulverizing equipment and the adoption of preheated air delivered to the burners un-