May 18, 1948. H. L. McNEILL 2,441,584

CLOSED CIRCUIT GRINDING WITH TWO-STAGE CLASSIFICATION

Filed June 20, 1942

FIG. 1

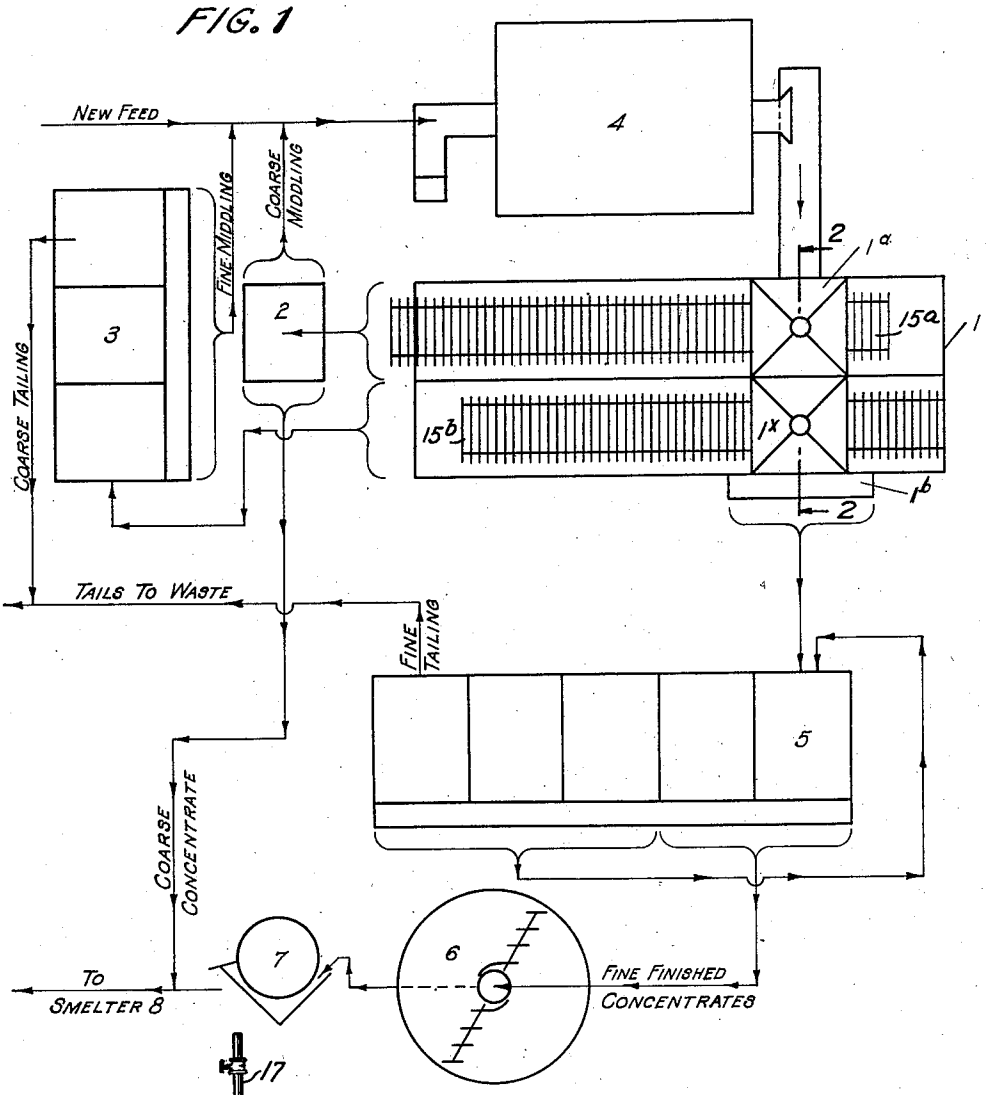
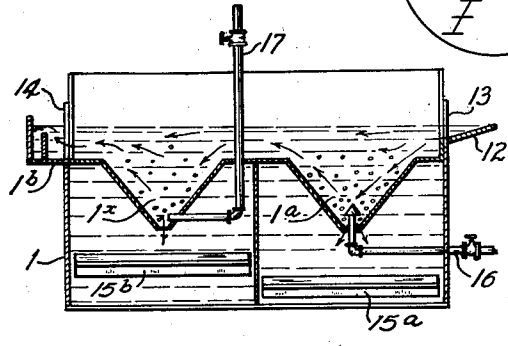


FIG. 2.



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Patented May 18, 1948 2,441,584

UNITED STATES PATENT OFFICE

2,441,584

CLOSED CIRCUIT GRINDING WITH TWO-STAGE CLASSIFICATION

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Application June 20, 1942, Serial No. 447,763

3 Claims. (Cl. 241—20)

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This invention relates to ore treatments and more particularly to improvements in ore dressing methods.

In the early days of our metal production, the valuable constituents were recovered from high grade ores by gravity methods before grinding mills had reached a commercial development.

Later as the ores became progressively lower in grade, grinding was employed to unlock mineral of a quality formerly discarded from the treatment as a tailing. In such operations a concentration stage was provided in the treatment following each reduction in particle size in the material under treatment.

In such an operation many machines were employed in relation to the quantity of ore treated and recoveries seldom averaged over 75%. Then with the advent of froth flotation, fine grinding was employed to unlock mineral particles of the type formerly lost in the tailings and recoveries improved progressively until today most plants recover 90% or over of the mineral.

Likewise under modern practice most plants only provide one stage in the circuit where concentrates are removed. A large part of the mineral which initially is freed in sizes too large to float, consequently is retained in the grinding circuit, and as a result instead of having one large particle permitting a 100% recovery, it is passed through the mill repeatedly until fine enough to overflow the classifier, and in the transformation becomes thousands of smaller particles, some extremely fine, thereby rendering a 100% recovery an impossibility.

Experience the world over has shown that the major losses in the tailings occur in the minus 200 mesh fraction. Consequently a substantial elimination of production of particles in the 200 mesh or finer ranges would appear to be one means of reducing tailings losses.

Modern practice also has deleterious results in connection with the treatment of the gangue or waste content. Thus a gangue particle containing no mineral and too coarse to float is subjected to repetitions of the grinding action until it, too, is reduced to a state of fineness sufficient to pass the classifier overflow.

Since the grinding stage is the most costly item in the operation of concentrating mills, it is apparent that all effort directed at a reduction of barren rock in the grinding stage is economic waste.

It is a principal object of the present invention to provide simple, efficient and economical ore dressing methods for the recovery of the mineral content of ores in larger and fewer particles than has been possible with methods heretofore in use.

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Another object of the invention is to provide a simple, economical and efficient method of grinding the middlings content of an ore in closed circuit.

A further object of the invention is to substantially eliminate slime conditions in the material under treatment in an operation utilizing closed circuit grinding of the middlings content of an ore so as to increase grinding efficiency.

Other objects reside in the provision of novel steps and treatments all of which will appear more fully in the course of the following description.

The present invention has been designed for use in a wide variety of treatments and, in fact, is generally applicable wherever froth flotation has been employed to concentrate one or more constituent minerals of a given ore. Likewise the invention is beneficial both in treatments where a single mineral is separated from gangue or waste constituents and other treatments wherein two or more minerals are differentially separated and recovered as concentrates separate from the gangue constituents.

In practicing the present invention, the classification stage is utilized to obtain a separation of constituents of the ore as well as to grade the material according to sizes. In so doing, it is possible to utilize a series of differential separations at each of which a valuable constituent is recovered separately from waste matter or other matter requiring additional treatment before separation of its mineral content can be effected.

Before undertaking a complete description of the operating procedure, it will be advisable to define certain terms employed in the specification, to distinguish from other meanings sometimes applied. Where the expressions "finished product" or "finished material" are used, they are intended to designate a product ground fine enough to overflow present type classifiers and pass to subsequent treatment. The term "gangue" as used in the specification is intended to designate any waste product which is barren of mineral.

To afford a better understanding of the practice of the invention, reference is made to the accompanying drawings, in which Fig. 1 is a flow sheet in which a typical milling circuit has been illustrated embodying the features of the present invention; and, Fig. 2 is a section taken along the line 2—2, Fig. 1.

In the circuit illustrated, the grinding circuit in addition to the classification stage 1 and grinding stage 4, has concentrating stages 2 and 3 respectively, the details of which will be fully set forth hereinafter.

In the aforesaid circuit, ore is fed to a tumble mill 4, usually a ball mill, and is there mixed with a sufficient quantity of a liquid, usually water, to form a free-flowing pulp. The pulp discharge of mill 4 is passed into a two-stage classification operation which may consist of a single duplex classifier or a series of individual classifiers arranged as hereinafter described.

The classification stage of the present invention is utilized to produce three products, namely, (*a*) finished product, (*b*) a mixture of coarse free mineral with larger middlings particles, and (*c*) a mixture of fine middlings with coarse gangue.

While a variety of apparatus may be utilized to produce the desired products at the classification stage, it will be essentially the same in function as apparatus of the type disclosed in my co-pending application Serial No. 289,466 now Patent No. 2,315,536, granted April 6, 1943, which is particularly suited for this purpose. Features disclosed but not claimed herein relating to the classification step per se, have been described and claimed in the aforesaid application.

The ball mill discharge constituting the classifier feed enters the tank 1 at the side through a feed box 12, the discharge of which passes through an opening 13, and through the provision of hindered settling means here illustrated as spigot compartments 1*a* and 1*x*, the portion of said feed constituting finished material is caused to pass directly across the classifier to its overflow 1*b* the discharge of which passes through an opening 14. At the same time the hindered settling action is utilized to induce a differential settling of the other feed constituents, with the result that coarse free mineral mixed with still larger sized middlings particles are settled in one zone, while finer middlings particles together with coarser gangue constituents are settled in a second zone. This hindered settling action may be produced either by introducing gas under pressure through a suitable valve-controlled conduit as shown at 16 in compartment 1*a*, or water under pressure through a suitable valve-controlled conduit as shown at 17 in compartment 1*x*.

Each of the graded settled products is separately removed from the classification stage by suitable conveyor mechanism 15*a* or 15*b*, with each product after removal from the unitary hydraulic classification treatment stage being subjected to a separation with only one of the products so separated returning to the mill for regrinding.

To this end, the mixture of coarse free mineral and larger middlings particles preferably is subjected to a jigging treatment as indicated at 2, after which the coarse middling so separated is mixed with the entering feed to the mill 4, while the coarse mineral concentrate is collected as a product for smelting.

Likewise, the rake product of classification comprising fine middlings mixed with coarse gangue preferably is subjected to separation by froth flotation as indicated at 3, with the froth concentrate comprising substantially all of the mineral content being mixed with the entering feed to the mill for further unlocking, while the residue product comprising essentially coarse gangues is passed to waste.

Thus, the closed circuit grinding of the present

invention differs essentially from prior practice in that substantially all finished product, coarse free mineral and barren gangue are eliminated in one pass through the classifier while the product returned to the mill for regrinding consists almost entirely of middlings requiring further unlocking before separation of constituents can be attained.

By so doing, the useful work of the grinding mill is limited to an initial reduction of oversize and further unlocking of mineral-bearing material only. The elimination of finished product in the first pass through the classifier prevents sliming to any appreciable degree.

As a consequence of these economies in operation, the capacity of the grinding mill may be reduced from that required in conventional practice without reducing the capacity of the circuit and in this way economies in initial cost and operating cost are effected.

The product overflowing the classifier at 1*b* is then taken as the feed of the flotation circuit, here represented as a plurality of rougher cleaner cells. The concentrate of this operation is then passed to a thickener 6, and the collected solids of the thickening operation are filtered as shown at 7 and are then ready to go to a smelter 8 which may or may not be associated with the milling operation.

The concentrate of the jig 2 also is taken to smelter 8 and where shipment is necessary to get these concentrated minerals from the mill to the smelter, they may be mixed for convenience in transportation.

The elimination of slimes from the feed to flotation has beneficial effects of a pronounced character. In the first place, a granular flotation concentrate requires smaller thickener and filter areas. Likewise, a granular filter cake contains less moisture than a slimy one, and where such products must be shipped to a smelter, a substantial savings in shipping expense results.

Furthermore, a granular concentrate has a much lower dust loss in the smelting operation and consequently a further economic gain results from the treatment of the present invention.

From the foregoing description of the practice of the present invention, it will be understood that the purpose of the initial separations is to free the product recirculating through the grinding mill of substantially all its barren gangue content, and all its free mineral, irrespective of size.

To this end, the finished product containing both free mineral and gangue, in sizes fine enough to pass the classifier overflow, is discharged from the grinding circuit without recirculation and is then in ideal condition for the subsequent flotation separation as the slime formation factor has been eliminated.

Likewise, the graded settling of the oversize products permits isolation of the middling by screen or gravity separation methods. Consequently, the material returning for regrinding is almost exclusively mineral-bearing and for the most part of a size permitting further reduction without producing slimes.

For example, in the operation a given middlings product of the mill may be substantially oversized and comprise 90% gangue and 10% mineral. When returned and further reduced, it is split into one oversize piece of gangue, and two smaller size pieces, one being classed as coarse middling and the other fine

middling. Each of these may comprise roughly 60% gangue and 40% mineral.

At this stage the specific gravities of these middlings constituents readily identifies them from the gangue and from the mineral.

This condition permits making the tailing at a substantially coarser grind than is possible in conventional practice. With the process I have developed it is possible to isolate the middling at the screen size at which the ratio of mineral to gangue in a particle gives it a specific gravity which identifies it from the free mineral on one hand and the gangue on the other.

While jigging has been designated as preferred treatment for separation of coarse free mineral and larger sized middlings, it will be understood that screening or other forms of gravity separation may be substituted where desired.

Similarly, froth flotation has been designated as the preferred treatment for collecting the fine middlings separately from the associated gangue, but screening or other forms of gravity separation also may be substituted in this stage as well.

As previously suggested herein, the preferred structural arrangement at the classification stage is a duplex-type classifier having a transverse trough or channel for the direct movement of the finished material through the classification stage and out of the treatment. To insure prompt elimination of substantially all finished material, the classifier feed preferably is subjected to hindered settling influences but other forms of treatment apparatus capable of attaining the same results may be substituted in place of the classifier hereinbefore described.

As the aforesaid treatment is not dependent upon chemical change or reaction except to the extent that froth flotation or leaching is recommended, it will be understood that all ores containing mineral which can be recovered on a commercial scale by ore dressing methods may be treated effectively by the methods of the present invention.

It is to be understood further that the invention is in no sense limited to the arrangement of treatment steps set forth in the accompanying flow sheet which is intended merely as a typical example, but rather embodies as essentials the elimination of substantially all ore constituents other than middlings in the product returned to the grinding circuit.

In the middlings flotation treatment the product treated is of relatively coarse mesh size and a large amount of reagent is required to collect all of the particles of varying mineral content in the froth concentrate. However, with slimes eliminated from the feed as described, the operation in this treatment becomes quite efficient, whereas if the slimes were permitted to remain in the feed the reagent would carry up all fines, both middlings and gangue, resulting in further sliming and wasteful grinding in the mill.

For this reason, flotation is recommended for the treatment of the mixture of fine middlings and coarse gangue. But as pointed out hereinbefore, a variety of treatments may be employed at this and other stages within the spirit and scope of the invention as defined in the hereunto appended claims.

More specifically, certain operations will involve leaching operations for the recovery of mineral in place of the froth flotation concentration hereinbefore described. The present process may

utilize leaching at either of the stages designated 3 or 5 in the flow sheet.

However, best results in leaching operations will be attained when the second compartment of the classifier is used for sands-slimes separations and each product of this separation thereafter is subjected to a different type of leaching.

In such an operation, the slimes or finished material will be passed from the grinding stage to leaching with agitation at a stage acting as an alternate for the flotation stage 5 of the flow sheet. The sands so separated will pass to a still leaching operation serving as an alternate for the stage 3 illustrated. Otherwise the treatment steps will be substantially as hereinbefore described.

What I claim and desire to secure by Letters Patent is:

1. In an ore dressing circuit, the steps of grinding an ore in a mill to produce a product containing some coarse free mineral, passing the grinding mill discharge containing granular material with only a minor quantity of slimes sizes directly into a two-stage classification separation, inclusive of a hindered settling treatment in which finished material, inclusive of slimes, is maintained at or near the surface and eliminated directly from the circuit, controlling the feed of hydraulic water to the hindered settling zone to produce two settled products, one consisting predominantly of coarse middlings together with some free mineral and the second consisting predominantly of fine middlings together with coarse gangue, elevating said segregated products through the liquid of the classification stage so that the discharge products are essentially dewatered, subjecting the coarse middlings and free mineral to a concentration treatment for the recovery of the free mineral, subjecting the fine middlings and coarse gangue to a different concentration treatment for the collection of the fine middlings and elimination of the coarse gangue from said circuit, and subjecting only the said middlings products so separated to regrinding in said circuit.

2. An ore dressing circuit of the character described in claim 1 wherein the concentration treatment to which the coarse middlings and free minerals are subjected comprises a jigging treatment.

3. An ore dressing circuit of the character described in claim 1 wherein the concentration treatment to which the fine middlings and coarse gangue are subjected comprises a gravity concentrating treatment.

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