

June 12, 1945.

L. J. ERCK

2,378,356

METHOD OF CONCENTRATING MINERALS

Filed Feb. 11, 1942

4 Sheets-Sheet 1

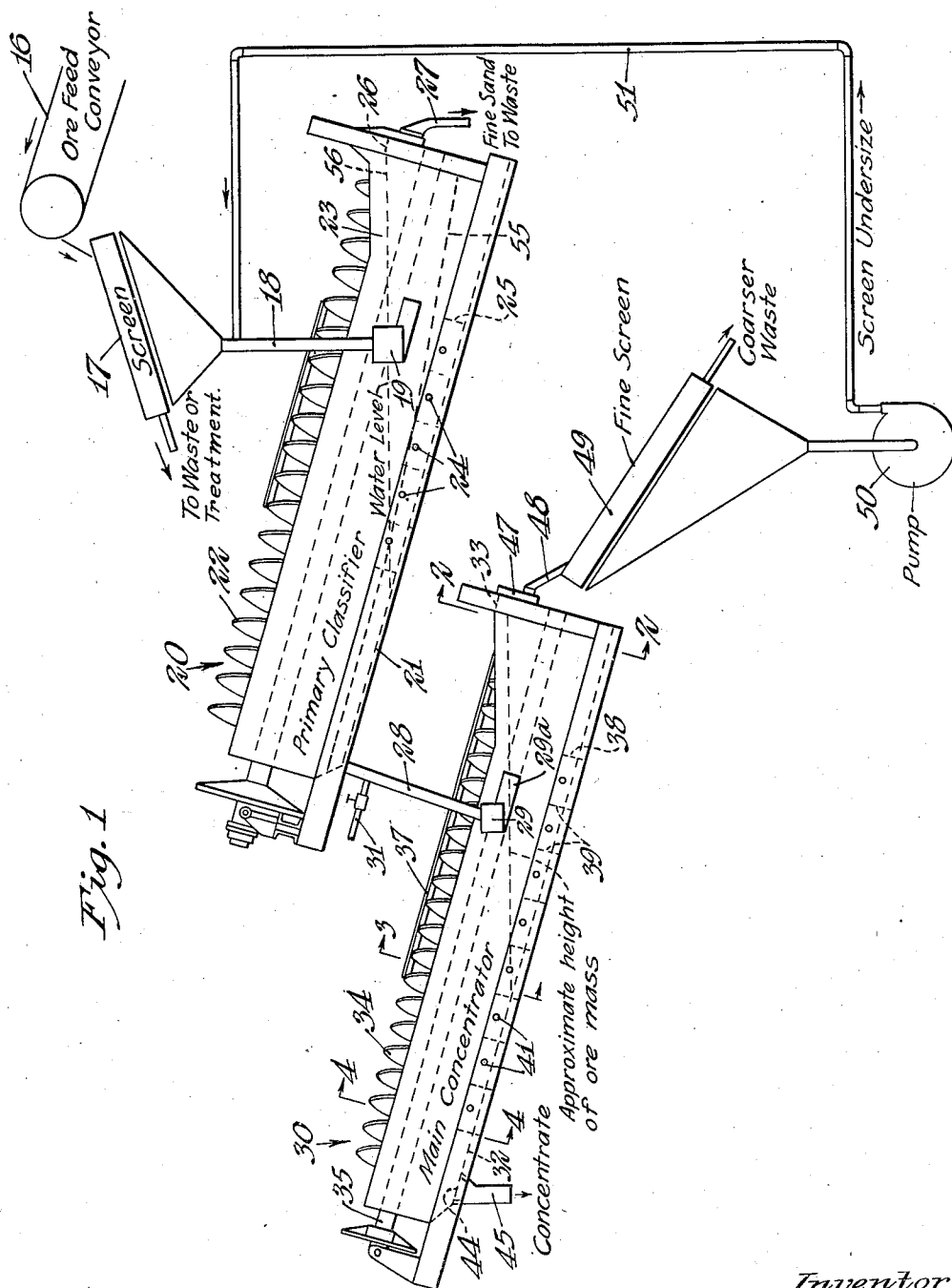


Fig. 1

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Fig. 5

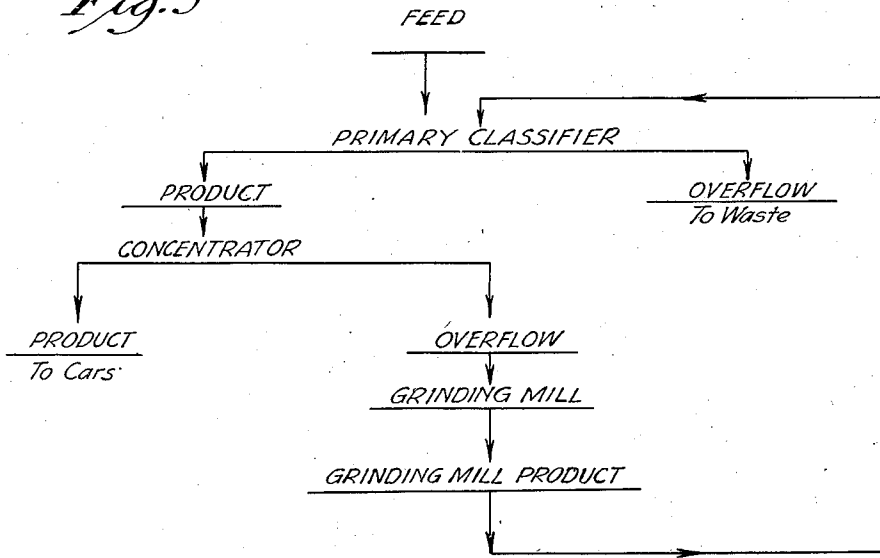


Fig. 2

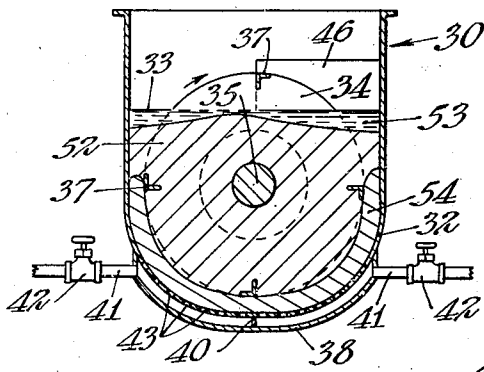


Fig. 3

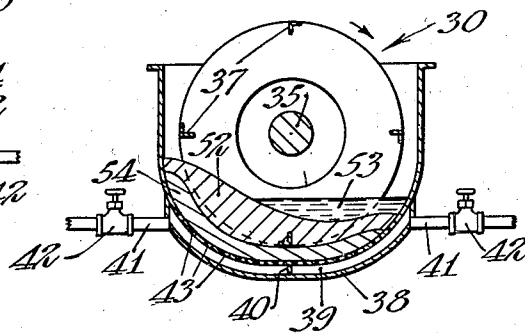
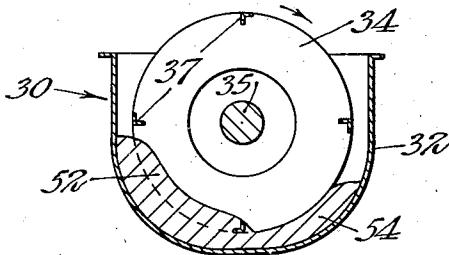


Fig. 4



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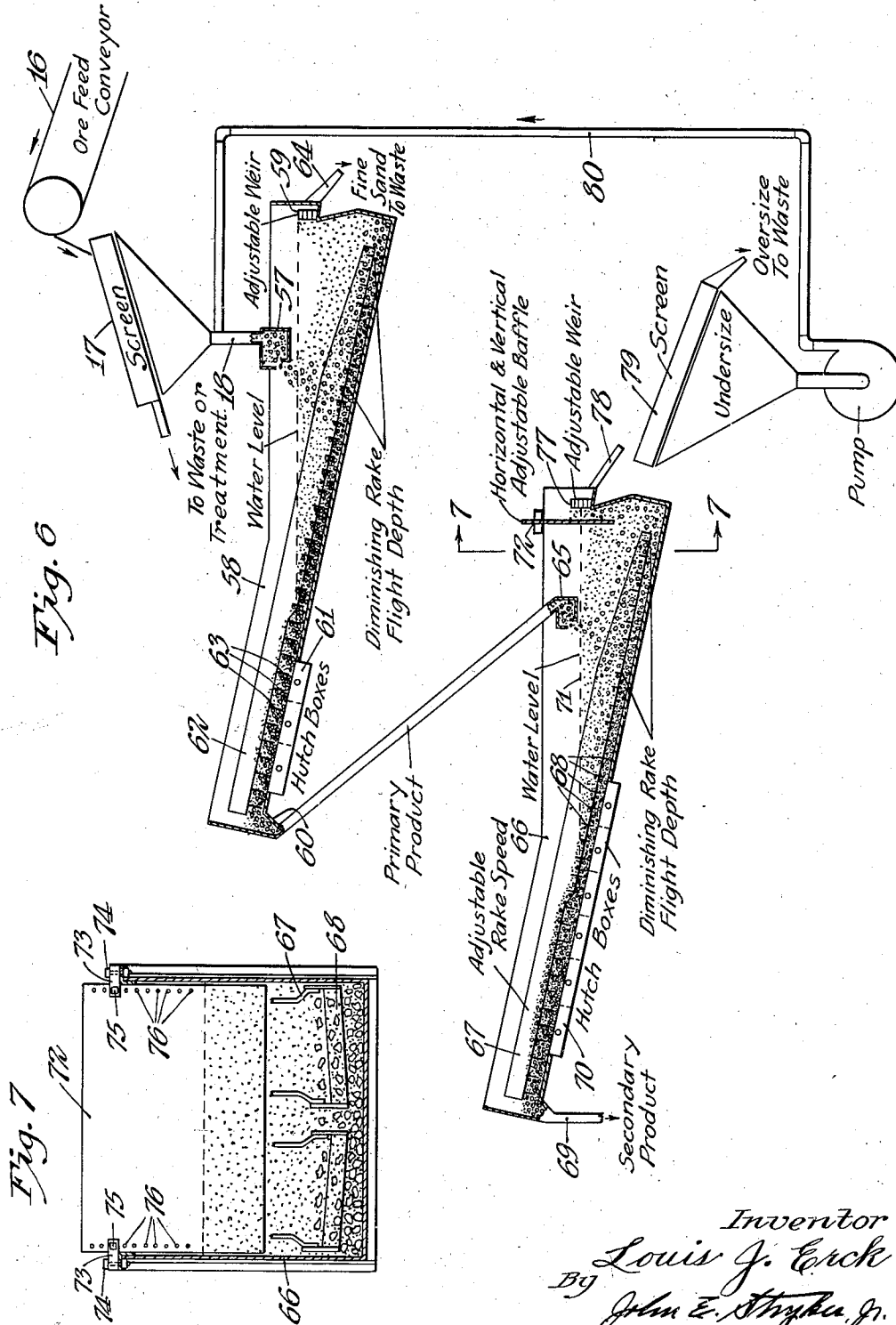
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METHOD OF CONCENTRATING MINERALS

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4 Sheets-Sheet 3



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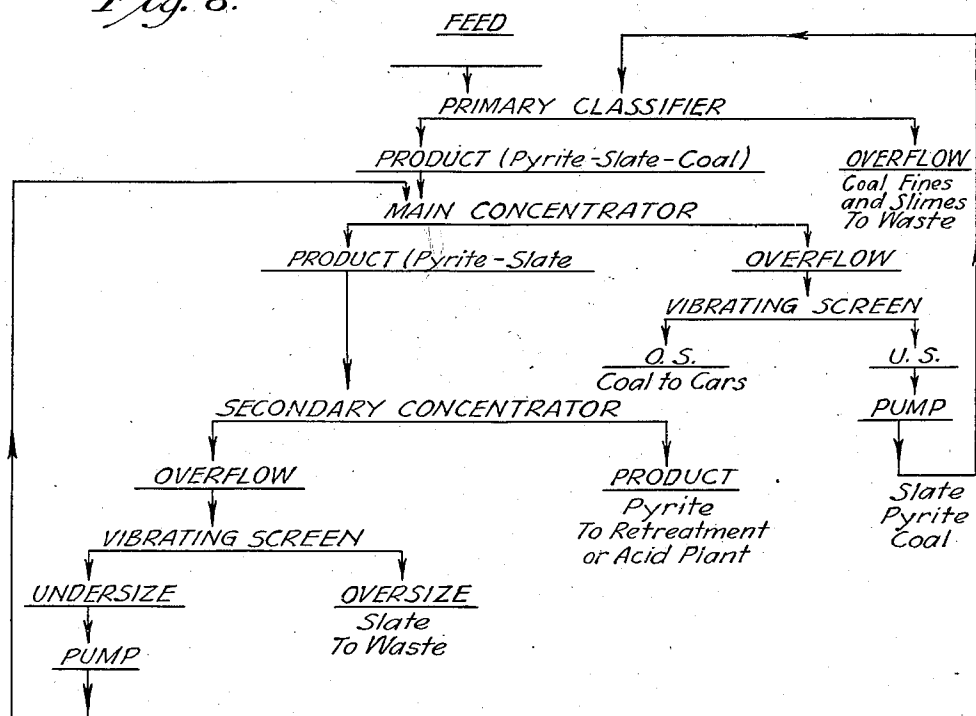
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Fig. 8.



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UNITED STATES PATENT OFFICE

2,378,356

METHOD OF CONCENTRATING MINERALS

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Application February 11, 1942, Serial No. 430,342

9 Claims. (Cl. 241—20)

It is an object of this invention to provide a method for concentrating fine ores and coal by the use of relatively inexpensive equipment and with increased efficiency and recovery as compared with known methods.

A further object is to provide a continuous, low cost method for concentrating certain fine materials, such, for example, as ores of minus one-quarter inch sizes and minerals generally of such character that they cannot be concentrated economically or efficiently by methods in general use such as those involving flotation in heavy density fluid, froth flotation or utilizing log washers and other known equipment.

A particular object is to concentrate minerals of mixed sizes and densities by employing a plurality of hydraulic concentration operations between which operations an intermediate or middlings product is withdrawn and treated to eliminate or reduce a substantial amount of the coarser, low density material, the product of the middlings treatment being further subjected to classification to separate the bulk of the fine, low density constituents from the fine, high density constituents.

My preferred procedure is as follows: After determining the maximum size of the material to be treated, whether this material be ore or coal, it is passed over a scalping screen for the removal of any fraction which may be coarser than that to be treated and then the undersize of this screen is fed to suitable apparatus for removing the extremely fine, lighter fraction of the material and slimes. For the latter operation any of a number of standard hydraulic classifiers may be employed. The fine, low density material overflows or is drawn off from the machine together with a small fraction of the extremely fine iron or other high density constituent. This fine product may be wasted or subsequently recovered, if recovery is commercially practical. The bulk of fine, high density material, together with the coarse high density and coarse low density materials, are discharged from the first classifying machine and then treated to separate much of the coarser low density material from the other constituents. For this treatment I maintain in the concentrating apparatus a mass of mineral which is too dense to permit classification depending on particle size and I work the coarser particles of low specific gravity to the surface of the mass by a combination of mechanical agitation having an upward component and upward percolation of water through the mass such that the hydraulic force

is insufficient to produce teetering of the mass.

The raw mineral or dewatered material from the primary classifier is fed to a main concentrating machine, which may be a machine of the rotary spiral, classifier type so altered as to permit the maintenance of a relatively dense and large mass of the mineral in the trough adjacent to the weir. In this machine the mass of material is agitated in such manner as to work the coarser particles of the lighter fraction (principally coarse silica in the case of iron ores) to the surface while continuously drawing off the lighter and coarser fraction from the lower end of the trough and removing the concentrates or heavier fraction from the upper end of the machine. In ore concentration work, some fine ore is drawn off from the lower or weir end of the machine with the coarse silica and it is desirable to recover this fine fraction by subsequent treatment. To accomplish this, I have found that the coarse silica and fine ore may be passed over a vibrating screen of suitable mesh to permit the oversize to be wasted or further treated as hereinafter described and the undersize from the screen, comprising principally fine ore, may be returned either to the primary classifier or to the main concentrator to be subsequently recovered from the latter. A number of modifications of and additions to the foregoing basic procedure, within the scope of my invention, are hereinafter described and claimed.

The present application is a continuation in part of my application serial No. 395,809, filed May 29, 1941, for "Method of concentrating minerals."

In the accompanying drawings I have illustrated two distinct types of hydraulic machines which are suitable for use in my improved process.

Referring to the drawings:

Figure 1 is a diagrammatic illustration of a flow sheet and apparatus, including a hydraulic concentrator of the screw type, for utilizing my invention in the concentration of minerals;

Figs. 2, 3 and 4 are sections taken respectively on the lines 2—2, 3—3 and 4—4 of Fig. 1;

Fig. 5 is a flow sheet diagrammatically illustrating a modification of the preferred process wherein the overflow from the main concentrator is passed through a grinding mill and the grinding mill product returned to the primary classifier;

Fig. 6 is a diagrammatic illustration of a flow sheet and apparatus, including hydraulic machines having inclined troughs and agitating and

conveying mechanism of the reciprocating rake type;

Fig. 7 is a section taken on the line 7—7 of Fig. 6, and

Fig. 8 is a flow sheet diagram of an application of the invention to the cleaning of fine coal and providing for the recovery of pyrite therefrom.

Referring to Fig. 1, an ore feed conveyor is indicated by the numeral 16. This conveyor delivers the ore to a scalping screen 17 of such mesh as to eliminate sizes larger than those to be concentrated. In the case of iron ore, the process being particularly applicable to minus one-quarter inch sizes, a screen of the corresponding mesh is employed and the oversize is either wasted or treated by some other suitable method. The undersize material, together with sufficient water to cause it to flow is conveyed through a conduit 18 to the feed box 19 of the primary classifier indicated generally by the numeral 20. This machine is of the conventional type having an inclined trough 21 in which a screw type conveyor 22 is continuously rotated to work the ore from the lower end to the upper end of the trough. A pool of water 23 is maintained in the lower portion of the trough, this water being supplied with the ore and also through pipes 24 communicating with a so-called hutch tank 25 extending along the bottom of the trough and communicating therewith through perforations. This tank extends only from the ore feed box a short distance toward the upper end of the trough 21. A considerable quantity of water is caused to overflow a weir 26 at the lower end of the trough and this water carries with it much of the fine sand and slimes which are washed from the ore. The overflow is discharged through a conduit 27.

The product of the primary classifier is carried up the trough 21 and is discharged through a conduit 28 to the feed box 29 of the main concentrator indicated by the numeral 30. The upper end section of the screw conveyor 22 has a de-watering effect on the ore and the latter is caused to flow through the conduit 28 by adding water from the pipe 31. My improved concentrator 30 has an inclined trough 32 formed with an arcuate bottom and provided with a weir 33 at its lower end over which the coarser silica, together with some fine ore, is discharged. A screw conveyor having spiral flights 34 and an axial shaft 35 extends longitudinally within the trough 32 from end to end thereof. The pitch of the flights 34 is such as to gradually work the ore toward the upper end of the trough when the shaft 35 is driven in the appropriate direction. The flights 34 are of the ribbon type having ample openings around the shaft 35 for the passage of liquid toward the weir 33. In operation, the shaft 35 is continuously rotated by an electric motor (not shown) which may be mounted near the normally upper end of the trough and connected by suitable speed reducing gearing to the upper end of said shaft.

Fixed at suitable intervals on the outer periphery of the flights 34 is a series of lifter bars 37 adapted to perform the important functions of loosening the mass of ore in the concentrator section of the machine and working the coarser tailings to the surface of the mass. These bars 37 extend in parallel relation to each other substantially from the weir 33 to the upper end of the main body of ore or other material to be concentrated. Extending along the bottom and side portions of the trough 32 is a hutch tank 38 for distributing water under pressure to the mass of

material. This hutch tank is subdivided into separate compartments by partitions 39 extending across the trough and by a central partition 40 extending longitudinally, approximately along the center line of the machine (Figs. 2 and 3). Water supply pipes 41 severally communicate with the compartments of the hutch tank and each of these pipes has a valve 42 for controlling the flow of water supplied thereby. As indicated in Figs. 2 and 3, the hutch tank communicates with the interior of the trough at the bottom and sides thereof through a multiplicity of small perforations 43. By this arrangement water is forced up through the mass of material in the trough and is properly distributed and controlled so that the resulting percolation is too weak to produce teetering of the mass.

The feed box 29 is preferably formed with a projection 29a extending obliquely downward and toward the weir end of the trough, Fig. 1. This projection is in communication throughout its length with the interior of the trough so that the material fed to the machine is distributed and directed in a corresponding direction in the accumulated mass of mineral. An outlet opening 44 is formed in the bottom of the trough 32 near its upper end for the discharge of the concentrate or heavier fraction of the material into a chute 45 (Fig. 1).

The weir 33 extends substantially horizontally from one side of the trough to approximately the center plane of the machine and is located at the side of the trough toward which the material is worked upward by the screw flights 34 and bars 37, as indicated in Fig. 2. A baffle 46 extending in the plane of the weir prevents the stream with entrained material from passing directly out of the lower or launder side of the mass in the trough. The material which passes over the weir is caught in a receptacle 47 mounted on the outer end of the trough and is discharged through an outlet conduit 48 at the bottom of this receptacle. The machine is preferably provided with the conventional Akins type mechanism for raising the screw conveyor out of the trough and for gradually lowering the conveyor into the trough when the machine is started after a shut down with a mass of material in the trough, to thereby avoid overloads on the conveyor when starting.

To recover the fine ore from the overflow from the weir 33 and receptacle 47, the overflow material is conveyed to a fine screen 49 (Fig. 1) of the vibrating type. The maximum particle size of the screen undersize should be approximately equal to the maximum particle size which is eliminated in the primary treatment step. Screen sizes from 28 to 48 openings to the inch inclusive are preferred for fine iron ore work. The oversize from the screen, comprising principally coarse silica, may be wasted and the undersize, principally fine iron ore, is fed to a sand pump 50 and returned thereby through a pipe 51 to the primary classifier feed conduit 18 to be further cleaned and finally recovered in the main concentrator.

Operation of the screw-type concentrator

Details of operation for the concentration of iron ore of minus a quarter inch sizes are here set forth by way of example. This material is fed into the feed box 29 of the concentrator 30, together with sufficient water to render the mass fluid. As the material enters the trough 32 the heavier fractions including much of the coarse iron ore and some coarse silica, together with

most of the finer iron ore, settle immediately to the bottom of the trough at the feed point and are started on their upward path by the screw flights 34. The intermediate grade material which is largely silica, together with some of the finer iron ore, is accumulated in the lower end portion of the trough where it forms a dense mass. By proper adjustment of the rate of feed relative to the speed of operation of the conveyor shaft 35, this mass is maintained to approximately the level of the top of the weir 33, and, as illustrated in Figs. 2 and 3 inclusive, it is continuously supplied with water from the hutch tank 38, the water entering the mass from the perforations 43 and rising to the surface.

As further indicated in Figs. 2 to 4 inclusive, the mass of material, indicated by the numeral 52, is maintained at a somewhat higher elevation at the left side of the machine than at the right side due to the rotation of the flights 34 and lifting bars 37 in the direction indicated. Along the opposite side of the trough, a stream of water 53 flows toward the lower end of the machine and carries with it the larger particles of tailings together with some fine iron ore and some of the remaining fine low density material or sand. Such tailings are gradually and continuously worked to the surface of the mass both by the rising water and by the mechanical lifting action of the rotating bars 37. A bed of fine material 54, largely fine, heavy ore, is maintained between the bottom of the trough and the conveyor flights 34. The stream of water 53 flowing down the side of the trough washes the coarse silica from the surface of the mass to the rear of the machine from which it is discharged over the weir 33. The bulk of the heavier material is gradually worked up the incline of the trough out of the water and is dewatered by the upper section of the conveyor, being finally discharged through the opening 44 and chute 45.

The primary classifier contains, near the lower end, only a relatively small mass of the ore 55 and a relatively large body of water 56 which is continuously supplied so that it overflows the weir 26 carrying the slimes and fine silica to waste, in accordance with conventional classifier practice. In order to maintain the relatively large mass of material in the main concentrator for my continuous process, the primary classifier must be considerably larger than the concentrator machine.

The density of the mass of iron ore and water in the concentrating section of the machine 30 should be maintained approximately within the limits of 55% to 75% solids, depending on the structure of the ore. In this mass the force of percolating water is insufficient to produce teetering and the solid particles are too densely crowded together to permit classification depending on particle size. This condition is obtained by controlling the relative rates of feed and discharge of the material, by adjusting the valves controlling the hutch water and by controlling the agitation produced mechanically by the screw flights and lifting bars. Concentration takes place in zones throughout the portion of the trough to which the hutch water is supplied, these zones extending approximately two-thirds of the length of the trough. Tests during runs of my process with iron ore in the screw type concentrator have shown that concentration takes place generally in three more or less distinct zones, the primary or rough concentration zone being the portion of the mass extending approximately from

the cross section through the point of feed to the rear end or weir. Considering the top surface of the mass, there is also what may be termed a secondary concentrating zone extending from the cross section through the point of feed centrally of the trough and upwardly from such section, and a final or third zone extending approximately from the point of feed to the upper end of the mass along the lower or launder side of the mass over which the stream 53 flows.

From the foregoing it will be evident that I maintain in the concentrating machine a long sloping sorting column of ore from which the coarser silica or lighter waste material is removed notwithstanding the fact that the treated material is of various sizes as well as different specific gravities. Unlike the vertical column laboratory glass classifier process, it is unnecessary for the success of my process to have all ore and waste particles of approximately the same size. It is thus apparent that one of the advantageous features of my invention resides in the economies resulting from obviating successive screening operations.

Hydraulic classifiers having inclined troughs and reciprocating rake-type conveying mechanism may be employed in carrying out my invention, as indicated in Figs. 6 and 7. In this case the product of the scalping screen 17 is fed through the conduit 18 to a feed box 57 extending across the top of an inclined trough 58. A weir 59 is provided at the lower end of the trough 58 and an outlet chute 60 at its upper end for the product. Water under pressure is supplied through hutch boxes 61 and perforations in the bottom of the trough in accordance with common practice. Suitable reciprocating rake mechanism includes longitudinal bars 62 supporting a multiplicity of rake blades 63 extending across the trough. Rake operating mechanism of conventional reciprocating type, such as that described in expired Patent No. 1,156,543, patented October 12, 1915, to D. J. Nevill, may be provided. Such mechanism moves the rake supporting bars 62 in parallel relation to the bottom of the trough and up the incline during the forward stroke, then raises the bars and rake blades in an arc during the reverse stroke, at the end of which the blades are lowered to position to start the next forward stroke. This movement carries the solid particles of mineral step by step up the incline of the trough against the current of water flowing toward the weir with the result that the slimes and extremely fine, low density material or mineral is discharged over the weir and through a conduit 64.

The product of the primary classifier trough 58 is conveyed to the feed box 65 of a second machine for further classifying and concentrating treatment in a trough 66. This machine has rake supporting bars 67 and transversely extending rake blades 68 generally similar to those of the primary classifier and operated in a similar manner to work the material up the incline of the trough and discharge it through a chute 69. Otherwise the secondary machine differs in a number of respects from the primary classifier in order to adapt the secondary machine to separate the coarser, low density material from the coarse and fine, high density material. For this purpose hutch boxes 70 are extended along the bottom of the trough 66 toward the lower end and beneath the pool of water 71 which is maintained in the trough. A denser mass of material is maintained in the secondary trough 66 than in the

primary machine trough 58 but with the rake type of conveying mechanism it is impractical to maintain as deep and dense a mass as in a machine having the screw type of conveyor hereinbefore described.

A baffle 72 extends across the trough near the weir, the lower edge of the baffle being submerged in the pool. As shown in Fig. 7, the baffle 72 is adjustable vertically as well as horizontally or to and from the weir and is supported on a pair of brackets 73 attached by bolts 74 to the upper edge of the trough, the brackets being adjustable along the upper edge of the trough. Each bracket 73 is connected to the baffle 72 by a bolt 75 adapted to be placed in any of a vertical series of perforations 76 in the baffle. The weir 77 is of the common adjustable type.

In the operation of the concentrator shown in Fig. 6 the material falls from the feed box 65 into the pool 71 which is supplied with water from the hutch boxes 70. A mass of the mineral too dense to permit classification depending on particle size is maintained in the lower portion of the trough 66 and the water flows toward the baffle 72 upon the surface of this mass carrying with it much of the coarser and lighter material so that the latter accumulates in a stratum near the weir and at approximately the depth of the lower edge of the baffle. The water flowing under the baffle carries this coarser and lighter material into the restricted space between the baffle and weir 77 and thence over the weir. The baffle 72 prevents the mass of finer and denser material from being carried over the weir with the coarser material. Some fine high and low density material is carried over the weir with the coarser low density material and is discharged with the latter from a conduit 78 onto a vibrating screen 79. The oversize from this screen may be wasted or ground and returned to the primary classifier, as hereinafter described. The undersize material is collected from the screen and pumped through a conduit 80 which returns it to the feed box of the primary classifier. It will be understood that the product of the secondary classifier which is discharged from the chute 69 comprises largely the fine and coarse, high density material or concentrates of the heavier ores.

The flow sheet shown in Fig. 5 illustrates a modification of the foregoing method of procedure which does not require the use of a screen to eliminate the coarse silica from the concentrator overflow. As indicated by the legends, the ore is fed to the primary classifier which operates as hereinbefore described to eliminate fine silica and slimes or other fine, low density material. The product of the primary classifier is continuously fed to the main concentrator as hereinbefore described and the product of the latter is the concentrate whereas the overflow, instead of being screened, is ground in a suitable mill, such as a ball or rod mill, to reduce the coarse silica to such a fine state that it may be eliminated in the primary classifier. The product of the grinding mill is pumped to the primary classifier feed box.

Another important field for the use of my process is in the treatment of fine coal. The principles of operation above described may be applied to the treatment of coal to produce a satisfactorily clean coal product for use in stokers or after grinding as pulverized coal. Much of the finer coal is wasted by methods in general use which ordinarily employ notoriously inefficient jigs and produce a relatively high priced product.

The flow sheet shown in Fig. 8 indicates how

my process may be used in the treatment of coal and recovery of pyrite therefrom. In this case the primary classifier eliminates slimes together with a small fraction of the fine coal and the product of this machine consisting largely of pyrite, slate and coal is fed to the main concentrator which operates as hereinbefore described, except that the heavier fraction consisting of pyrite and slate is discharged from the upper end of the trough, whereas the overflow from the weir containing the bulk of the coal is fed to a vibrating screen of suitable mesh. The oversize or coarser fraction from the screen is the marketable coal product and the undersize, consisting of fine slate, pyrite and coal, is preferably pumped back into the primary classifier. To recover the pyrite from the slate, the product of the main concentrator is fed to a secondary concentrator. The heavier fraction comprising largely pyrite is separated from the slate in the secondary concentrator which is operated as hereinbefore described in detail. The overflow from this secondary concentrator is conveyed to a vibrating screen of suitable mesh to allow the passage of the smaller material containing some coal and fine pyrite. Finally, the undersize material from the screen is pumped to the feed box of the main concentrator, as indicated, while the oversize from the screen, consisting largely of slate, is wasted.

It will be understood that my invention may be employed in the concentration of ores other than iron ore and to non-metallic minerals where there is a fairly wide spread in specific gravity between the desired concentrates and the desired rejects. In the treatment of non-metallic minerals, as in the case of coal, the concentrate is discharged from the concentrator over the weir and the waste or tailings are discharged from the upper end of the trough. For non-ferrous ore treatment it is not necessary to produce a finished concentrate since the end point is usually reached after a further refining process, such, for example, as oil flotation. With such refining processes my procedure may be used to advantage in discarding the bulk of the waste material. Other modifications of the flow sheets herein described within the spirit of my invention may include the use of three or more concentrator machines and the recirculation of the overflow from one machine to the machine preceding it.

It will be evident that my process involves not only progressive classification and concentration in a plurality of operations, but also the treatment of a middlings product such as the coarser, low density material which has been separated in one of these operations, to either eliminate such material from the circuit or to reduce it to finer sizes which may be recirculated or subjected to further classifying treatment. At least part of my middlings product, after screening or grinding, is returned to the circuit for further hydraulic classification treatment. All fine low density constituents of most minerals cannot be eliminated in my primary classifying step. Consequently, the material that is ordinarily fed to the main concentrator machine contains some fine low density constituents as well as coarse low density constituents and coarse and fine high density constituents. It will also be evident that with each of the several types of classifiers some of the fine low density material is discharged over the weir or through the elevated outlet together with the coarse low density material and some fine high density material.

This invention has been used with marked success in concentrating iron ores from the present tailings basins which are made up of ore rejected from the former concentration operations and containing fine iron and porous iron of sizes and types of ore which are extremely difficult to treat in jigs or other conventional equipment. Fairly good recovery of high grade material has been obtained from material on which jigs show practically no recovery.

Having described my invention, what I claim as new and desire to protect by Letters Patent is:

1. The continuous method of concentrating mineral containing substantial quantities of particles of substantially all size ranges up to the maximum size of the particles being treated and of high density and of lower density which comprises subjecting the mineral to a hydraulic classification operation causing fine, low density material to be separated and leaving a product containing coarse, low density and both coarse and fine, high density material, subjecting this product to hydraulic concentration in a separate apparatus wherein a mass of said mineral too dense to permit classification depending on particle size is subjected to upward percolation of water having force insufficient to produce a teetering of the mass and mechanical agitation causing localized lifting and releasing effects to separate coarse and fine, high density material from a product containing coarse low density material and fine high density material, transforming said last mentioned product into one substantially free from coarse low density material and reintroducing a sufficient quantity of the transformed product into the first classification operation to maintain the density of said mass in the concentrating apparatus.

2. The continuous method of concentrating mineral containing substantial quantities of particles of substantially all size ranges up to the maximum size of the particles being treated and of high and low density which comprises subjecting the mineral to a hydraulic classification operation causing fine, low density material to be separated leaving a product containing coarse, low density and both coarse and fine, high density material, subjecting this product to hydraulic concentration in a separate apparatus wherein a mass of said mineral too dense to permit classification depending on particle size is subjected to upward percolation of water having force insufficient to produce a teetering of the mass and mechanical agitation causing localized lifting and releasing effects to produce two products, one of which is relatively rich in high density material and relatively poor in low density material, and the other of which is relatively rich in coarse low density material associated with high density material, grinding the last mentioned product and reintroducing a sufficient quantity of the ground material into the first classification operation to maintain the density of said mass in the concentrating apparatus.

3. The continuous method of concentrating mineral containing substantial quantities of particles of substantially all size ranges up to the maximum size of the particles being treated and of high and low density which comprises subjecting the mineral to a hydraulic classification operation causing fine low density material to be separated and leaving a product containing predominantly coarse low density and both coarse and fine high density material, subjecting this product to hydraulic concentration in a separate

apparatus wherein a mass of said mineral too dense to permit classification depending on particle size is subjected to upward percolation of water having force insufficient to produce a teetering of the mass and mechanical agitation causing localized lifting and releasing effects to produce two products, one of which is relatively rich in high density material and relatively poor in low density material, and the other of which is relatively rich in coarse low density material associated with fine high density material, screening the last mentioned product and reintroducing a sufficient quantity of the screen undersize material into the first classification operation to maintain the density of said mass in the concentrating apparatus.

4. The continuous method of concentrating mineral containing substantial quantities of particles of substantially all size ranges up to the maximum size of particles being treated and of high and low density which comprises subjecting the mineral to a hydraulic classification operation causing fine low density material to be separated leaving a product containing predominantly coarse low density and both coarse and fine, high density material, subjecting this product to hydraulic concentration in a separate apparatus wherein a mass of said mineral too dense to permit classification depending on particle size is subjected to upward percolation of water having force insufficient to produce a teetering of the mass and mechanical agitation causing localized lifting and releasing effects to produce two products, one of which is relatively rich in high density material and relatively poor in low density material, and the other of which is relatively rich in coarse low density material associated with fine high density material, subjecting the product which is relatively rich in high density material and relatively poor in low density material to further hydraulic concentration in a second apparatus wherein a mass of said mineral too dense to permit classification depending on particle size is subjected to upward percolation of water having force insufficient to produce a teetering of the mass and mechanical agitation causing localized lifting and releasing effects to produce two products one of which is relatively rich in high density material and relatively poor in low density material and the other of which is rich in coarse low density material associated with fine high density material, transforming said last mentioned product into one substantially free of coarse low density material and reintroducing at least a portion of the transformed material into the first concentration apparatus, processing the relatively coarse low density product of the first concentrating apparatus to produce a relatively fine product and reintroducing the last mentioned product into the first classification operation.

5. The method of concentrating ores of minus one-quarter inch mesh containing substantial quantities of particles of substantially all size ranges up to the maximum size of the particles being treated which comprises the steps of eliminating slimes and fine silica therefrom, then subjecting the residue of the ore to hydraulic concentration in a separate apparatus wherein a mass of the ore too dense to permit classification depending on particle size is subjected to upward percolation of water having insufficient force to produce teetering of the mass and mechanical agitation causing localized lifting and releasing effects to work the coarser par-

ticles of tailings to the surface of the mass, overflowing the coarser tailings and some fine ore and water from the apparatus, discharging the concentrated ore from the apparatus, recovering the fine particles of ore from the overflow tailings and returning a sufficient quantity of the fine recovered ore to the first mentioned step of the process for the elimination of fine silica therefrom and to maintain the density of said mass in the concentrating apparatus.

6. The method of concentrating iron ores of minus one-quarter inch mesh containing substantial quantities of particles of substantially all size ranges up to the maximum size of the particles being treated which comprises the steps of eliminating slimes and fine silica therefrom, then subjecting the residue of the ore to hydraulic concentration in a separate apparatus wherein a mass of the ore containing between 55% and 75% solids and too dense to permit classification depending on particle size is subjected to upward percolation of water having insufficient force to produce teetering of the mass and mechanical agitation causing localized lifting and releasing effects to work the coarser particles of tailings to the surface of the mass, overflowing the coarser tailings and some fine ore and water from the apparatus, discharging the concentrated ore from the apparatus, recovering the fine particles of ore from the overflow tailings and returning at least a portion of the fine, recovered ore to the concentrating apparatus.

7. The method described in claim 5 which includes the step of recovering the fine ore particles from the tailings by passing the overflow

material over a vibrating screen of such mesh as to allow the passage through the screen openings of the particles of ore to be recovered and to reject the coarser tailings.

8. The method described in claim 6 which includes the step of recovering the fine particles of ore from the coarser tailings by screening, the mesh of the screen being not larger than twenty-eight openings to the inch and the undersize of the screen being returned to the concentrating apparatus.

9. The method of concentrating ores of minus one-quarter inch sizes containing substantial quantities of particles of substantially all size ranges up to the maximum size of the particles being treated which comprises the steps of eliminating slimes and fine silica therefrom, then subjecting the ore to hydraulic concentration in a separate apparatus wherein a mass of the ore too dense to permit classification depending on particle size is subjected to upward percolation of water having insufficient force to produce teetering of the mass and mechanical agitation causing localized lifting and releasing effects to work the coarser particles of tailings to the surface of the mass, overflowing the coarser tailings and some fine ore from the apparatus, continuously discharging an ore concentrate from the apparatus, grinding the overflow material from the concentrating apparatus and recirculating a sufficient quantity of the ground material to the first step of the process for the elimination of fine silica therefrom and to maintain the density of said mass in the concentrating apparatus.

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