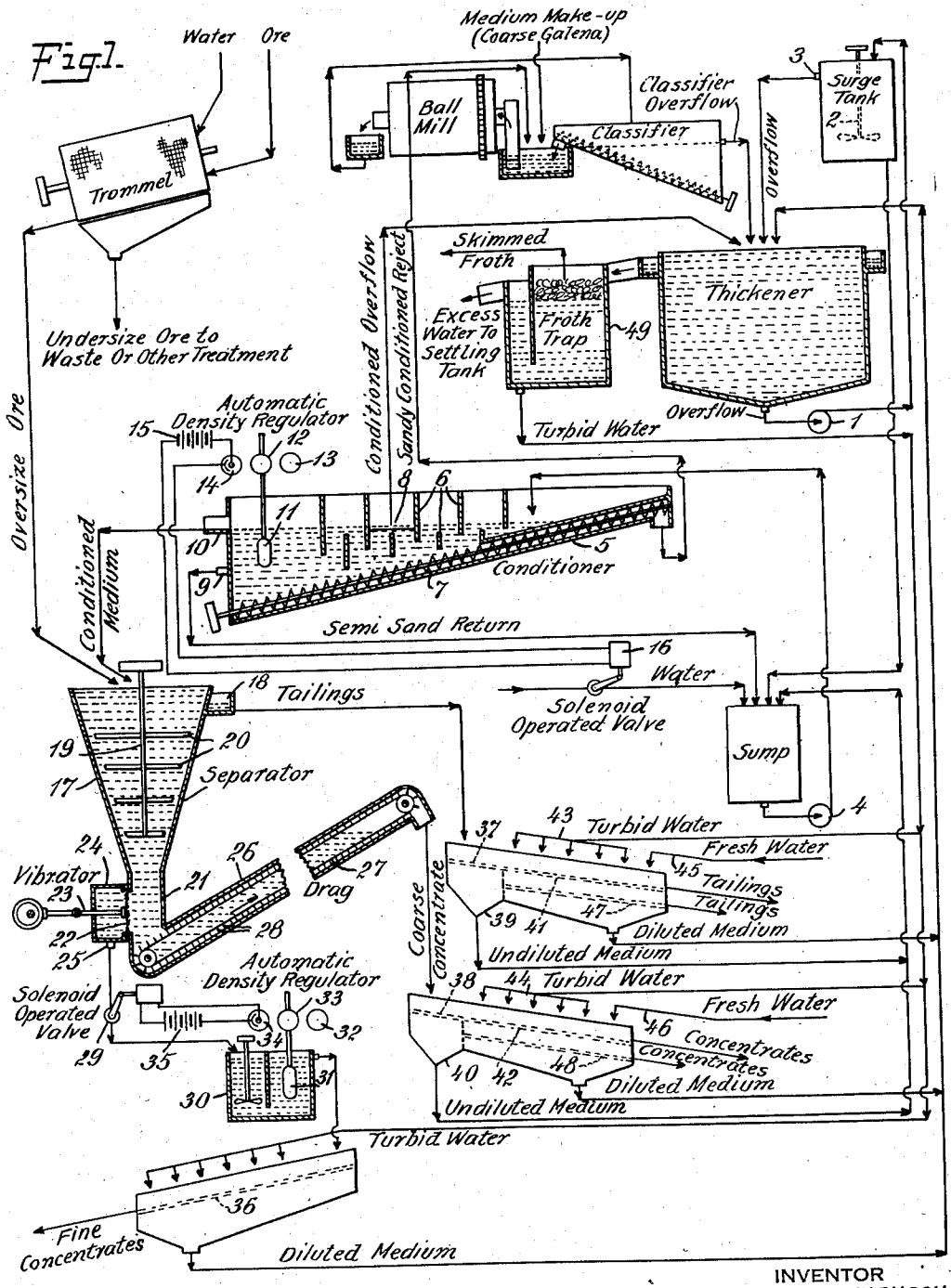
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CONCENTRATION

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Fig. 1.



INVENTOR
CHARLES ERB WUENSCH

BY
Pennie, Davis, Marvin and Edmonds
ATTORNEYS

Nov. 8, 1938. C. E. WUENSCH 2,135,957

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Filed April 8, 1935 2 Sheets-Sheet 2

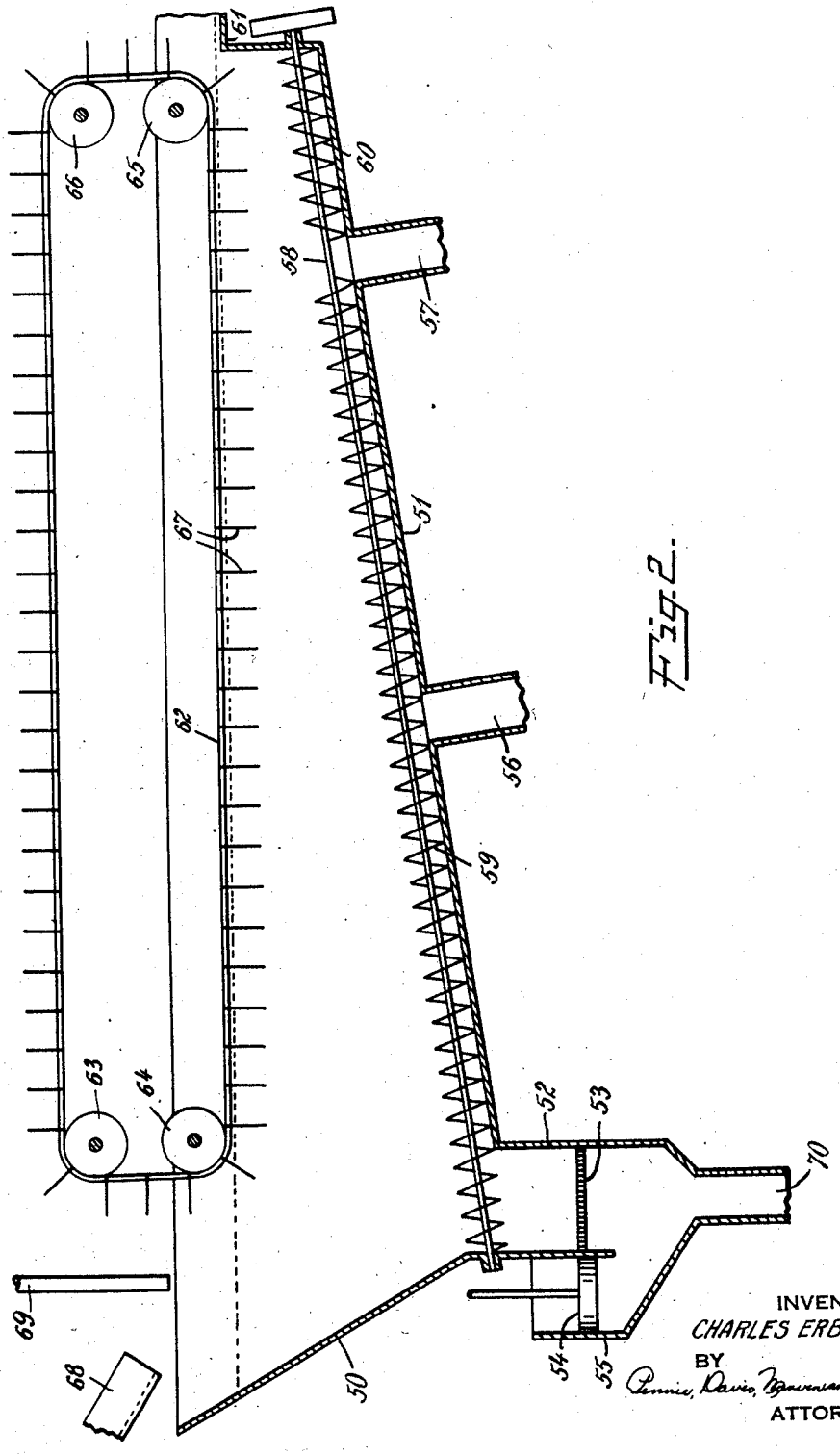


Fig. 2.

INVENTOR
CHARLES ERB WUENSCH
BY
Pennie, Davis, Marvin & Edmonds
ATTORNEYS

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CONCENTRATION

Charles Erb Wuensch, South Orange, N. J., assignor to Wuensch Hetero Concentration Process Company, Wilmington, Del., a corporation of Delaware

Application April 8, 1935, Serial No. 15,217

5 Claims. (Cl. 209—422)

This invention relates to the separation of heterogeneous mixtures of solid particles having different densities, and contemplates the provision of an improved method of and apparatus for effecting such separation. More specifically, the invention contemplates improvements in the separation of two or more minerals or other solids having different specific gravities by employing gravitational forces in the presence of a heavy fluid.

In the heretofore customary practice of ore dressing and allied arts, mixtures of mineral particles having different densities have been separated by adding the mixture to a fluid having a density intermediate the densities of the minerals to be separated. Under these conditions the mineral particles having a density greater than that of the fluid tend to sink, whereas mineral particles which are lighter than the fluid tend to float. The products are thus separated, and may be withdrawn separately from different zones in the fluid medium.

The term "fluid" is used here to include true liquids, such as aqueous salt solutions of high specific gravity and heavy organic liquids such as tetrabromethane ($C_2H_2Br_4$), as well as multiphased mixtures of finely divided solids with liquids, usually referred to as "suspensions".

Mineral separating processes employing heavy fluids have presented attractive possibilities because of their apparent simplicity, and promising results have been obtained when some of these processes have been employed in the laboratory under carefully controlled conditions. However, duplication of these results in commercial practice has been impossible except in rare instances. Processes employing heavy organic liquids such as tetrabromethane have not come into commercial use because the relatively high cost of such liquids usually requires a high initial investment and excess replacement costs, for in commercial operations a substantial loss of the separating medium is almost inevitable. Commercial application of processes that employ heavy salt solutions for mineral separation has been handicapped by the presence of at least three outstanding disadvantages:

(1) The capital expenditure involved in employing large volumes of such solutions.

(2) The cost of solution losses in the operation of the process.

(3) The fact that such solutions become contaminated or diluted in commercial use. In order to restore the solutions to the proper concentration, evaporation is necessary, and this entails large expense. Furthermore, removal of contaminants without removing the necessary salts which impart the necessary increase in density to the solutions is frequently impossible, and costly in any event.

Commercial examples of processes employing aqueous suspensions of finely divided solids in place of true heavy liquids have met with some success. Aqueous suspensions of finely ground clay, galena, hematite, barytes, silica, and mixtures of these and other minerals have been prepared. Such suspensions are not subject to the aforementioned objections in that they are less expensive, so that first cost and the cost of losses are relatively less. Suspensions possess a further advantage over true liquids in that they may be restored from a diluted state by settling or filtration, which are less expensive than the evaporation required to remove excess liquid from true solutions.

Accompanying these advantages which the use of suspensions afford there are, however, serious disadvantages. Unless the suspended solid particles are so fine as to be practically colloidal, they tend to settle out, so that the density through a column of the suspension varies. Unless means are taken to prevent such settlement, the delicacy of the separation is deleteriously affected, not only by the variation in density from top to bottom of the column, but also by the fact that the particles crowd into the bottom of the column, where instead of exerting an unimpaired and delicate buoyant effect, they form a mat which prevents separation of the heterogeneous mixture. Lastly, for any given density, a suspension is usually considerably more viscous than an equivalent true liquid, so that hindrance to separation may be excessive.

Separating processes employing suspensions have been at least partially successful in separating constituents having a marked difference in density. Thus, such processes have been employed for the separation of coal from slate and pyrite, but have failed to accomplish an adequate separation in commercial practice when there was but a slight difference in the density of the minerals to be separated. This failure may be attributable to the following and other factors:

(1) Improper average density of the suspension.

(2) Variation in density throughout the suspension.

(3) Excessive viscosity of the suspension.

(4) Coarse particle size of the solids comprising the suspension.

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g separation.
) Adhesion between the
ension and the particles
gate undergoing separati
(7) "Crowding", i
the minerals agg
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5

water valve. Because of the fact that the gelena slime delivered by the thickener will ordinarily be denser than is required for the separating medium leaving the lip of the conditioner, no automatic means for increasing the amount of solids added to the conditioner feed is required. In the event that such a procedure were necessary the hydrometer could be provided with a second shield (not shown), movement of which would actuate a second photoelectric cell circuit (not shown) which would in turn control the amount of solids admitted to the sump.

The requisite delicacy of the automatic density control will depend, of course, upon the difference in specific gravity between the minerals to be separated. When this difference is small the density regulator may be made correspondingly delicate by increasing the sensitivity of the hydrometer employed.

The mineral aggregate to be separated (designated on the flow sheet as "ore") is first screened and washed with water in an appropriate device such as a trommel, to remove the bulk of the fine material. The size of the material retained on the screen will depend in some measure upon the nature of the mineral aggregate. In the treatment of Joplin jig tailings containing about 1.5 to 2.0 percent of zinc in the form of sphalerite, it has been found that the material should range in size from ½ to ¾ inch down to 20 mesh (Tyler scale). The fines produced by the trommel may be wasted, or if the practice is economically justified they may be ground and treated by flotation or other appropriate methods. The oversize from the trommels in a clean and slightly moist condition is transported to a separator of novel design as shown on Fig. 1.

Washing the aggregate and supplying it to the separator in a slightly moist condition is desirable for several reasons, viz.

(1) Soluble contaminants are thus removed.

(2) Materials are removed which are too fine to be separated by heavy fluid methods because of the excessive surface exposed per unit of volume.

(3) The wet surfaces of the aggregate reduce any deleterious effect of adhesion between particles of the mineral aggregate and the particles comprising the suspension or medium, at the same time facilitating removal of entrained medium from the products made in the separator.

(4) The presence of a slight amount of moisture dilutes the medium in the top of the separator, thus permitting light minerals to be immersed in the medium in the first instance so that they do not form a floating mat which would block the fall of heavy particles which follow.

When only two products are to be separated, I prefer to employ a separator of the type illustrated in Fig. 1, comprising an inverted conical chamber 17, having a peripheral tailing trough 18 tangential to its upper edge and a concentric rotatable agitator 19 equipped with horizontally adjustable blades 20 positioned within it. The lower end of the conical chamber terminates in a substantially cylindrical pipe 21. A fine meshed screen 22 (say 25 mesh) is affixed on the side of the cylindrical pipe, and may be vibrated by an arm 23 which extends through a hutch 24. A drain pipe 25 is provided at the bottom of the hutch. The bottom of the pipe 21 is connected to a housing 26, which is inclined upwardly and extends to a point slightly above the top of the conical chamber. A conveyor 27 provided with scrapers 28 is positioned within the housing and serves to drag out coarse concentrates falling through the pipe 21.

The drain pipe 25 is equipped with a solenoid operated valve 29 and drains into an agitator box 30 in which a hydrometer 31 of an automatic density regulator is located. This density regulator is similar to that located at the conditioner outlet and comprises a light 32, a shield 33, a photoelectric cell 34, a current source 35 and the solenoid operated valve 29. The agitator box should be so constructed as to provide a quiescent zone for the hydrometer without, however, providing a space in which substantial settlement of solids can occur.

In operation, moist oversize from the trommel and medium of substantially constant density and consistency are run continuously into the top of the separator near its center. The agitator 20 is revolved slowly by a chain or other appropriate means. The peripheral speed of the blade tips should not exceed 150 feet per minute. Separation begins immediately, the light minerals tending to rise and flow outwardly due to buoyancy exerted by the medium of galena slime and to the slight centrifugal force induced by the agitator. Under the influence of these forces the light minerals, designated on the flow sheet as "tailings", pursue an ascending spiral path and overflow into the peripheral tailings launder accompanied by a portion of the medium. The heavier minerals or "concentrates" sink through the cone into the pipe 21, and come within the influence of the vibrating screen, the function of which is to prevent "crowding" or matting of the concentrates and of the galena particles. Unless the washing of the material from the trommel has been perfect and the ore is unusually hard so that no attrition occurs in the separator, a small amount of relatively fine heavy mineral particles will tend to settle along with a portion of the galena in the medium, thus increasing the "bottom density", aggravating the tendency for crowding, and thus interfering with the separation. The vibrating screen 22 is sufficiently coarse to permit the fine mineral particles (due to attrition or imperfect washing) together with coarse galena particles to pass out into the hutch 24 and thence through the drain pipe 25 and the valve 29 into the agitator box 30. The valve 29 is so constructed that it is never completely closed. When the density of the material draining out of the hutch rises to a predetermined point which indicates that crowding or excessive bottom density is about to occur in the pipe 21 or in the bottom of the conical chamber, the density regulator operates to open the valve still further and permit the outflow of the material which is about to cause the crowding. When the density of the material leaving the hutch returns to normal the hydrometer drops; the circuit of the density regulator is broken; and the valve, under the influence of an appropriate spring or counterweight, resumes its normal opening. It will be apparent that the feature of the invention whereby a portion of the medium contaminated with fine concentrate is continuously withdrawn from the separator at a rate depending upon the density of the material withdrawn is also applicable to processes in which the separating medium or heavy fluid is a true heavy liquid instead of a suspension.

When the amount of fine concentrate drained out of the hutch warrants recovery, or when the contamination which would result from the presence of the concentrate in the galena slime re-

turned to the separating circuit cannot be tolerated, outflow from the agitator box is washed in a screen 36 of appropriate mesh (say 50 to 80). The concentrate is retained on the screen and the undersize, consisting chiefly of dilute galena slime is returned to the thickener. If contamination of the medium equal in amount to this fine concentrate can be tolerated, and if the amount of this fine concentrate does not warrant recovery, the screen 36 can be eliminated and the outflow from the agitator box may be returned to the ball mill for further grinding, or to the thickener.

The coarse concentrates falling through the conical chamber and the pipe 21 are picked up by the conveyor and dragged out above the level of the medium in the drag housing. Some galena accompanies these coarse concentrates, so that drainage and washing on a screen are necessary. The coarse concentrates are removed from the upper surface of the screen and sent to further processing. The galena is returned to the circuit as hereinafter described.

The tailings are removed from the peripheral trough at the top of the separator and subjected to screening and washing to remove galena. The galena is returned to the separating circuit. The tailings (assuming that further treatment is not economical) are transported to the dump.

As shown on Fig. 1, the draining and washing of the concentrates and tailings in order to produce clean products and to recover the galena slimes are subjected to the following treatment:

The concentrate and tailings are transported respectively across screens 37 and 38 of appropriate mesh. Such medium as will drain off without the addition of water is permitted to pass through the screens into separate receptacles 39 and 40, and is returned in an undiluted condition to the sump. The drained concentrates and tailings next pass respectively over screens 41 and 42 under water sprays 43 and 44. The water for these sprays is the slightly turbid overflow from the thickener. The partially washed concentrates and tailings are given a final washing under fresh water sprays 45 and 46, and are discharged respectively from the screens 41 and 42 in a slightly moist condition, i. e. containing about 3 to 5% of water. The dilute medium products resulting from the dual washing treatment of concentrates and tailings are passed respectively through finer screens 47 and 48 (say 50–80 mesh) in order to remove any coarse material which would contaminate the medium circuit, i. e. the circulating suspension of galena. Because the screening of the ore is not perfect and because the screening and washing are advantageously conducted on moving or vibrating screens, some attrition occurs and a secondary screening of the dilute medium is usually necessary before it is returned to the circuit. In this way, the sandy material will not prevent the maintenance of optimum conditions in the separator. The sandy concentrates removed in this secondary screening operation are recovered. The sandy tailings are wasted, or subjected to further treatment. The dilute medium from which the sand has been removed is returned to the thickener.

Appropriate reagents to promote settling, such as lime or alum, may be added to the pulp in the thickener. In commercial operation, a small amount of oil almost inevitably leaks into the suspension or separating medium at some point in the circuit. If the solid or solids in suspension are amenable to flotation (as in the case with galena and many other minerals with metallic surface) there is a tendency for a mineral bearing froth to form on the surface of the thickener or at other points in the circuit. Froth formation is objectionable, but it may be minimized by adding appropriate depressing agents to the circuit.

The thickener overflow is run into a trap 49 from the top of which any froth may be skimmed. After appropriate treatment to remove oleaginous substance, the solid constituents of the froth may be returned to the medium or suspension. Water for the sprays employed in the first washing of the concentrate and tailings is withdrawn from the bottom of the trap. The controlled excess water overflows from the trap and is sent to settling ponds (not shown) or to other appropriate treatment, if the amount of suspended galena or other valuable solid is such as to warrant recovery. The bleeding off of this controlled excess water at this point prevents an undue accumulation of deleterious soluble contaminants in the circuit.

In the event that the mineral aggregate undergoing treatment is such that more than two classes of products should be separated from each other, I prefer to employ a novel separating apparatus of my invention as illustrated in Fig. 2. This apparatus comprises a trough 50 having a gently sloping bottom 51, and adapted to be partially filled with the separating medium or suspension employed. Underneath the deep end of the trough is located a jig chamber 52 equipped with a screen 53 of such mesh that a jig bed of concentrates will be retained thereon. A movable piston 54 operating in a box 55 which communicates with the jig chamber serves to pulsate the bed on the screen. Two middling traps 56 and 57 are located in the bottom of the trough intermediate the ends thereof. A screw conveyor 58 extends lengthwise along the bottom of the trough and is provided with a helix 59 on its lower portion and a helix 60 on its upper portion. The helix 59 is adapted to move aggregate which settles to the bottom of the trough following the jig upwardly to middling traps 56 and 57. The helix 60 is adapted to move material settling in the upper portion of the trough downwardly to the middling trap 57. An overflow 61 is provided at the shallow end of the trough. A drag conveyor 62 supported by pulleys 63, 64, 65 and 66 and provided with blades 67 is positioned within and above the trough. The blades on the lower portion of the drag conveyor are adapted to be partially immersed in the contents of the trough and are adapted to move continuously and slowly toward the shallow end thereof.

Mineral aggregate is supplied to the lower end of the trough through a chute 68 located at a point such that the aggregate will tend to fall into and not beyond the pulsating current induced by the jig. The separating medium (an aqueous suspension of galena, for example) is supplied to the deep end of the trough through a conduit 69 in amount sufficient to maintain the level of the contents of the trough approximately constant. Concentrates fall into and through the jig chamber and the screen into a concentrate trap 70, from which they are withdrawn together with some of the separating medium or suspension. Middlings fall to the bottom of the trough and are moved to the middling traps by the screw conveyor. Tailings overflow into the shallow end

of the trough together with some of the medium.

The function of the drag conveyor is to supplement the natural current in the shallow end of the trough and to prevent "crowding".

In the event that only three products are desired, the middling trap 56 may be omitted. Should more than three products be desired, additional product traps may be provided in the bottom of the trough.

The separating apparatus illustrated in Fig. 2 is adapted to be substituted for the conical separator shown in Fig. 1, when a multiple separation is desired.

It will be understood that my invention is not limited to the use of a separating medium of suspended galena. Any appropriate solid may be substituted for galena. Thus, an aqueous suspension of hematite, barytes, pyrite, silica, clay, etc., or combinations thereof may be employed depending upon the respective densities of the minerals to be separated.

It will also be understood that the application of my invention is not limited to a case in which the specific gravity of the medium is intermediate the specific gravity of two minerals which are to be separated. By appropriate control, a plurality of minerals which are either heavier or ligher than the medium may be separated from each other for the reason that these minerals will rise or fall in the medium with different velocities and thus become separated. The apparatus illustrated in Fig. 2 is particularly adapted to such practice.

I claim:

1. In an apparatus of the character described, a tank having a bottom sloping toward one end of the tank, means for admitting material to be concentrated into the tank, a concentrating cell in the sloping bottom of the tank and supporting a bed of the material with the top surfaces thereof extending in a plane substantially parallel with the bottom of the tank, means movable over the cell to effect removal of the lighter material while the heavier material in said bed moves to the opposite side of the cell, and means for pulsating water through the bed in the cell to promote separation of the light and heavy materials.

2. In an apparatus of the character described a tank having a sloping bottom, a jig chamber opening into the bottom of the tank, means for pulsating the contents of the jig chamber, and means disposed adjacent the sloping bottom of the tank and above the opening of the jig chamber into the tank for conveying settled material along the slope.

3. In an apparatus of the character described an elongated tank having a bottom sloping lengthwise of the tank, a jig chamber opening into the bottom of the tank, means for pulsating the contents of the jig chamber in an upward direction, a screen in said jig chamber for retaining a bed of coarse solids, a conveyor for solids disposed lengthwise of the tank adjacent the sloping bottom and above the opening of the jig chamber into the tank for moving solids along the sloping bottom, means for introducing liquid into the tank, means for introducing solid particles to the tank, and means for withdrawing separated products from opposite end portions of the tank.

4. Apparatus for effecting the separation of heterogeneous mixtures of relatively coarse solid fragments in the presence of a heavy fluid which comprises a chamber, means for introducing the heterogeneous mixture into the chamber, means for introducing the heavy fluid into the chamber, means for vibrating the contents of the lower portion of the chamber, means for withdrawing relatively light coarse fragments from an upper portion of a chamber, means for withdrawing relatively coarse heavy fragments from a lower portion of the chamber, a conduit connected to the lower portion of the chamber, screening means near the inlet of the conduit to prevent the entrance of relatively coarse heavy fragments thereinto, a valve in said conduit and means for varying the setting of the valve in response to variations in the density of material passing through said conduit.

5. Apparatus for effecting the separation of heterogeneous mixtures of relatively coarse solid fragments in the presence of a heavy fluid which comprises a chamber, means for introducing the heterogeneous mixture and the heavy fluid into said chamber, means for continuously withdrawing relatively light coarse fragments from an upper portion of the chamber, means for withdrawing relatively coarse heavy fragments from a lower portion of the chamber, a conduit connected to a lower portion of the chamber, a screen disposed adjacent the inlet to said conduit for preventing the entrance of relatively coarse fragments into the conduit, a valve disposed in said conduit, and means for varying the setting of the valve in response to variations in the density of a mixture of heavy fluid and relatively fine fragments removed from the chamber through the screen.

CHARLES ERB WUENSCH.