April 30, 1963 M. KRAUT 3,087,619

METHOD AND APPARATUS FOR CONCENTRATION OF ORES

Filed Nov. 27, 1959 7 Sheets-Sheet 1

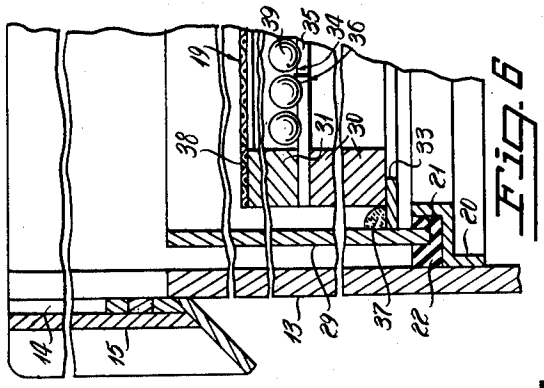


Fig. 6

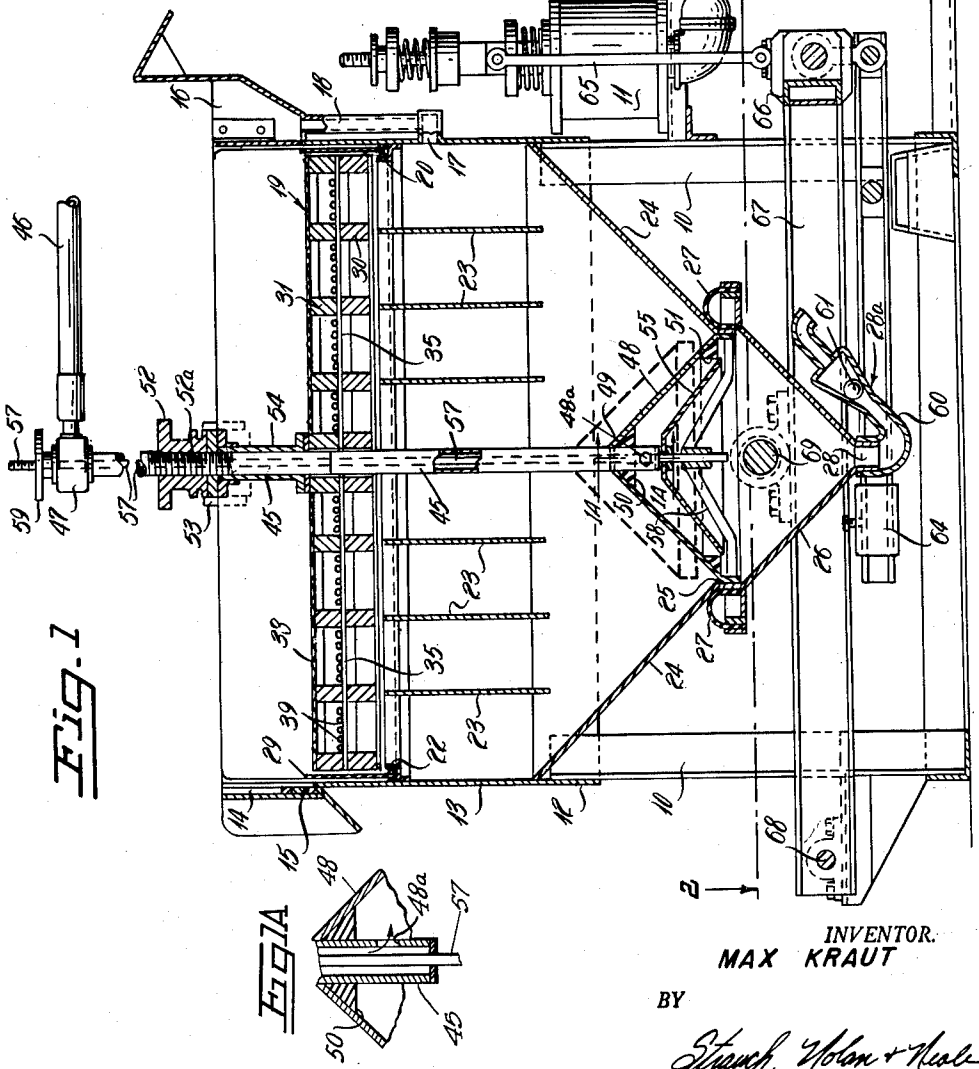


Fig. 1

Fig. 7A

INVENTOR.
MAX KRAUT

BY

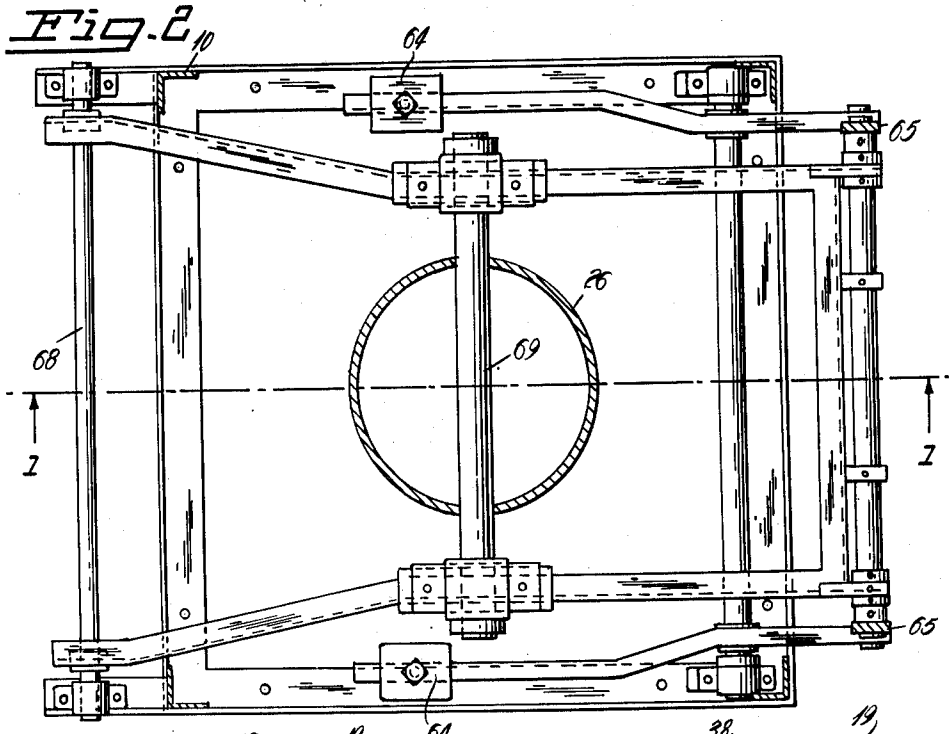
Staunch, Nolan & Neale
ATTORNEYS

April 30, 1963 M. KRAUT 3,087,619

METHOD AND APPARATUS FOR CONCENTRATION OF ORES

Filed Nov. 27, 1959 7 Sheets-Sheet 2

Fig. 2



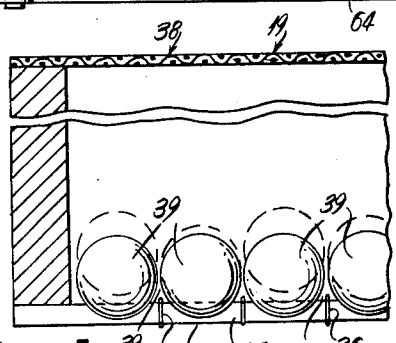


Fig. 3

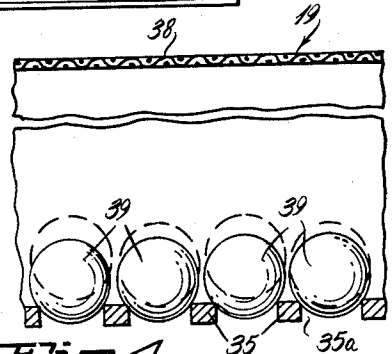


Fig. 4

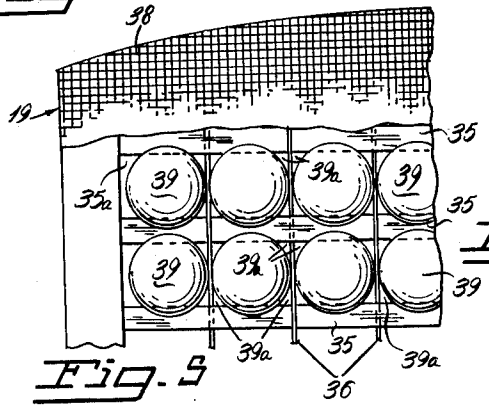


Fig. 5

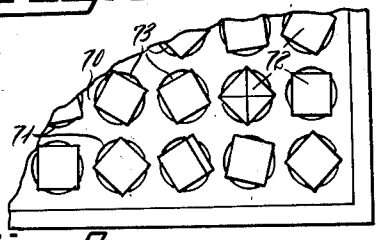


Fig. 7

INVENTOR.
MAX KRAUT
BY
Strauch, Nolan & Neale
ATTORNEYS

April 30, 1963 M. KRAUT 3,087,619

METHOD AND APPARATUS FOR CONCENTRATION OF ORES

Filed Nov. 27, 1959 7 Sheets-Sheet 3

Fig. 8

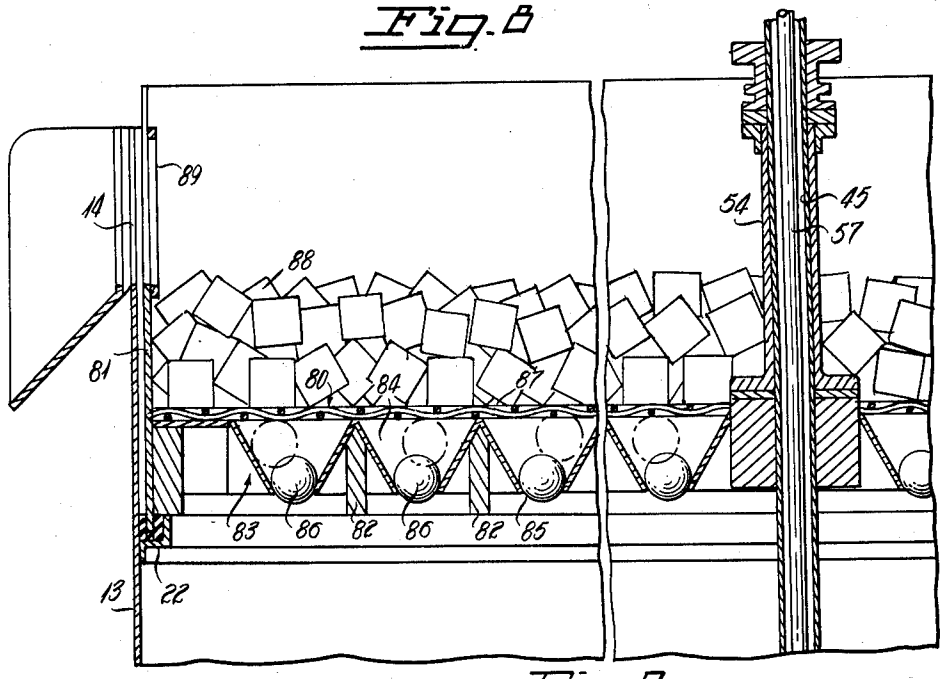


Fig. 9

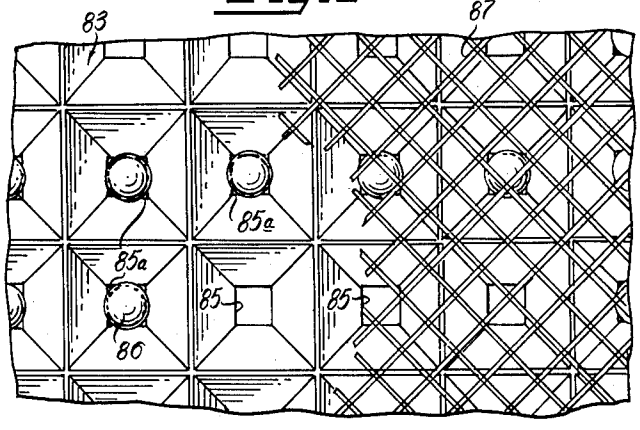


Fig. 10

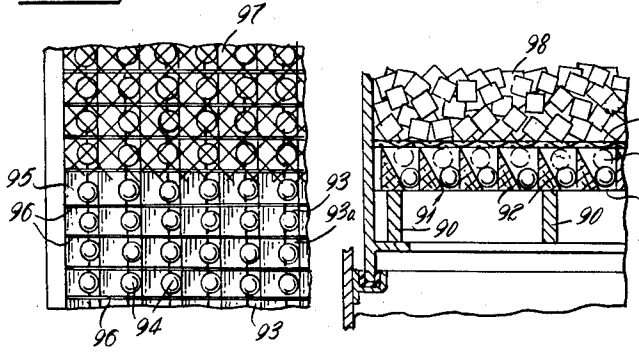


Fig. 11

INVENTOR.
MAX KRAUT
BY
Strauch, Nolan & Neale
ATTORNEYS

April 30, 1963 M. KRAUT 3,087,619

METHOD AND APPARATUS FOR CONCENTRATION OF ORES

Filed Nov. 27, 1959 7 Sheets-Sheet 4

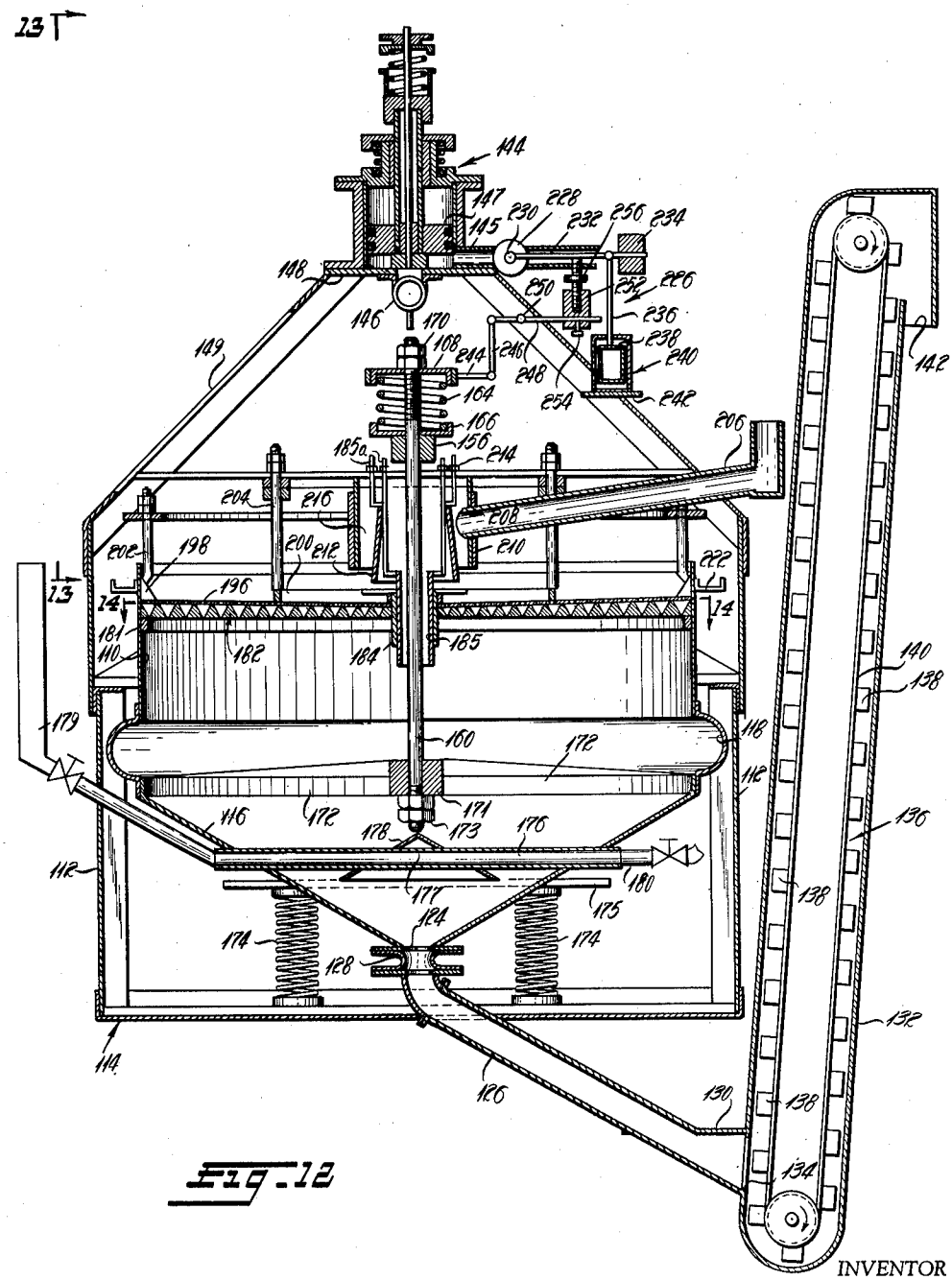


Fig. 12

INVENTOR
MAX KRAUT

BY Brumbaugh, Graves, Donohue & Raymond

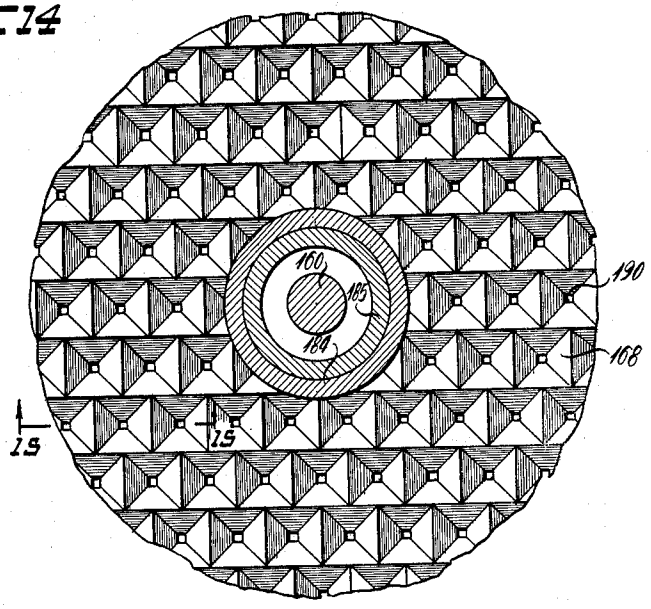
ATTORNEYS

April 30, 1963 M. KRAUT 3,087,619

METHOD AND APPARATUS FOR CONCENTRATION OF ORES

Filed Nov. 27, 1959 7 Sheets-Sheet 5

Fig. 14



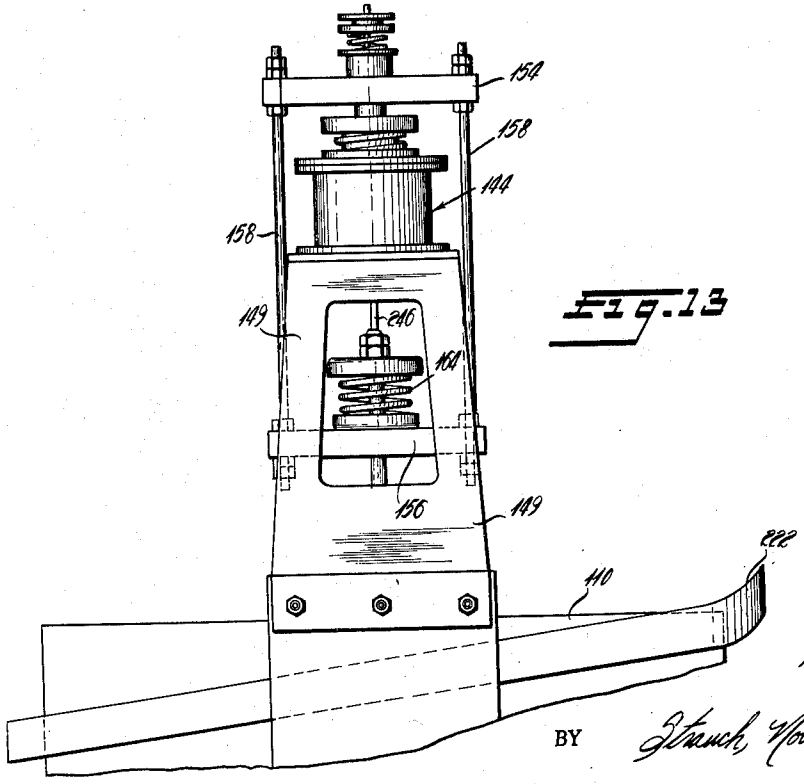


Fig. 13

INVENTOR

MAX KRAUT

BY Strauch, Nolan & Hale

ATTORNEYS

April 30, 1963 M. KRAUT 3,087,619

METHOD AND APPARATUS FOR CONCENTRATION OF ORES

Filed Nov. 27, 1959 7 Sheets-Sheet 6

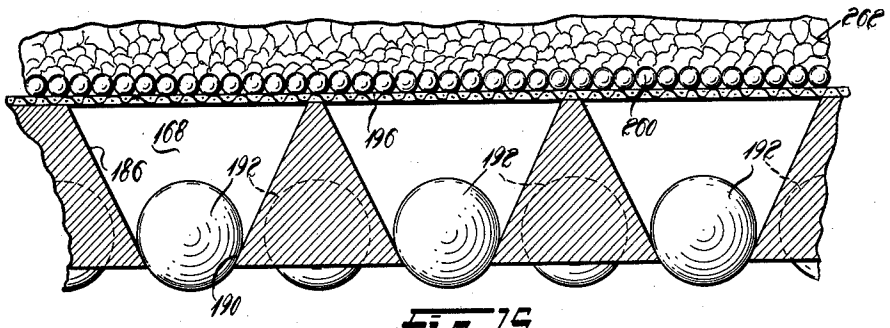


Fig. 15

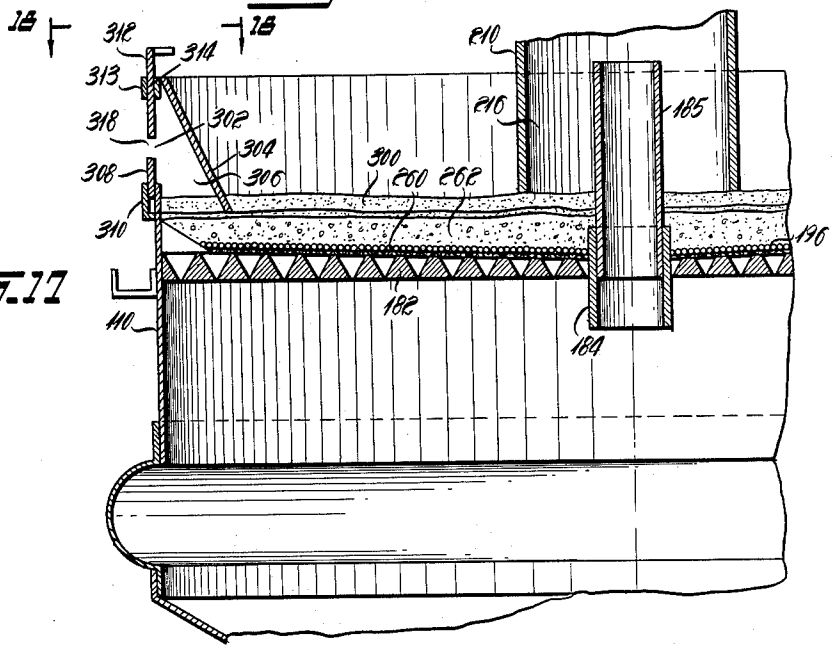


Fig. 17

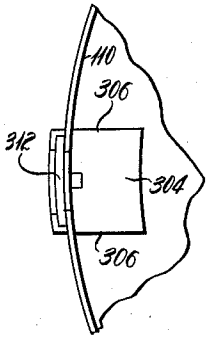


Fig. 18

INVENTOR
MAX KRAUT

BY Schuck, Nolan & Neale

ATTORNEYS

April 30, 1963 M. KRAUT 3,087,619

METHOD AND APPARATUS FOR CONCENTRATION OF ORES

Filed Nov. 27, 1959 7 Sheets-Sheet 7

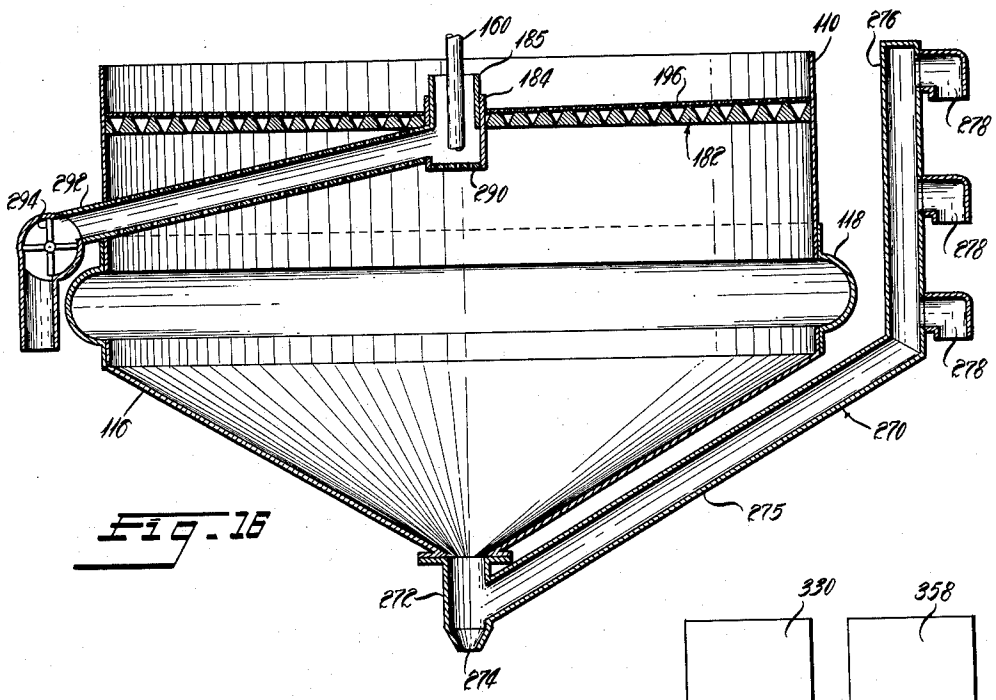


Fig. 18

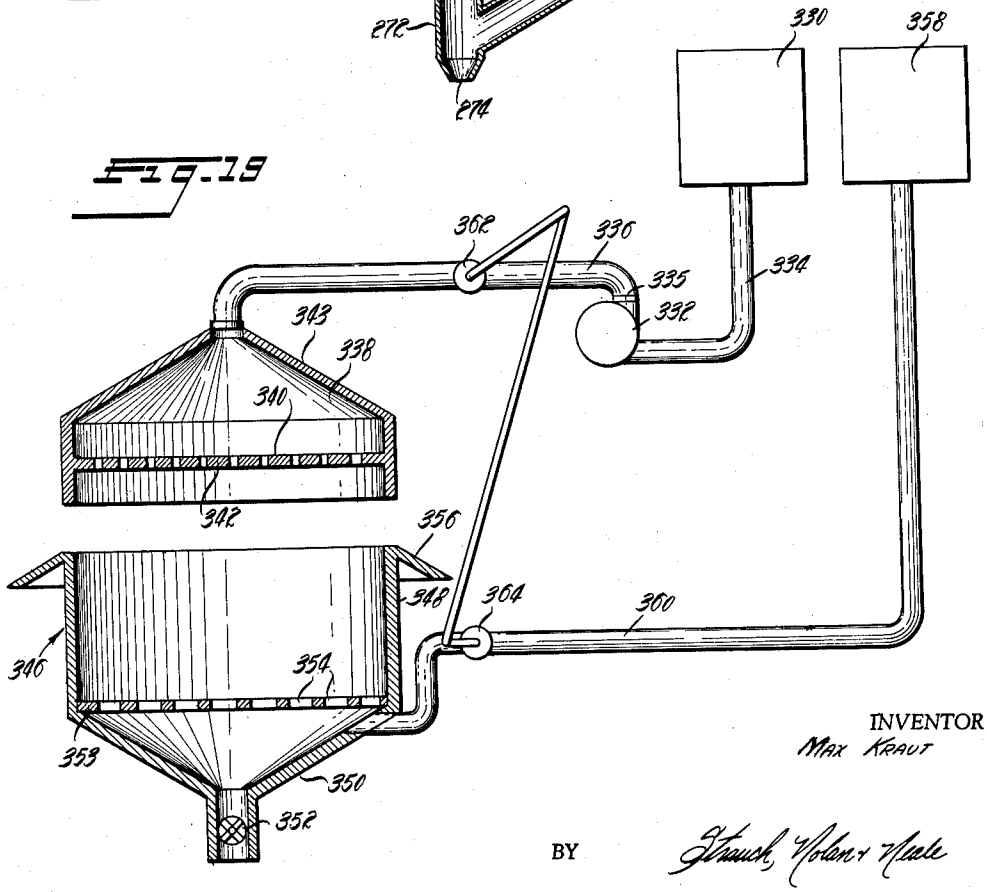


Fig. 19

INVENTOR
MAX KRAUT

BY Strauch, Nolan & Neale

ATTORNEYS

United States Patent Office 3,087,619 Patented Apr. 30, 1963

3,087,619

METHOD AND APPARATUS FOR CONCENTRATION OF ORES

Max Kraut, San Francisco, Calif., assignor to Western Machinery Company, San Francisco, Calif., a corporation of Utah

Filed Nov. 27, 1959, Ser. No. 855,597
27 Claims. (Cl. 209—456)

The present invention relates to improvements in methods of an apparatus for separating fine mineral particles of a high density from fine particles of lower density in a fluid or liquid medium. The present invention is of particular utility in the separation of suspensoids which as the term is herein used are particles which are too fine to settle in a specific medium within a practical time limit allowable under operating conditions.

This application is a continuation in part of my copending application Serial No. 674,266, filed July 15, 1957, which was a continuation in part of my application Serial No. 601,924, filed August 3, 1956, both now abandoned.

Conventional methods such as jigging and apparatus for performing these methods have no effect on suspensoids and can not effect their separation. Jigging and other similar methods can only effect separation on relatively coarse particles by stratification, wherein the particles readily settle in a pulsating medium with the heavier particles displacing lighter particles by gravity.

Examples of prior devices and methods are disclosed in United States Patents No. 2,242,020, issued May 13, 1941, to Wood, for Concentrating Cell; No. 2,271,650, issued February 3, 1942, to Kraut, for Jig; No. 2,523,364, issued September 26, 1950, to Glover, for Ore Concentrating Jig; No. 2,570,035, issued October 2, 1951, to Laughlin, for Means of Wet Screen Sizing; No. 2,638,220, issued May 12, 1953, to Schneider, for Underwater Screening; No. 2,708,032, issued May 10, 1955, to Heyman, for Mica Flake Classifying Device and Method; and No. 2,765,911, issued October 9, 1956, to Vissac for Fluidized Pulsating Jig.

In the present invention particles of differing size and density are discharged at substantially equal velocity into a fluid body. Particles of equal mass (volume×density) will have equal momentum (mass×velocity) as they approach the fluid body but the more dense smaller particles, having a smaller exterior surface, will encounter lower resistance to movement through the fluid and will thus penetrate the fluid body more readily and deeply than particles of equal mass but lesser density. Particles of equal volume but differing densities when discharged toward the fluid body at equal velocities will have differing momenta proportional to their respective densities as they approach the fluid body so that the more dense particles will have greater power of penetration into the fluid body than equal volume particles of lesser density and likewise penetrate the fluid body more deeply.

The present invention utilizes these principles by alternately discharging a high velocity jet of intermixed particles of varying volume and density into a stationary body of fluid of predetermined density and viscosity and subsequently imparting a substantially slower counter movement to the fluid body at a velocity sufficient to overcome the momentum of the less dense suspended particles. In this manner the more dense particles continue moving through the fluid body to a first point of removal and the less dense particles are returned toward the jet to a second point of removal.

The method, according to the present invention, is based on the principle of imparting to the particles greater momentum or kinetic energy to overcome the resistance

of the medium (viscosity resistance) whereby particles of equal diameter but of greater density acquire greater energy than lighter particles and thereby have greater penetrating power in the medium. Applying this principle to a slurry carrying suspensoids by injecting the slurry at high velocity into a vessel carrying a liquid medium, particles with greater kinetic energy will penetrate the medium to greater depth than particles with lesser energy.

Small particles of greater density may acquire equal momentum with larger particles of lesser density, but in that case the larger particles meet a larger viscosity resistance due to their larger surface which lessens their penetrating power. A counter current applied to the medium will readily carry back or reverse the direction of motion of particles of lighter density and greater surface area. The combined alternate action of jet and reversing counter current effect a positive separation of the heavier from the lighter suspensoids within certain size limits and thereby effect the desired concentration of suspensoids of greater density. These suspensoids of greater density are usually mineral particles which are recovered for further processing.

The following description of the present invention will proceed first with a description of several jigs constructed in accord with and utilizing the method of the present invention and then with a description of the utilization of the present method in other apparatus to illustrate the broad applicability of the principles of the present invention.

Briefly described, the apparatus and the method, as employed in jigs, are such to impart alternately and successively to the mass of the pulp or slurry induced relatively slow upward movements through a suitable supporting screen having floatable objects thereon of substantially the same specific gravity as the slurry followed by an induced greatly accelerated downward movement through the screen. The objects, preferably balls, rise with upward fluid movement to open the screen orifices and fall to partially close the screen orifices on the high velocity downward fluid movement. The downward movement of the fluid below the screen and the orifice restricting movement of the objects is sufficiently rapid that a vacuum suction space is created under the screen and a high pressure differential between the top of the fluid above the screen and the underside of the screen which provides a large number of high velocity downward jets discharging into the fluid body beneath the screen. The high velocity of the slurry in the downward jets imparts to the suspended particles therein high kinetic energies or momenta in proportion to their respective masses. Relatively large gangue particles of low density acquire equally high kinetic energy and momentum as fine equal mass mineral particles of high density, but due to their larger volume and exposed surface area encounter greater resistance to movement through the fluid body into which they are discharged than more dense particles of equal mass. Likewise, as between the particles having equal volume, high density particles will have higher kinetic energy and momentum and can penetrate the fluid body beneath the screen more readily and can overcome the resisting upward slow currents of slurry and water beneath the screen and continue on their downward path, whereas having lesser kinetic energy and momentum of the less dense small gangue particles will be overcome and the less dense particles will be carried along with the upward current of slurry and water through the screen.

If the kinetic energy of any coarse low density gangue particles is not completely overcome by the upward movement of the fluid body through the screen, then in a second step of treatment, such as any well-known jigging or

tabling operation, the relatively coarse or large gangue particles of low density which are recovered together with the fine mineral particles of high density can be readily separated from each other, resulting in a relatively high grade final concentrate of the fine mineral particles.

For definition purposes it is to be understood that the method step of screening and the structure which, for lack of a more descriptive term, is referred to herein as a screen, does not contemplate a screen member having openings or mesh which separates components of the slurry by flow therethrough, but rather contemplates openings in the screen which are sufficiently large at all times to permit passage therethrough in either direction of all component particles of the slurry, the separation being accomplished by the relatively slow upward movement of the slurry through relatively large orifices followed by relatively fast downward movement through orifices which have been reduced in size, the downward movement including inducing a vacuum below the screen.

Exemplified forms in which a suitable apparatus and method of the invention may be embodied are described herein, the apparatus of the invention being illustrated in the accompanying drawings which are made a part hereof, and the method being also described by reference to said drawings:

In the drawings:

FIGURE 1 is a vertical transversely central view in section of the apparatus of the invention, on line **1—1** in FIGURE 2;

FIGURE 1*a* is an enlarged fragmentary section taken substantially along lines **1***a*—**1***a* of FIGURE 1;

FIGURE 2 is a horizontal transverse view on line **2—2** of FIGURE 1;

FIGURE 3 is an enlarged fragmentary longitudinally transverse detailed view of a portion of FIGURE 1;

FIGURE 4 is an enlarged fragmentary laterally transverse detailed view of a portion of FIGURE 1;

FIGURE 5 is an enlarged fragmentary plan view of a portion of FIGURE 1, the view being partly broken away;

FIGURE 6 is an enlarged fragmentary vertical section of a portion of tank and supporting screen or grille shown in FIGURE 1;

FIGURE 7 is an enlarged fragmentary plan view of a modified form of supporting screen or grille means;

FIGURE 8 is an enlarged fragmentary centrally transverse vertical section of another modified, and preferred, form of supporting screen unit, including portions of the tank structure;

FIGURE 9 is a fragmentary plan view of a portion of FIGURE 8;

FIGURE 10 is a fragmentary plan view of still another modified form of supporting screen structure, reduced in size in relation to FIGURE 6;

FIGURE 11 is a fragmentary transverse vertical section of the screen structure shown in FIGURE 10;

FIGURE 12 is a vertical cross-section viewed from the front of the apparatus and illustrating a further embodiment according to the present invention;

FIGURE 13 is an enlarged fragmentary elevational view substantially along the line **13—13** of FIGURE 12;

FIGURE 14 is an enlarged fragmentary section substantially along the line **14—14** of FIGURE 12;

FIGURE 15 is an enlarged fragmentary section along line **15—15** of FIGURE 12 more clearly illustrating the pocket grid screen with the pocket recessed flow retarding balls removed;

FIGURE 16 is a cross-sectional view in elevation similar to FIGURE 12 but showing a modified form for removing the heavier concentrates;

FIGURE 17 is a cross-sectional view in elevation similar to FIGURE 12 but showing another modified form for removing the small less dense particles;

FIGURE 18 is a section substantially along line **18—18** of FIGURE 17;

FIGURE 19 is a diagrammatic view illustrating still another embodiment of the present invention.

Referring to the drawings in which like reference characters indicate corresponding parts in the several views, **10** indicates a supporting frame which is preferably rectangular in plan, at one side of which is a source of power for operating the apparatus, herein illustrated as any suitable motor generally indicated **11** for providing a differential of a relatively slow upward and a relatively fast downward motion to a hutch of the concentrating apparatus, the motor preferably being of the type illustrated and described in my United States Letters Patent No. 2,766,735, dated October 16, 1956.

Supported upon the upper portion of the frame **10**, as at **12**, is securely mounted a tank **13** for containing a slurry, illustrated as an open top boxlike receptacle preferably in this embodiment squarely rectangular at its upper portion, though it may equally well be circular in plan if desired.

At one portion of its peripheral wall adjacent the upper edge, the wall of the tank has an overflow opening **14** adjustably regulated by a suitable gate **15** which may open into any suitable discharge launder (not illustrated).

Suitable feed means are provided for feeding ore pulp into the tank comprising a feed hopper **16** adjacent the upper edge of the tank, having suitable communication with the interior of the tank through feed chute **18**, the feed opening **17** into the tank being preferably below a supporting screen structure generally indicated **19**, to be further described.

While in FIG. 1 the feed for the ore pulp is shown below the screen as the preferred form of the invention, it is to be understood that with certain types or fineness of ground ore containing no sandy material, the ore pulp may be fed above the supporting screen.

The screen structure is supported in the upper portion of the tank, preferably above the feed opening **17**, by a screen-supported channel member **20** extending around the interior wall of the tank and providing a groove **21** into which the screen structure sits with a suitable packing seal **22**. Depending into the tank below the channeled support member **20** and extending transversely across the tank there may be a plurality of relatively spaced baffle partitions **23**.

The lower portion of the tank comprises an inverted frusto-conical wall member or vessel **24** having a relatively large opening **25** at its bottom which, in turn, is closed by an inverted conical hutch **26** having sealed connection to said open end **25** of the conical vessel by means of a flexible diaphragm **27**, such as rubber, by means of which the hutch may be vertically reciprocated relative to said opening **25** of the conical lower wall of the tank, manifestly to provide said upward and downward movements of the slurry. At the vertex of its cone the hutch has an outlet opening **28** to which is connected a valve member **28***a*, to be further described.

The supporting screen structure **19** which is mounted within the upper portion of tank **13** comprises a peripheral supporting side wall **29** fitting conveniently and slidably removably within the tank wall, the lower edge of said side wall of the screen structure resting in the groove **21** and being sealed by the rubber packing **22**.

The supporting screen may be any suitable mechanical form which may effectively provide for carrying out the invention, several modifications thereof being exemplified herein. In FIGS. 1 to 6 the screen structure comprises screen-supporting bars **30** and **31** mounted transversely within the confines of the side wall **29**, being suitably supported at ends, as by a bracket **33** connected to the side wall. The support bars **30**, **31** are preferably in pairs in which the bars in each pair have overlying relation, the opposed faces of the bars in each pair being spaced and mounting between the opposed faces thereof a suitable supporting screen member **34**

which may be made of relatively spaced parallel slats **35**, providing openings or orifices **35***a*, therebetween, the slats being exemplified as spaced apart substantially 6 mm. (about 1/25 inch). Suitable supporting cross bars or tie members **36** may also be employed to support and maintain the spacing of the screen slats. The lower tier **30** of the support bars may be fixedly welded in place as at **37** and preferably the upper tier is removable for cleaning or replacement of the screen slats **35**.

On the upper face of the screen slats **35** are loosely deposited a plurality of small objects of relatively light weight and susceptible to up and down movement with the pulsations or movements of the slurry. Such objects in order not to pass through the screen, manifestly should be of slightly greater diameter than the spacing or slot openings **35***a* between the slats **35**, and they should have a slightly, almost minutely, greater specific gravity than the slurry, so that such objects and the slurry are substantially in balance by the same order of specific gravity, whereby such objects may be raised with the slightest upward movement of the slurry through the screen. As an example, if the slurry be of the order of 1.1 the specific gravity of such objects may be 1.2. An example of such objects may be cited as polyethylene or vinyl pellets or balls **39**, the diameter of which may, for example, be 7 mm. if the slots **35***a* between the screen bars are 6 mm. A sufficient number of these balls are placed upon the screen openings to provide a plane thereof illustrated herein as one ball deep. In FIGS. 1 to 6, the balls are closely spaced, to be substantially in relative contact at the opposed portions of their circumferential faces, and provide a layer of balls which may rise with the upward movement of the slurry to provide relatively large screen openings, and fall with the downward movement of the slurry body, whereby, when they are levelled out upon the screen openings, they provide orifices **39***a* of reduced size through which induced accelerated high velocity downward jets of slurry may flow. An example of such reduced area of opening may be one-third to one-fourth of the area of the full opening. Because of the slow upward movement of the slurry, they are not excessively displaced, though, as a precaution against such displacements, any suitable guide means may be provided for the balls in their said movements. The screen and balls thereon may best be described as a floating check valve portion of the screen with return by-pass of slurry as downward jets through the reduced orifices **39***a*. As a further precaution against such upward movement of the balls to an extent that they might be permanently carried out of the screen structure and be discharged at outlet **14**, a retaining guard screen **38** of a mesh that will not pass the balls may be placed over the compartments in which the balls operate, a 6 mm. screen being satisfactory for this purpose if the balls are 7 mm.

The density of the slurry is determined by the relative contents of solids, sands and slime in water. Therefore, means are provided for introducing water into the slurry for the purpose of independently regulating its density and controlling the quantity of water which may be introduced, such regulation and control preferably being at or adjacent to the annular opening **25** of the conical portion **24** adjacent to the diaphragm **27**. Such a means is herein exemplified by conduit pipe **45** which communicates at its upper end with a source of water supply **46** through an elbow **47**. The conduit pipe **45** is co-axial with the conical vessel portion **24**, and at its lower end the conduit passes through the apex of, and thereby communicates with, the interior of a hollow conical hood valve **48** which is fixedly mounted thereto as at **49**, by a suitable sealing body **50**. Fluid communication between the interior of pipe **45** and the interior of valve **48** may be established by any suitable passage means such as a port **48***a* (FIGURES 1 and 1*a*) formed in pipe **45**. At the base of its cone the outwardly flared tapered wall of the conical hood is of a diameter substantially similar to the diameter of the opening **25** so as to snugly fit said opening for selectively and adjustably opening and closing said opening, as shown by broken lines in FIG. 1. For purposes to be described, the conical hood **48** may have a ring **51** internally adjacent to its base edge.

At its opposite or upper end the water conduit **45** has an adjustment means whereby it may be raised and lowered and thereby raising or lowering the hood **48** and thus selectively determining the area of annular opening between the base edge of hood **48** and the wall of opening **25** whereby the quantity of water flowing into the lower portion of the conical vessel at the opening **25** may be controlled and adjusted relative to the slurry, the means for such adjustment comprising a rotatable hand wheel **52** at the upper end of the water conduit which may be supported on a cross bar **53** at the top of the tank. If desired, a tubular sleeve **54** may enclose said water conduit and extend from the under side of said cross bar to the upper face of screen structure **19**. Since the water conduit is vertically adjustable, manifestly, it has a sliding relation in such a sleeve.

Means for regulating the quantity of water discharged into the slurry includes a secondary hood valve **55** within the hood valve **48**. Preferably it is also conical conforming generally to the form of the interior of the conical hood **48**, with relation to which it is spaced, and of lesser diameter at its base, providing for a flow of water therebetween. This secondary hood valve **55** is mounted at the lower end of a control rod **57** which is mounted longitudinally through the conduit **45**, the lower end of the rod being stabilized at the vertical axis of the cone **48** by a bracket **58** transversely of the opening **25** of the conical vessel **24**, the rod **57** extending through and beyond the opposite upper end of the conduit **45** whereat it is longitudinally adjustable by a threadedly mounted hand wheel **59** to raise and lower the secondary hood valve. The base peripheral edge of this secondary hood valve thus opens and closes relative to the annular ring **51** of the conical hood and thereby regulates the quantity of the flow of water into the slurry.

Valve **28***a* mounted at the outlet opening **28** of the hutch **26** preferably is an upwardly retroverted goose-neck tube **60** communicating with said outlet opening **28**, and having a check valve **61** therein which opens upon the upward movements of the hutch to permit outward flow through the tube and closes against reverse or backflow into the hutch upon the downward suction stroke of the hutch, since it is undesirable to have air drawn into the hutch on the downward or suction stroke which creates a vacuum suction under the screen.

Since the structure and operation of the apparatus contemplates a vertical reciprocation of the hutch relative to conical member **24**, by flexure of the resilient diaphragm **27**, means are provided for such vertical reciprocation of the hutch comprising the prime mover or motor **11** which, by suitable connection **65**, vertically reciprocates a cross arm **66** of a jig yoke having spaced parallel arms **67** which are pivoted at opposite ends as at **68**. Transversely between the two pivoted arms **67** of the jig yoke is a rocker shaft **69** which extends centrally through the inclined conical wall of the hutch with sufficient pivotal action so that the hutch may be vertically reciprocated on its axis. Manifestly the hutch may ride up and down with the rocker shaft relative to opening **25** responsive to the flexure of the resilient diaphragm **27** and provide upward and downward movement of the slurry. For conservation of motive power the jig yoke may be counter-balanced by any suitable means, such as the balancing weight and bar **64**.

The prime mover or motor **11** is, as stated, preferably of the structure disclosed in my aforesaid United States patent, but whether of this or other type, it has the characteristics of imparting to the hutch a relatively slow upward movement followed by a rapid downward

movement, the upward movement forcing the slurry mass relatively slowly upwardly toward and through the screen, and the rapid downward movement setting up a vacuum suction below the screen, the purpose of which is to be explained in connection with the operation of the method which may be carried out by the apparatus as herein described.

In FIG. 7 there is shown a modified form of supporting screen member in which a plate **70** has relatively closely spaced circular openings **71** and through which the slurry may flow upon the upward and downward movements thereof, small objects such as cubes **72** larger than the openings **71** serving the same purpose and function, relative to the openings in the plate, as the balls **39** in FIGS. 1 to 6 of the drawings, the upward movement of the slurry raising the cubes and the downward movement reseating the cubes in the openings and leaving a portion **73** of the openings free for downward flow of jets of slurry through orifices of reduced area as previously described.

FIGS. 8 and 9 illustrate a second modified and preferred form of screen structure. In this modification the screen structure is generally indicated **80**, which includes a peripheral side wall **81**, supported in the sealing seat **22** of the tank, and in which the side wall may be of greater height than in FIGS. 1 to 6 for purposes to be described. In this modification transverse screen supporting bars **82** support a transversely horizontal screen plate **83** comprising a plurality of side-by-side or juxtaposed downwardly tapered recesses **84** which are exemplified as inverted frusto-pyramidal pockets substantially squarely rectangular at their open top and having side walls convergingly tapered downwardly, preferably at an angle of substantially 60 degrees, to a squarely rectangular opening **85** at the bottom. The objects or balls **86** have characteristics similar to the balls **39** previously described and have substantially the same specific gravity as the slurry, and therefore function in the same manner, rising and falling within the recessed pockets. Each ball is guided within a pocket by the side walls thereof, the balls being retained in the recessed pockets by an overlying retaining screen **87** mounted upon the upper face of the screen plate **83**, and supported upon the upper edge of the tapered walls. It may again be pointed out by way of example that if the balls **86** are of 7 mm. diameter the rectangular opening **85**, at the bottom of the recessed pockets, as well as the mesh of the retaining screen **87**, may be 6 mm. Upon relatively slow upward movement of the slurry the balls rise to provide relatively large open orifices of the lower screen openings **85** and fall with the vacuum-induced relatively fast downward movement of the slurry, effectively reducing the fluid flow area of the rectangular screen openings **85**, and providing the orifices **85***a* of reduced open area through which high velocity vacuum-induced jets of slurry are projected downwardly upon the downward movement of the hutch, as indicated by the broken lines in FIGURE 9 showing the seating area of the balls relative to the rectangular openings **85**.

The screen structure may be further modified by a deposit of a relatively thick layer **88** of loosely and miscellaneously disposed objects on the upper face of the retaining screen **87**, a layer thickness of six inches being stated as a practical and efficient example. These loosely disposed objects are preferably polyvinyl cubes having substantially the same specific gravity as the slurry (previously stated as 1.1), and dimensioned in size so as to be suporpted above the retaining screen **87**, that is, substantially 7 mm. if the retaining screen is 6 mm. mesh. The inclusion of the layer **88** may make it desirable to appropriately increase the height of the side wall of the screen structure and correspondingly raise the overflow discharge outlet **14**. A grill **89** may be mounted across said overflow discharge outlet to prevent the objects or cubes **88** from being carried out of the tank with the overflow waste slurry. It is to be understood that these loosely disposed particles deposited above the retaining screen may be similarly employed in relation to all forms of the supporting screens and balls described in the several exemplifications of the supporting screen structure.

In FIGURES 10 and 11, another modified form of screen is disclosed in which there are transverse supporting bars **90** which support a ball-supporting screen **91** of relatively spaced screen slots **92** triangularly normal in vertical section, providing elongated rectangular orifices **93**. Balls **94** in this modified form of screen operate in the same manner as the balls **39** in FIGURES 1 to 6 to open the screen orifices **93** upon upward movement of the slurry and partially close said openings **93** to provide the reduced openings **93***a* upon downward movement of the slurry as previously described.

In this modification of FIGURES 10 and 11, the balls are guided in such vertical movement in pockets **95** formed by the slot members **92** and vertical partitions **95** upstanding from the screen **91**. A retaining screen **97** may overlie the supporting screen and balls, and have superimposed thereupon a layer of miscellaneously and loosely disposed objects **98** having characteristics as previously described. The guide members or pockets thus provide three vertical walls substantially perpendicular to the plane of the screen, and the fourth wall is divergingly inclined upward and outward at substantially a 30 degree angle, whereby the pockets are downwardly tapered from a relatively large upper open area to a smaller lower area in which the openings **93** are positioned, whereby the freedom of space for upward movement of the slurry is increased and the balls **94** are guided to seat rapidly and accurately in the openings **93** responsive to the downward movement of the slurry to provide the orifices **92***a* of reduced area.

The operation of the method and apparatus may be basically described with reference to FIGURES 1 to 6, supplemented by further references appropriate to the modifications of the supporting screen structures of FIGURES 7 to 11.

In operation, the ore pulp enters the slurry mass in tank **13** as indicated by hopper **16** and the feed opening **17** in the drawing. It is preferred and is believed to be important for most efficient operation that the ore pulp enter the slurry below the supporting screen for the reason that if it is fed above the screen the slow upward current would not maintain the relatively large gangue sand particles in suspension above the screen whereupon these rapidly settle, choking the openings and thus form a matting on the screen, which would prevent the most efficient functioning of the method and apparatus. By feeding the ore pulp below the supporting screen structure **19** these larger gangue sands settle downwardly in the slurry toward the bottom of the vessel **24**.

With the slow upward current of the slurry, the light layer of balls or spheres on top of the screen openings, being substantially the same specific gravity as the slurry, are raised thus opening the full area of the orifices of the entire screen free for the rising current of the slurry to pass at a slow upward velocity through said openings. The slow upward motion of the slurry through the full-sized screen openings carries in suspension the fine and light gangue particles together with fine mineral particles of high specific gravity, but not the sands of larger gangue particles. By successively repeated slow upward pulsations, the slimes and the fine light gangue particles gradually work to the upper stratum of the slurry above the screen and are discharged in the overflow at outlet **14**. The slow upward current of the slurry is, however, insufficient to carry with the current to said waste overflow the fine mineral particles, since, because of their high specific gravity, they do not flow upwardly as readily as the slimes and fine gangue and, secondly, because the upward motion imparted to the slurry through the full

openings of the screen is followed by an accelerated very rapid downward motion through screen openings of reduced size responsive to a vacuum suction below the screen, as will be further described.

On the following rapid downstroke of the hutch, responsive to the motor as aforesaid, the hutch drops quickly and with it the pulp level beneath the screen, which causes a downward vacuum suction under the screen. The balls on top of the screen openings settle rapidly responsive to the vacuum suction, whereby the balls close the screen openings only partly, leaving a large number of small openings **39***a* between the balls and through the screen, whereby high velocity jets of the slurry are induced through these small openings by the high differential pressure across such openings between the top and bottom of the screen due to the vacuum suction under the screen and the weight of the slurry trapped above the screen augmented by atmospheric pressure. These jets carry with them the mineral particles which are thus invested with high kinetic energy. The jets, upon striking the slurry level below the screen, are resisted by the next succeeding up-current of slurry and hutch water, permitting only particles with high kinetic energy to continue downward against the slowly rising current. The preconcentrate thus formed below the screen is a composite of the fine mineral particles of high specific gravity and the relatively large gangue particles of lower specific gravity. The smaller and lighter gangue particles and the slimes with low kinetic energy and relatively small surface area are carried along with the rising current of the pulp through the screen and eventually are discharged over the discharge tailings lip **14**.

The preconcentrates, in successive cycles of pulsations continue to work down into the hutch and are discharged from the bottom of the conical hutch through the automatic valve **28***a* which opens on the upward or pressure stroke of the hutch and closes on the downstroke or suction stroke of the hutch and thus prevents an intake of air which may destroy the vacuum and would have a deleterious effect on the operation of the method. The velocity of the current in the annular space around the circumferential base of the hood **48** is regulated and controlled by the position of said conical hollow hood relative to the circumference of opening **25**, and the quantity of hutch water admitted is controlled by the hollow cone valve **55** within said hood, thereby affecting the grade of concentrates of the slurry being processed.

Having described the method of operation in relation to the structures shown in FIGURES 1 to 6, the modified screen structures shown in FIGURES 8 to 11, provide for guiding of the balls in the upward and downward movement thereof, which is especially advantageous in relatively fast operation of the method. In other respects the operation is the same.

Referring to the layer of objects or cubes **88**, as shown in FIGURES 8 and 9, this ancillary miscellaneously and loosely disposed layer of objects may be employed above the retaining screen with any or all of the forms of ball-supporting screens illustrated and described. The phenomena effected by such layer is to more completely separate the fine mineral particles from the slimes and fine gangue particles in the slurry that passes upwardly through the ball-supporting screen. The said objects above the retaining screen, being relatively light in weight and of the same order of specific gravity as the slurry, rise and fall with the respective slow upward and fast downward movements of the slurry, and because of their miscellaneous positioning they do not obstruct the normal currents of such flow. The employment of such layer above the retaining screen has an appreciable effect of maintaining the fine mineral particles of high specific gravity at the lower level of the body of slurry above the ball-supporting screen, but permitting the lighter slimes and gangue to rise to the discharge level. In actual operation, the inclusion of such an ancillary layer above the supporting screen unit has increased the overflow of slime waste by twenty percent, and correspondingly decreased the content of slimes and fine gangue particles in the preconcentrate drawn off from the hutch.

The velocity of the slurry operative over the entire screen area is a function of the volume of the feed intake of the slurry and the quantity of the hutch water added.

The preconcentrates discharged at the outlet valve **28***a* consisting of relatively coarse gangue particles and fine mineral particles are then readily separated from each other by any well-known jigging or tabling operation whereby there is produced a final relatively high grade concentrate of fine mineral particles.

The recovery of fine mineral particles may be further promoted by taking advantage of mass action by adding to the ore slurry in the tank a quantity of finely ground material of high specific gravity, such as ferro-silicon, magnetite, metallic iron, which may then be readily separated magnetically or by gravity concentration from the concentrates and returned to the tank feed in a closed circuit.

By way of example of operation and not as a limitation, the timing of the relative up and down movements imparted to the slurry may be of a ratio of 40 or 50 to 1, such as an upward movement of four to five seconds and a downward movement of one-tenth of a second, the desirable number of such two-way strokes per minute depending on the fineness of the material of the ground ore, which may make it desirable to vary the length of the stroke and the number of such strokes between ten and sixty per minute.

By way of further explanation of the operation of the exemplified supporting screens and the balls thereon it will be noted that the mode of operation is closely akin to a plate having perforated therein a number of small swing-check valves corresponding to the number of balls as herein exemplified, each of such valves having a relatively smal return by-pass operating in the same manner as the relatively small orifices **39***a* between the balls exemplified herein, whereby the slow upward movement of the slurry would open the entire valve for a relatively free flow therethrough and the accelerated downward movement, which creates a partial vacuum under the screen, as previously explained, would close the valve and provide the downward jets of high velocity through the small return by-pass orifices.

The recovery of fine mineral particles further may be economically promoted by improving the apparatus above described to eliminate preliminary sizing of the feed.

In the past, it has been the custom to first treat different sizes of mineral and gangue particles in separate jigs to facilitate a more efficient subsequent separation of fine mineral particles of high density from its fine less dense gangue particles. In the fine or suspensoid size particle ranges particularly treated by the present invention, preliminary sizing of the fines to separate large mineral and gangue particles from relatively smaller mineral and gangue particles, is costly and difficult.

Thus, in order to further improve the separation of high density particles of small volume from low density particles of varying volumes density, a further embodiment of the present invention is illustrated in FIGURES 12 to 15 for obtaining separation of the fine mineral particles having high density from relatively low density gangue particles of varying volumes over an exceptionally wide range of sizes, thereby obviating, or at least limiting to a large extent, the necessity of costly preliminary ore treatments involving fine screening and classification.

Referring now to FIGURES 12 to 15, and more particularly to FIGURE 12, wherein the further construction embodying the principles of the present invention is shown, the reference numeral **110** designates a cylindrical slurry tank open at its ends and fixedly supported upon

the upper ends of angle iron corner posts **112** of a rigid generally rectangular structural frame **114**.

The bottom end of slurry tank **110** is closed by an inverted conically shaped hutch **116** which is coaxially and flexibly attached in fluid tight relationship to tank **110** by means of a circumferentially extending diaphragm **118** made of flexible material such as rubber so as to permit vertical displacement of hutch **116** relative the rigidly supported tank **110**. At the vortex of its cone, hutch **116** is provided with an outlet port **124** which is connected to a downwardly sloping pipeline **126** by means of a flexible coupling **128**.

The lower end of pipeline **126** terminates in a flared portion **130** rigidly secured to a closed elevator casing **132** in communication with an opening **134** formed in the casing. Casing **132** houses a conventional upright continuous bucket-type elevator **136** having a series of material receiving buckets **138** suitably secured to a moving continuous belt **140**. At the upper end of elevator casing **132**, a material discharge opening **142** is provided for emptying the contents of buckets **138**.

Referring now to FIGURES 12 and 13, the means for vertically reciprocating hutch **116** comprises any suitable hydraulic motor **144** having fluid inlet and outlet connections **145** and **146** respectively for imparting a differential of a relatively slow upward motion and a relatively fast downward motion to hutch **116**. Motor **144** is preferably of the type illustrated in the embodiment of FIGURES 1 to 6, being fully described in said United States Letters Patent No. 2,766,735, wherein the power member **147** is slowly raised by introduction of fluid pressure through inlet **145** and allowed to rapidly fall by gravity upon release of pressure fluid through outlet **146**.

Motor **144** is mounted coaxially above slurry tank **110** on a base plate **148** rigidly supported on frame **114** by means of a series of inclined angle irons **149** secured at their lower outwardly extending ends to frame **114**. As best shown in FIGURE 13, the reciprocable power member **147** of motor **144** carries at its upper end a cross arm **154** which is connected to and supports a jig cross arm **156** below motor **144** by means of a series of cables or rod and nut assemblies **158**.

As clearly shown in FIGURE 12, an upright jig operating shaft **160** slidably extends through cross arm **156** coaxial with motor **144** and is resiliently suspended from cross arm **156** for reciprocable movement therewith by means of a coiled compression spring **164**. Compression spring **164** is mounted on top of jig cross arm **156** between two guide covers **166** and **168** in surrounding relationship to shaft **160**. The upper end of shaft **160** extending beyond spring guide cover **168** is threaded and receives a tightening lock nut assembly **170** bearing against the upper face of cover **168** which is urged upwardly by spring **164**.

The lower end of shaft **160** slidably extends through a hub **171** rigidly fixed to hutch **116** by means of a series of radially extending structural brace members **172**. The portion of shaft **160** extending downwardly beyond hub **171** is threaded to receive a tightening and lock nut assembly **173** which bears against the bottom face of hub **171** so as to resiliently suspend hutch **116** and shaft **160** from cross arm **156** in the position shown in FIGURE 12.

Also supporting hutch **116** is a series of equiangularly spaced heavy duty upright coiled compression springs **174** anchored at their respective bottom ends to frame **114** and affixed at their upper ends to a rigid horizontal plate **175** fixedly secured to hutch **116**. For a purpose as will hereinafter become apparent, compression springs **174** flexibly support only a predetermined part of the dead weight of hutch **116**.

By this structure, it will be appreciated that hutch **116** is resiliently suspended from frame **114**. When pressure fluid is introduced into motor **144** to uniformly and slowly raise power member **147**, cross arm **156** is carried upwardly by movement of cross arm **154** so as to compress spring **164** and raise shaft **160**. Since nut assembly **173** bears against hub **171** in the lowered or bottom position of shaft **160**, vertical displacement of shaft **160** in an upward direction slowly lifts hutch **116** to its upper or raised position. When the pressure fluid acting on power member **147** is released as described in said Letters Patent No. 2,766,735, the power member **147** falls rapidly under its own weight causing cross arm **156** to drop a corresponding distance by gravity. The sudden release of pressure on spring **164** allows the energy stored in the spring to be released so that it expands and follows cross arm **156** in its downward movement.

The portion of the weight of hutch **116** and its contents not supported by spring **174** now acts to cause the hutch to fall rapidly from its raised position, carrying with it shaft **160** which moves against the bias of spring **164** in its expanded condition. Hutch **116** continues to fall until spring **164** becomes sufficiently compressed by the downward movement of shaft **160** to resiliently support from cross arm **156** the rest of the weight of hutch **116** and its contents not supported by springs **174**.

In this manner, the downward movement of hutch **116** is cushioned and the hutch is shocklessly brought to rest in its lowered position without sudden or abrupt stopping to thereby preclude the occurrence of excessive strains and stresses in the other structural components of the apparatus that would otherwise occur. Since springs **174** only support a predetermined part of the dead weight of hutch **116**, the gravitational force corresponding to the remainder of the weight of the hutch not supported by springs **174** overcomes the bias of spring **164** and the atmospheric pressure forces tending to hold the hutch as will be explained so as to facilitate the requisite rapid downward movement of the hutch.

A pipeline **176** for introducing either hutch water or heavy media into hutch **116**, extends horizontally through the conical walls of hutch **116** and has a fluid outlet port **177** communicating with the interior of the hutch. Supported above outlet port **177** on pipeline **176** is a perforated inverted conical shaped hood **178** for evenly and uniformly distributing heavy media or water discharged for outlet **177** into the interior of hutch **116**.

The opposed ends of pipeline **176** extending beyond hutch **116** respectively are connected to suitable heavy media and water sources (not shown) by means of valved pipes **179** and **180**.

Supported within the upper portion of slurry tank **110** by a ring **181** secured to tank **110**, is a pocketed grid member **182** disposed in a generally horizontal plane but having its top face somewhat gradually and uniformly conically sloped downwardly from its peripheral outer edge toward the center of tank **110**. A central opening is formed in grid member **182** through which shaft **160** extends. Received through the central opening of grid member **182** and rigidly fixed thereto is a discharge tube **184** for discharging coarse gangue particles of light density into hutch **116** where they are removed together with the fine mineral particles of high density. With the present embodiment additional jigging treatment of the particles removed from the bottom of hutch **116** is required to separate the dense small mineral particles from the large light gangue particles. Slidably received in tube **184** is a sleeve **185** which is vertically adjustable and held rigid with frame **114** by means of bolts **185***a*. By this construction, sleeve **185** is readily adjustable to control the depth of concentrate formed above grid **182**.

As best shown in FIGURES 12 and 14, and 15, member **182** is provided with a series of upstanding projections **186** having inverted cone shaped cross sections to form a series of individual equidistantly spaced side-by-side or juxtaposed downwardly tapered pockets **188** having substantially squared bottom openings **190** providing fluid communication between the top and bottom of the grid and side walls shaped to conform to inverted frusto-pyramids so as to be squarely rectangular at their open

top. Recessed pockets **188** are substantially identical to the shape of recesses **84** described in connection with the screen embodiment illustrated in FIGURES 8 and 9.

Freely received in each pocket **188** is a ball **192** identical to and having the same functional characteristics of balls **86** and **39** illustrated in the previously described embodiments. Balls **192** as hereinbefore described have substantially the same specific gravity as the slurry introduced into tank **110** and therefore function in the same manner, rising and falling within their individual recessed pockets **188**. Each ball **192** is guided into a seated position over bottom opening **190** in its recessed pocket by the side walls thereof and are of such diameter with respect to the dimensions of the pocket opening **190** that they are retained within their pockets to prevent their falling through the pocket openings.

As hereinbefore described, upon relatively slow upward movement of the slurry introduced into tank **110**, the balls **192** rise to provide relatively large open orifices in grid member **182** and fall with the vacuum induced relatively fast downward movement of the slurry in tank **110** to seat over the pocket openings **190** and thereby reduce the effective fluid flow area of these openings, providing orifices with the side walls of the recessed pockets that are of reduced open area and through which high velocity vacuum induced jets of slurry are projected downwardly upon the downward movement of hutch **116**.

A retaining screen **196** supported by grid member **182** and conically shaped to correspond to the conically shaped upper face of grid member **182** overlies the pocket recesses and retains balls **192** in their respective pockets. Retaining screen **196** is held firmly in place over grid member **182** by means of structural ring-shaped members **198** and **200** respectively urged downwardly in the abutting contact with the upper face of screen **196** by bolts **202** and **204** which are secured to frame **114**.

The means for introducing feed into slurry tank **110** comprises a downwardly sloping duct **206** positioned above the tank and extending radially toward the center thereof. Feed duct **206** communicates at its inner end with a radial opening **208** formed in a sleeve **210** supported above retaining screen **196** on frame **114** coaxially with tank **110** and in surrounding concentric spaced apart relationship to jig shaft **160**. Between sleeve **210** and jig shaft **160** an inverted conically shaped tube **212** is adjustably supported on frame **114** in concentric spaced relationship to sleeve **210** by means of bolts **214**. The lower wide end of the conical tube **212** extends downwardly beyond the lower edge of sleeve **210** and forms a feed well space **216** with sleeve **210**.

Tailings or light low density particles discharged over the peripheral edge of slurry tank **110** are collected in a peripherally sloped launder **222** surrounding the tank near the upper edge thereof.

Thus by the means above described for centrally feeding the ore into the slurry tank **110** and peripherally discharging the tailings, surface cross currents are minimized so as to permit the fine dense mineral particles to settle instead of being carried away over the tailings discharged by the cross currents. The inwardly sloping conical shape of screen **196** and grid **182** urges the layer of coarse heavy mineral particles towards the center discharge **184**.

In operation of the above apparatus thus far described, fluctuations in the rate of ore feed and variations in the character of the feed correspondingly affects the density of the slurry in the hutch. Increases in the feed cause corresponding increases in the slurry density. Variations in the slurry density have been found to have a substantial effect upon the separation of particles. To this end, it will be appreciated that increases in the feed rate tend to increase the density of the medium in the slurry tank and a denser medium, while assisting in the removal of fine gangue particles, resists and decreases the settling velocity of the fine heavier mineral particles thereby retarding the separation of these particles. Similarly, a reduction or interruption in the rate of feed tends to lower the density of the medium in the slurry tank and a less dense medium will not provide sufficient fluid resistance to keep the fine gangue particles from settling with the fine heavier mineral particles.

In order to compensate for variations in the density of the slurry medium to thereby assure a more uniform and efficient separation of particles over a wide range of particle sizes and to prevent serious metallurgical losses, a speed control unit **226** is provided for hydraulic or air motor **144** and comprises a rotary valve **228** in motor inlet **145** for controlling the admission of pressure air or fluid to hydraulic motor **144**. Actuation of valve **228** controls the speed at which power member **147** is raised from fully lowered position to fully raised position as is more fully described in said Letters Patent No. 2,766,735. Rigidly secured to the operating stem **230** of valve **228** is an operating lever **232** having a weight **234** attached to the free end thereof so as to bias the operating stem **230** to valve closed position. Secured transversely to operating lever **232** intermediate weight **234** and operating stem **230** is an arm **236** which carries at its lower end the inner telescoping member **238** of a conventional mercury dash pot **240** having a support base **242** rigidly secured to frame **114**. By this structure, dash pot **240** resists movement of valve operating stem **230** in either direction and weight **234** tends to rotate stem **230** toward valve closed position.

With continued reference to FIGURE 12, the linkage for operating the lever **232** comprises a link **244** rigidly secured at one end to spring cover **168** and pivotally secured at its opposite end to the lower end of a generally upright link **246**. The upper end of link **246** is pivotally connected to the left-hand end of a force multiplying lever **248** which is fulcrumed about a machine screw **250** threadedly secured in frame **114**. At the opposite right-hand end, as viewed from FIGURE 12, lever **248** carries a mounting block **252** which is adjustably secured to lever **248** by means of a screw **254**. Mounting block **252** is formed with a tapped bore which threadedly receives a stud **256** adjustable in height to abuttingly engage operating arm **232** between valve stem **230** and dash pot cross arm **236**.

By means of this construction, the admission of air or hydraulic fluid into hydraulic motor **144** is regulated by the height to which cover **168** and consequently shaft **160** and hutch **116** are raised. As the density of the medium in hutch **116** increases, the force needed to raise the hutch to its normal raised position correspondingly increases. For a given hutch weight, when valve **228** is set in one position to admit pressure fluid into motor **144** at a predetermined flow rate, the power member **147**, and consequently hutch **116**, will be raised in a predetermined period of time corresponding to the rate at which fluid is being introduced into motor **144**. When the density of the slurry increases so as to increase the weight of the slurry in the hutch and valve **228** is held in its same setting, a longer period of time will be required to raise the hutch to its upper position. As a result, it will be appreciated that the time required for raising the hutch will therefore increase with corresponding increases in the weight of the slurry in the hutch for a single setting of valve **228**.

In raising hutch **116** as hereinbefore described, a resistive countercurrent of fluid resists the settling of the particles in the slurry so as to urge particles of low density to the surface of the slurry. This resistive countercurrent of the slurry caused by raising hutch **116** also tends to resist to a lesser extent downward movement of the fine high density particles of small volume which are settling in the slurry for discharge through the hutch outlet **124**. Thus when the upward movement of hutch **116** is prolonged, then the resistive counterforce tending to restrain the fine high density particles from settling is increased

in proportion to the length of time that it is required to raise the hutch, thereby tending to make the separation of the fine dense particles more difficult.

In accordance with the present invention, springs **174** are fully compressed when hutch **116** is dropped to its lowered position and are constructed to support only a predetermined part of the dead weight of the hutch when fully compressed. Thus, the loads carried by springs **174** in elongated and compressed positions corresponding to raised and lowered positions of the hutch, remain substantially constant irrespective of variations in the weight of the slurry in the hutch. Spring **164** accordingly supports a load equivalent to all of the remaining weight of the hutch and the slurry not supported by springs **174**. Since the maximum load supported by springs **174** remains constant, variations in the weight of the slurry are therefore taken up by spring **164**. When the weight of the slurry is increased, the magnitude of deflection of spring **164** is also increased to support the additional weight and when the weight of the slurry is decreased, the magnitude of deflection of spring **164** is correspondingly reduced. For example, if the total weight of hutch **116** and the slurry is 3000 pounds and the constant load carried by springs **174** when compressed is 2000 pounds, then the remaining 1000 pounds is carried by spring **164**. If the density of the slurry is increased so that the total weight becomes 3300 pounds, the load carried by springs **174** remains constant and the load taken up by spring **164** accordingly increases to 1300 pounds thereby causing a further increment of compression of spring **164**. Thus the magnitude of deflection of spring **164** varies correspondingly according to changes in the weight of the slurry. Since spring cover **168** is subject to variations in the magnitude of deflection of spring **164** and since the operating arm **232** is connected through the system of linkage arms **244**, **246** and **248** to the spring cover **168**, then variations in the magnitude of deflection of spring **164** are transmitted to valve **228** to control the rate of pressure fluid flow being introduced into motor **144**.

Thus, valve **228** is readjusted by speed control unit **226** at the end of each stroke of power member **147** and jig shaft **160** in accordance with variations in the density of the slurry. When the weight of slurry in hutch increases, operating arm **232** rotates valve stem **230** between positions permitting an overall increased rate of pressure fluid flow into motor **144**. As the rate of fluid flow is increased, the added pressure fluid force acting on the power member **147** to compensate for the additional weight of the slurry in hutch **116** causes power member **147** and consequently hutch **116** to again be raised in a changed time period needed to effect efficient separation of the particles in the slurry.

Similarly, speed control unit **226** functions to decrease the rate of fluid flow into motor **144** as the density of the slurry is reduced. Thus, it will be appreciated that the speed control unit **226** controls the rate of pressure fluid flow into motor **144** in response to variations in the weight of the slurry. The time period for raising the hutch can therefore be changed to a value at which the most efficient separation of particles occurs irrespective of changes in the density of the slurry.

In order to protect screen **196** which is generally of fine mesh from rapid wear, a thin layer of lead shot **260** is placed over screen **196** as shown in FIGURE 15. The density of the lead shot is substantially greater than that of the slurry so that the lead shot will not be readily shifted with the pulsations of the slurry caused by the jig action. The layer of lead shot **260** performs the function of a fine screen.

On top of the lead shot **260**, a layer of relatively coarse bedding material **262** is placed. Bedding material **262** is selected to have about equal density as the minerals to be recovered.

In operation of the apparatus above described, the feed of mixed sizes enters through opening **208** into the feed well **216**. Motor **144** sets in motion movable hutch **116** with a relatively slow upward stroke followed by a rapid downward stroke causing the pulsations of currents in the slurry which bring about the separation of light particles of low density from small heavier particles of high density. Above bedding **262** the slurry becomes stratified on the slow upstroke followed on the downstroke by the heavier coarse gangue particles displacing lighter particles thus forming a bed of coarse concentrates of heavier coarse particles on top of bedding **262** which is the common method of concentration in jigging. During this action the slurry containing the neo-suspensoids and very fine high density mineral particles and fine gangue particles of low density which do not stratify and cannot be concentrated above the screen by the jigging operation indicated, are drawn down through screen **196** and pocket grid **182** in the form of high velocity jets into the hutch and separation of the fine heavy mineral particles from the lighter fine gangue particles takes place as fully described in the operation of the previous embodiments. The layer of coarse concentrates formed on top of bedding **262** gradually moves with the pulsations of the slurry toward the center discharge tube **184** with its height adjustment sleeve **185**. The movement of the concentrates toward the center is helped by the conical shape of grid **182** and screen **196**. The discharge of the coarse concentrate into the hutch is principally effected by the differential in pressures above and below grid **182** as created by the rapid downward motion of the hutch. Trailings or fine light particles of low density are discharged over the peripheral edge of the tank **110** and collected in peripheral launder **222** surrounding the tank.

The separation of gangue particles from fine mineral particles may be effectually enhanced by the introduction of heavy media into the hutch through pipe **176** under the perforated conical hood **178**. Heavy media at the bottom of the hutch promotes cleaning of the concentrates without interfering with free settling of mineral particles at the top as would occur where heavy media is introduced with the ore due to increased viscosity.

The discharge of concentrates (gangue in the case of coal) may be effected and controlled in various manners depending largely on the kind and size of the material. In FIGURE 12 the discharge is illustrated as being controlled by means of elevator **136** which provides a wide discharge opening from the hutch and tends to maintain at all times a constant level in the hutch irrespective of load.

FIGURE 16 illustrates a modified form of concentrate discharge generally indicated at **270** and basically consisting of an outlet pipe **272** having a downwardly facing sand bleed **274**. Pipe **272** is connected to an upwardly sloping duct **275** communicating with an upright overflow duct **276** having a series of overflow outlets **278** at different elevations.

By this structure, the rate of discharge from hutch **116** is increased proportionally with respect to the head of the slurry in hutch **116**, since as the level of the slurry in hutch **116** increases, the level of slurry in overflow duct **276** correspondingly increases to communicate with an increasing number of outlets **278**.

In some cases it may be desirable to keep the coarse concentrates separate from the fine concentrates which later may require a subsequent treatment such as pelletizing in iron ores. That may be readily accomplished by placing a screen **290** underneath discharge tube **184** and connecting it to separate discharge duct **292** controlled by a rotary valve **294** as shown in FIGURE 16. The screen **290** functions to maintain pulsations of the slurry and suction in the tube **184**.

When treating fine material by the apparatus described above, a problem is encountered in that the pulsating currents permit fine particles to pass through bedding **262**, but the bedding will retain the relatively coarser but light sand particles of the ore which tend to accumulate on top of the coarse bedding forming a layer of fine sands

indicated at **300**, FIGURE 17. If this layer **300** is allowed to build up and increase in thickness, it eventually fills up to the mouth of feed well **216**, preventing the further admission of feed and interfering with the proper operation of the apparatus. In treating fines, the jig motion, as hereinbefore described, must be kept relatively slow and uniform on the upstroke to prevent undue agitation of the slurry which would tend to keep fine mineral particles in suspension and prevent them from settling. In order to maintain the slow motion of the upward slurry current it is preferable to remove the sand layer **300** and thereby maintain the apparatus in continuous operation. To accomplish the removal of sand layer **300**, the side of slurry tank **110** is provided with an opening **302** of suitable width and height as best shown in FIGURE 17. Opening **302** is covered with an inclined shield **304** having closed sides **306** as clearly shown in FIGURE 18. Shield **304** is positioned adjacent to the peripheral overflow edge of tank **110** and slopes down into the bedding slightly below the level of fine sand layer **300**. Slats **308**, held by bracket **310**, are removable to adjust the height and level of sand overflow. A slide **312** is shiftable in a slot **314** formed by bracket **315** to adjust the discharge overflow **318** between slats **308** and slide **312**. With continued reference to FIGURES 17 and 18, the sand level is shown to be slightly raised above its normal level. As the level of sand layer **300** increases, the portion under shield **304** is subject to a squeezing action as a result of the inclination of the shield. By this action, the sand under shield **304** readily builds up and is discharged through opening **318** into launder **222**. A series of shields **304** may be arranged around the edge of slurry tank **110** so that the sand level adjusts itself with the pulsations of the jig. In this manner an effectual sand discharge is obtained while maintaining a normal fine sand level.

By the above constructions of FIGURES 12 to 18, exceptionally wide ranges of particle sizes can be efficiently separated to facilitate the recovery of mineral particles without requiring costly preliminary screening, classification or sizing operations. This is particularly accomplished in accordance with the present invention by means of the central feed **206** and peripheral discharge of tailings above the cylindrical tank **110**, the maintenance of a slow and uniform upward movement of hutch **116** with sufficient speed to keep bedding **262** in fluid condition and to allow ample time for stratification of coarse particles above grid member **182**, the provision of bedding **262** to retain the coarser fraction of less dense particles above grid **182**, the provision of speed control unit **226** to compensate for changes in the density of the slurry, and the provision for uniform distribution of the high velocity fluid jets by means of grid member **182**. By this construction, for example, particles ranging in size from approximately ½ inch down to sizes in a micron range can be effectively and efficiently separated.

While the foregoing descriptions have been largely concerned with the elements of the particular apparatus, it is obvious that the invention is not necessarily restricted thereto and that functional equivalents may be employed to carry out the method of particle separation. For example, different screens and motors for operating the hutch may be used.

To illustrate the broad applicability of the method of the present invention and to more clearly distinguish the action from known methods of jigging, a further embodiment is illustrated in FIGURE 19 wherein the reciprocal movement of structural parts that is representative of jigging methods is not present.

Refrering now to FIGURE 19, a slurry supply tank **330** is connected to a suitable feed pump **332** by means of a duct **334**. Pump **332** is provided with a pressure outlet **335** connected by a duct **336** to a stationary pressure chamber **338** rigidly supported by any suitable means (not shown). Pressure chamber **338** is formed with a generally horizontal bottom wall **340** having a series of downwardly extending uniformly spaced orifices **342** and closed side walls **343**. Disposed in spaced relationship beneath bottom wall **340** is a stationary receiving tank **346** rigidly supported by any suitable framework (not shown) and having an upper cylindrical wall portion **348** open at the top and closed at the bottom by a lower inverted conically shaped wall portion **350** rigidly secured to cylindrical wall **348** around the bottom peripheral edge thereof. At the vertex of wall portion **350** a valved fluid outlet **352** is provided to permit discharge of fluid and particles from tank **346**.

Adjacent to the bottom edge of cylindrical wall portion **348** is secured a circular generally horizontal plate **353** interfitting with tank **346** and having a series of uniformly spaced openings **354**.

A peripheral lip **356** is secured to tank **346** adjacent the upper edge thereof to facilitate removal of fluid and particles overflowing the tank.

In order to supply fluid to tank **346** such as water or heavy media, a storage tank **358** is provided for and is connected to tank **346** by means of a duct **360**. Duct **360** communicates with an opening **362** formed in tank **346** beneath plate **353**.

The means for controlling the flow of fluid through ducts **336** and **360** comprises valves **362** and **364** respectively. Valves **362** and **364** are mechanically interlocked as by arm **366** so their operation is simultaneous. As shown in FIGURE 19, movement of arm **366** upwardly opens valve **362** and concomitantly closes valve **364**. Correspondingly, movement of arm **366** downwardly opens valve **364** and closes valve **362**.

By this construction, it will be appreciated that with the exceptions of valves **362** and **364** and pump **332**, the apparatus basically has no relatively movable parts for facilitating the separation of intermixed particles in the feed as will now be described.

Thus, in operation, tank **346** is filled with water or heavy media from tank **358**. The slurry containing the intermixed suspensoids to be separated is stored in tank **330** and is pumped from tank **330** to pressure chamber **338** by pump **332** to fill chamber **338** with slurry under pressure. The slurry in pressure chamber **338** is discharged downwardly through orifices **342** in high velocity jets into the medium in tank **346**.

Since equal velocities are imparted to the intermixed particles in the jets, those particles of equal mass will acquire equal momentum (mass×velocity) or kinetic energy. Small particles of greater density acquire equal momentum with larger particles of lesser density but the larger particles of lesser density owing to their relatively larger surface, meet with a greater viscosity resistance as they enter the fluid in tank **346** in comparison to the smaller particles of greater density. Thus for particles of equal mass and momentum, the smaller particles of greater density have a greater penetrating power than the larger particles of lighter density.

Small particles of equal volume but of differing densities acquire different momentums upon being discharged in the high velocity jets. Consequently, the particles of greater density have greater penetrating power than the particles of equal volume but of lesser density.

By reversing the position of valves **362** and **364** so as to open valve **364** and close valve **362**, the high velocity jet flow from the pressure chamber is interrupted and water or heavy media is introduced into tank **346** adjacent the bottom thereof at a flow rate to provide for a slow upward current in the medium in tank **346** which is uniformly distributed by passage through plate openings **354**. This slow upward current which is counter to the downwardly penetrating particles will readily carry back or reverse the direction of motion of particles of lesser penetrating power.

In this manner, the combined alternate action of jet and counter-current effectuates a positive separation of

small particles of high density from less dense particles of equal or greater volume. The small dense particles are recovered from the bottom outlet in tank 346 and the remaining less dense particles are removed as tailings, overflowing the top edge of tank 346.

Thus, in accordance with the present invention, the method of separating intermixed suspensoids of particles of varying size and differing densities, basically consists of discharging a stream of a suspension of such intermixed particles at a first relatively high predetermined velocity into a fluid body of predetermined density and then imparting a movement to the fluid that is in countercurrent to the movement of the particles penetrating into the fluid and is of such velocity to overcome the momentum of low density particles irrespective of their size while merely reducing the momentum of the high density particles.

The invention may be embodied in other specific forms without departing from the spirit or essential characteristics thereof. The present embodiments are therefore to be considered in all respects as illustrative and not restrictive, the scope of the invention being indicated by the appended claims rather than by the foregoing description, and all changes which come within the meaning and range of equivalency of the claims are therefore intended to be embraced therein.

What is claimed and desired to be secured by United States Letters Patent is:

1. A method of separating particles of varying size and differing densities in accord with their densities comprising the steps of discharging a stream of a suspension of such particles at a first predetermined velocity for penetration into a body of liquid medium having a predetermined density and imparting movement to said body which is counter to the movement of said stream and which is at a velocity sufficient to overcome the momentum of the low density particles in the stream irrespective of their size while merely reducing the momentum of the high density particles in the stream, said first predetermined velocity being imparted to said particles prior to introduction into said body.

2. A method of separating particles of varying size and differing densities in a slurry body comprising the steps of moving said slurry body in a first direction at a first velocity to impart like velocities and differing momenta to said particles proportional in magnitude to their respective masses, and reversing the direction of movement of the lower density particles therein while merely retarding the rate of movement of the higher density particles therein in said first direction by applying a uniform current of viscous resistance to said particles only after the like velocities have been imparted to said particle.

3. A method of separating relatively high density fine particles from relatively low density particles in a slurry, said method comprising the steps of providing a confined body of such slurry, providing a member having a horizontally disposed orifice immersed in said slurry body, acting upon said slurry body beneath said member to produce vertical undulant movement of said slurry through the orifice, the upward movement of the slurry body being relatively slow and the downward movement being relatively rapid, and constricting said orifice immediately upon initiation of downward slurry movement to a degree to prevent downward movement of the portion of the slurry body above the member at the same rate as the portion thereof beneath said member to thereby create a void between the bottom of said member and top surface of said slurry body portion beneath said member and thereby induce the formation of downwardly directed jet discharge stream through the constricted orifice.

4. The method according to claim 1 comprising the steps of confining said body with at least an intermittent free surface, and emitting said stream at a predetermined distance from said free surface and in the direction of said free surface to enable said particles to penetrate into said body.

5. The method according to claim 4 comprising the steps of alternating the counter movement of said body relative to said stream with a concurrent movement that is in the same direction as the movement of said stream to produce an undulant movement of said body, and maintaining a predetermined timed relationship between the concurrent and counter current movements of said body and the discharging of said stream.

6. The method according to claim 5 comprising the step of producing a sub-atmospheric space above said free surface by said concurrent movement of said body to establish a pressure differential for causing emission of said stream.

7. A method of concentrating fine particles of high density from finely ground ore, including the steps of providing a generally horizontally oriented orificed screen embodying fluid flow responsive means for opening the orifices thereof in response to upward fluid flow therethrough and for substantially constricting the orifices in response to downward fluid flow therethrough, immersing said screen in a confined body of slurry, inducing in said slurry below said orificed screen successive alternating flows of relatively slow upward movement followed by a relatively accelerated downward movement through the orifices of the screen, the rate of downward slurry movement being sufficiently great to induce a vacuum suction space immediately below the screen substantially simultaneously with the commencement of and responsive to the rapid downward movement of the slurry and to thereby induce the formation of downwardly directed jets of slurry through the constricted orifices of the screen and through said space into the body of slurry therebelow whereby greater kinetic energy and momentum are imparted to fine particles of high density in said downward jets than to the particles of low density therein, the succeeding slow upward movement of the slurry being of such velocity that the lesser downward momentum of the particles of relatively lower density is overcome and the low density particles are carried upwardly through the screen open orifices to the upper surface of the slurry for discharge as waste while the relatively higher momentum and kinetic energy of the high density particles is merely reduced so that such high density particles continue downward movement, and drawing off concentrate portions of the slurry below the level of the screen.

8. The method for concentrating finely ground mineral particles in a slurry as defined in claim 7, including the steps of fully opening the orifices in the screen substantially immediately upon initiation of upward slurry movement and maintaining such orifices open during the upward movements of the slurry, and partly closing said orifices responsive to and substantially simultaneously with the commencement of the downward movement of the slurry.

9. Apparatus for concentrating finely ground particles in a slurry, including a tank for containing a slurry therein and having a slurry feed inlet, a discharge outlet for concentrates at a lower portion of the tank and a discharge outlet for waste at an upper portion of the tank, and means operative in said lower portion of the tank for successively pulsating said slurry at a differential of velocity respectively slowly upwardly and rapidly downwardly, the combination therewith of an orificed supporting pocket screen structure mounted transversely across said tank and dividing the tank into the said upper portion and lower portion said screen structure having spaced apart upper and lower faces and having its area divided into separate pockets open at both ends to provide fluid communication through said screen and adapted for separately seatingly receiving and holding a ball therein, the openings of said pockets at said lower face being of relatively smaller area than the openings at said upper face, at least one of the side walls of each of said pockets being inclined up-

wardly and outwardly between the said respective upper and lower openings to permit movement of said balls in said pockets, and means overlying the pockets for limiting the upward movement of balls in the pockets beyond the confines of the pockets.

10. In an apparatus for concentrating finely ground particles in a slurry, including a tank for containing a slurry therein and having a slurry feed inlet, a discharge outlet for concentrates at a lower portion and a discharge outlet for waste at an upper portion, and means operative in said lower portion of the tank for successively pulsating said slurry at a differential of velocity respectively slowly upwardly and rapidly downwardly, the combination therewith of an orificed supporting screen structure mounted transversely across said tank and dividing the tank into the said upper portion and lower portion, said screen structure having separate pockets open at the top and each formed with an orifice disposed in the bottom thereof to provide fluid communication through said screen structure through which flows of slurry may be pulsated, a ball shiftably positioned in each pocket, being of a shape and area relative to the size of the balls whereby the balls in the respective pockets are adapted to be seatingly supported by the edges of said pocket forming said orifices and to maintain a portion of said lower orifices open for passage of slurry therethrough, and a guard grille overlying the pockets in sufficient proximity thereto for confining said balls against movement out of pockets by the force exerted by the upward flow of the slurry.

11. In an apparatus for concentrating finely ground particles in a slurry, including a tank for containing a slurry therein and having a slurry feed inlet, a discharge outlet for concentrates at a lower portion and a discharge outlet for waste at an upper portion, and means operative in said lower portion of the tank for successively pulsating said slurry at a differential of velocity respectively slowly upwardly and rapidly downwardly, the combination therewith of a supporting screen structure mounted transversely across said tank and dividing the tank into the said upper portion and lower portion said screen structure having a plurality of orifices through which flows of slurry may be pulsated, a plurality of balls associated individually with said orifices, said orifices being of a shape and area relative to the size of the balls whereby the balls associated with the respective orifices may be supported by the edges of said orifices and maintain a portion of said orifices open for passage of slurry therethrough, and a guard grille overlying said screen in sufficient proximity thereto for confining said balls against the upward flow of the slurry.

12. In an apparatus for separating intermixed particles having varying size and differing densities in accord with their densities, a vessel confining a body of slurry having a free unconfined top surface; means for projecting at least one stream of a suspension of said intermixed particles at said free surface of said body of slurry with a sufficient predetermined first velocity to penetrate said body of slurry including a member having at least one orifice therein disposed over said free surface in fluid communication therewith and supply means for delivering said suspension of intermixed particles to said orifice under a predetermined pressure; and delivery means separate from said supply means for introducing a fluid medium to said vessel at a point to cause an upward movement of said slurry in counter current to said stream.

13. The apparatus as defined in claim 12 wherein said member is fixed relative to said vessel.

14. The apparatus as defined in claim 12 wherein means are provided for controlling the delivery of said suspension and said medium in interlocked relationship so that the delivery of said suspension and said medium takes place in sequence.

15. The apparatus as defined in claim 12 wherein said supply means comprise means defining a pressure chamber with said member and fluid pump means having an outlet in fluid communication with said pressure chamber and operative to establish a pressure differential across said orifice for producing said stream.

16. In an apparatus for separating intermixed particles suspended in a fluid, a tank open at least at its bottom end, a rigid closure member disposed beneath the bottom end of said tank, flexible means attaching said closure member in liquid tight relationship to said tank so that said closure member is at least vertically displaceable relative to said tank and encloses the bottom open end thereof, flexible means resiliently supporting only a predetermined portion of the dead weight of said closure member, and means resiliently supporting the remainder of the weight of said closure member and the weight of the contents in said tank comprising motor means having a power member operably movable in opposed directions at differing predetermined velocities, means including a resilient member operably coupling said closure member with said power member for transmitting motion of said power member to said closure member to reciprocate said closure member with a slow upward movement and a relatively rapid downward movement, said flexible means and said resilient member cushioning and shocklessly interrupting the downward movement of said closure member.

17. In an apparatus for separating intermixed particles suspended in a fluid, a tank for confining a body of said fluid and open at least at its bottom end, a rigid closure member disposed beneath the bottom end of said tank, flexible means attaching said closure member in fluid tight relationship to said tank so that said closure member is at least vertically reciprocable to said tank, drive means operably coupled to said closure member for imparting alternating and successive slow upward and rapid downward movement to said closure member, and means for controlling the magnitude of velocity at which said closure member is moved upwardly in response to variations in the density of said fluid.

18. The apparatus as defined in claim 17 wherein said drive means includes fluid operated motor means having a pressure fluid inlet, closure member support means operably coupling said motor means to said closure member and including a movable member responsive to variations in the weight of fluid in said tank, valve means in said pressure fluid inlet for controlling the introduction of pressure fluid into said motor means, and means operatively connecting said movable member to said valve means to operate said valve means and control the rate of pressure fluid flow to said motor means in proportion to the changes in density of said tank.

19. In an apparatus for separating particles suspended in a slurry in accordance with their densities, a tank for containing a slurry therein and having a slurry feed inlet, a discharge outlet for concentrates at a lower portion and a discharge outlet for waste at an upper portion, movable means operative in said lower portion of the tank for pulsating said slurry, a grid structure mounted transversely across said tank in a predetermined position and dividing the tank into the said upper portion and lower portion, said grid structure having a plurality of orifices providing fluid communication between the upper and lower portions of said tank, motor means operatively coupled to said movable means for successively and alternately imparting slow upward movement and relatively rapid downward movement to said movable means whereby the slurry in said tank is alternately moved slowly upwardly through said orifices and above said grid structure and rapidly downwardly through said orifices and means cooperating with said orifices in said grid structure and operative by the pulsations imparted to said slurry to allow fluid flow through the entire cross sectional flow area of said orifices upon upward movement of said slurry but to effectively partially reduce the magnitude of the flow area through said orifices upon downward movement of said slurry to thereby temporarily trap a portion of said slurry above said grid structure

and to establish a low pressure void immediately below said grid structure whereby slurry from above said grid structure is discharged through the effectively reduced flow area of said orifices in the form of jet streams of predetermined velocity, said orifices being approximately vertically disposed so that said jet streams project toward the free surface of said slurry below said grid structure to penetrate said slurry, said inlet feed being centrally disposed above said grid structure and including a feed duct, means defining a feed well centrally above said grid structure and communicating with said duct, said discharge outlet for waste being disposed above said grid structure about the periphery of said tank whereby cross currents of slurry between said inlet feed and said discharge for waste are minimized.

20. In an apparatus for separating particles suspended in a slurry in accordance with their densities, a tank for containing a slurry therein and having a slurry feed inlet, a discharge outlet for concentrates at a lower portion and a discharge outlet for waste at an upper portion, movable means operative in said lower portion of the tank for pulsating said slurry, a grid structure mounted transversely across said tank in a predetermined position and dividing the tank into the said upper portion and lower portion, said grid structure having a plurality of orifices providing fluid communication between the upper and lower portions of said tank, motor means operatively coupled to said movable means for successively and alternately imparting slow upward movement and relatively rapid downward movement to said movable means whereby the slurry in said tank in alternately moved slowly upwardly through said orifices and above said grid structure and rapidly downwardly through said orifices and means cooperating with said orifices in said grid structure and operative by the pulsations imparted to said slurry to allow fluid flow through the entire cross sectional flow aera of said orifices upon upward movement of said slurry but to effectively partially reduce the magnitude of the flow area through said orifices upon downward movement of said slurry to thereby temporarily trap a portion of said slurry above said grid structure and to establish a low pressure void immediately below said grid structure whereby slurry from above said grid structure is discharged through the effectively reduced flow area of said orifices in the form of jet streams of predetermined velocity, said orifices being approximately vertically disposed so that said jet streams project toward the free surface of said slurry below said grid structure to penetrate said slurry, a centrally disposed discharge being provided to withdraw concentrates collected above said grid structure and the upper face of said grid structure being sloped downwardly toward said discharge from the periphery of said tank to enhance movement of concentrates toward said discharge.

21. In an apparatus for separating particles suspended in a slurry in accordance with their densities, a tank for containing a slurry therein and having a slurry feed inlet, a discharge outlet for concentrates at a lower portion and a discharge outlet for waste at an upper portion, movable means operative in said lower portion of the tank for pulsating said slurry, a grid structure mounted transversely across said tank in a predetermined position and dividing the tank into the said upper portion and lower portion, said grid structure having a plurality of orifices providing fluid communication between the upper and lower portions of said tank, motor means operatively coupled to said movable means for successively and alternately imparting slow upward movement and relatively rapid downward movement to said movable means whereby the slurry in said tank is alternately moved slowly upwardly through said orifices and above said grid structure and rapidly downwardly through said orifices and means co-operating with said orifices in said grid structure and operative by the pulstations imparted to said slurry to allow fluid flow through the entire cross sectional flow area of said orifices upon upward movement of said slurry but to effectively partially reduce the magnitude of the flow area through said orifices upon downward movement of said slurry to thereby temporarily trap a portion of said slurry above said grid structure and to establish a low pressure void immediately below said grid structure whereby slurry from above said grid structure is discharged through the effectively reduced flow area of said orifices in the form of jet streams of predetermined velocity, said orifices being approximately vertically disposed so that said jet streams project toward the free surface of said slurry below said grid structure to penetrate said slurry, said means co-operating with said orifices in said grid structure comprising a plurality of orifice closure members associated with said orifices and movable relative to said grid structure by the pulsations of said slurry, said orifice closure members being of a shape and size relative to the area and shape of said orifices so as to be supported by the edges of said orifices and maintain a portion of said orifices open for passage of slurry therethrough, a screen like guard grille overlying said grid structure in sufficient proximity thereto confining said orifice closure members against upward flow but allowing limited free movement of said orifice closure members to permit fluid flow substantially through the entire flow area of said orifices, a centrally disposed discharge being provided to withdraw concentrates collected above said guard grille and said guard grille being sloped downwardly toward said discharge from the periphery of said tank to enhance movement of concentrates toward said discharge.

22. In an apparatus for separating particles suspended in a slurry in accordance with their densities, a tank for containing a slurry therein and having a slurry feed inlet, a discharge outlet for concentrates at a lower portion and a discharge outlet for waste at an upper portion, movable means operative in said lower portion of the tank for pulsating said slurry, a grid structure mounted transversely across said tank in a predetermined position and dividing the tank into the said upper portion and lower portion, said grid structure having a plurality of orifices providing fluid communication between the upper and lower portions of said tank, motor means operatively coupled to said movable means for successively and alternately imparting slow upward movement and relatively rapid downward movement to said movable means whereby the slurry in said tank is alternately moved slowly upwardly through said orifices and above said grid structure and rapidly downwardly through said orifices and means co-operating with said orifices in said grid structure and operative by the pulsations imparted to said slurry to allow fluid flow through the entire cross sectional flow area of said orifices upon upward movement of said slurry but to effectively partially reduce the magnitude of the flow area through said orifices upon downward movement of said slurry to thereby temporarily trap a portion of said slurry above said grid structure and to establish a low pressure void immediately below said grid structure whereby slurry from above said grid structure is discharged through the effectively reduced flow area of said orifices in the form of jet streams of predetermined velocity, said orifices being approximately vertically disposed so that said jet streams project toward the free surface of said slurry below said grid structure to penetrate said slurry, said means co-operating with said orifices in said grid structure comprising a plurality of orifice closure members associated with said orifices and movable relative to said grid structure by the pulsations of said slurry, said orifice closure members being of a shape and size relative to the area and shape of said orifices so as to be supported by the edges of said orifices and maintain a portion of said orifices open for passage of slurry therethrough, a screen like guard grille overlying said grid structure in sufficient proximity thereto confining said orifice closure members

against upward flow but allowing limited free movement of said orifice closure members to permit fluid flow substantially through the entire flow area of said orifices, a layer of particles having individual densities substantially greater than the density of said slurry being disposed over said guard grille.

23. The apparatus as defined in claim 22 wherein a layer of coarse bedding material is disposed over the top of said layer of particles, the density of said bedding material having a density approximately equal to the minerals to be recovered from said slurry.

24. In an apparatus for separating particles suspended in a slurry in accordance with their densities, a tank for containing a slurry therein and having a slurry feed inlet, a discharge outlet for concentrates at a lower portion and a discharge outlet for waste at an upper portion, movable means operative in said lower portion of the tank for pulsating said slurry, a grid structure mounted transversely across said tank in a predetermined position and dividing the tank into the said upper portion and lower portion, said grid structure having a plurality of orifices providing fluid communication between the upper and lower portions of said tank, motor means operatively coupled to said movable means for successively and alternately imparting slow upward movement and relatively rapid downward movement to said movable means whereby the slurry in said tank is alternately moved slowly upwardly through said orifices and above said grid structure and rapidly downwardly through said orifices and means co-operating with said orifices in said grid structure and operative by the pulsations imparted to said slurry to allow fluid flow through the entire cross sectional flow area of said orifices upon upward movement of said slurry but to effectively partially reduce the magnitude of the flow area through said orifices upon downward movement of said slurry to thereby temporarily trap a portion of said slurry above said grid structure and to establish a low pressure void immediately below said grid structure whereby slurry from above said grid structure is discharged through the effectively reduced flow area of said orifices in the form of jet streams of predetermined velocity, said orifices being approximately vertically disposed so that said jet streams project toward the free surface of said slurry below said grid structure to penetrate said slurry, and means for introducing media of selected density into said tank comprising a duct adapted to be connected to a source of media and extending into the interior formed by said tank and said movable means and terminating in an outlet below said grid structure, and a perforated hood disposed over said outlet to uniformly distribute liquid introduced through said duct into said tank.

25. The apparatus as defined in claim 23 wherein means are provided for removing of sands accumulating on top of said bedding comprising means forming an opening in the side of said tank above sand bedding and a plate structure having closed sides and an inclined portion extending downward from said tank from above said opening between said sides and terminating a predetermined height above said bedding.

26. Apparatus for concentrating finely ground particles in a slurry, including a tank for containing a slurry therein and having a slurry feed inlet, a discharge outlet for concentrates at a lower portion of the tank and a discharge outlet for waste at an upper portion of the tank, and means operative in said lower portion of the tank for successively pulsating said slurry at a differential of velocity respectively slowly upwardly and rapidly downwardly, the combination therewith of a planar orificed supporting pocket screen mounted laterally transversely across said tank and dividing the tank into the said upper portion and lower portion, said screen comprising a planar body having an upper face and a lower face which are relatively spaced by the planar body, said screen body having its planar area divided into separate pockets each adapted for separately receiving and holding a ball therein, the said separate pockets being open at said upper face and having an opening at said lower face of relatively smaller area than the upper opening, the side walls of said pockets being inclined upwardly and outwardly between the said respective upper and lower openings, and means overlying the pockets for limiting the upward movement of balls in the pockets beyond the confines of the pockets.

27. In apparatus for concentrating finely ground particles in a slurry, including a tank for containing a slurry therein and having a slurry feed inlet, a discharge outlet for concentrates at a lower portion and a discharge outlet for waste at an upper portion, and means operative in said lower portion of the tank for successively pulsating said slurry at a differential of velocity respectively slowly upwardly and rapidly downwardly, the combination therewith of a planar orificed supporting screen mounted laterally transversely across said tank and dividing the tank into the said upper portion and lower portions, said screen having separate pockets each provided with an orifice through which flows of slurry may be pulsated, a separate ball in each pocket, the said pockets being open at the upper planar portion and having the orifices thereof at a lower planar portion, said lower orifices of the pockets being of a shape and area relative to the size of the balls whereby the balls in the respective pockets may be supported by the edges of said lower pocket orifices and maintain a portion of said lower orifices open for passage of slurry therethrough, and a guard grille overlying the pockets in sufficient proximity thereto for confining balls in said pockets against the upward flow of the slurry.

References Cited in the file of this patent

UNITED STATES PATENTS

1,078,520	Stromberg	Nov. 11, 1913
2,138,810	Wood	Nov. 29, 1938
2,199,091	Pardee	Apr. 30, 1940
2,242,020	Wood	May 13, 1941
2,271,650	Kraut	Feb. 3, 1942
2,416,066	Phelps	Feb. 18, 1947
2,708,517	Evans	May 17, 1955