Dec. 11, 1934. W. G. CLARK 1,983,968

ORE CONCENTRATION

Original Filed Jan. 22, 1931 3 Sheets-Sheet 1

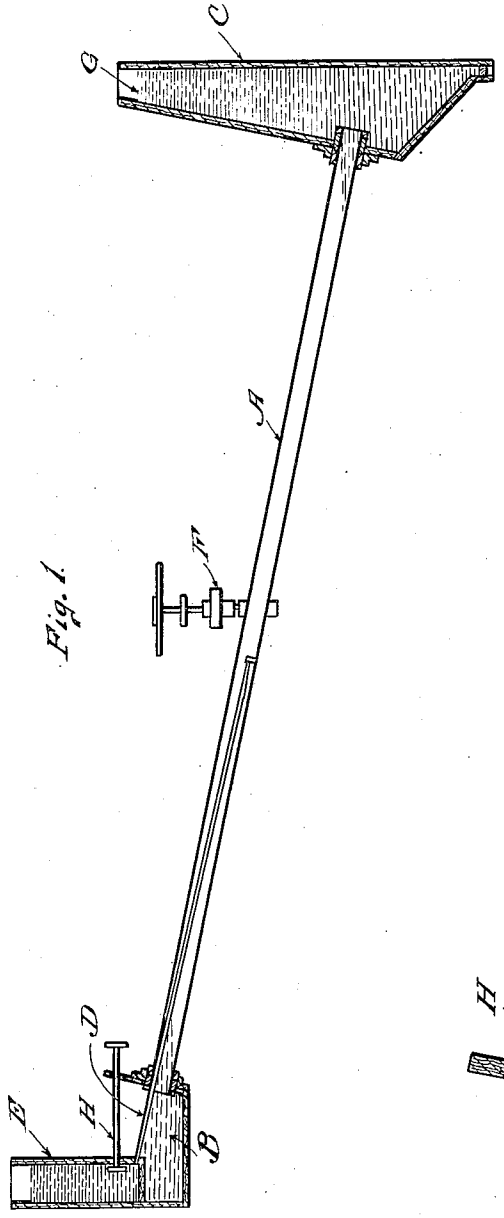


Fig. 1.

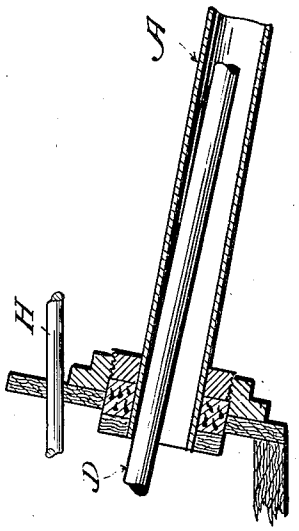


Fig. 1A

Inventor
Walter G. Clark,
By G. M. Houghton
his Attorney

Dec. 11, 1934. W. G. CLARK 1,983,968

ORE CONCENTRATION

Original Filed Jan. 22, 1931 3 Sheets-Sheet 2

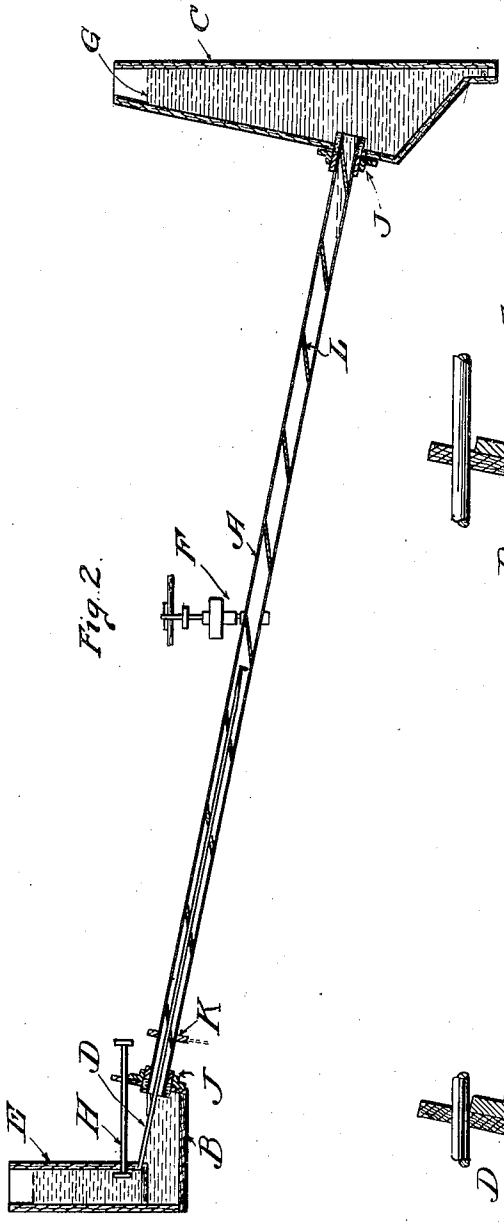


Fig. 2.

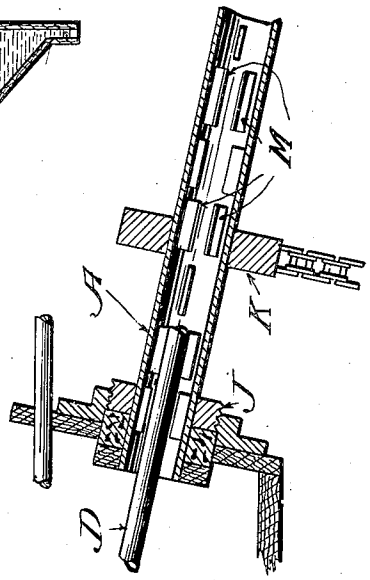


Fig. 2B.

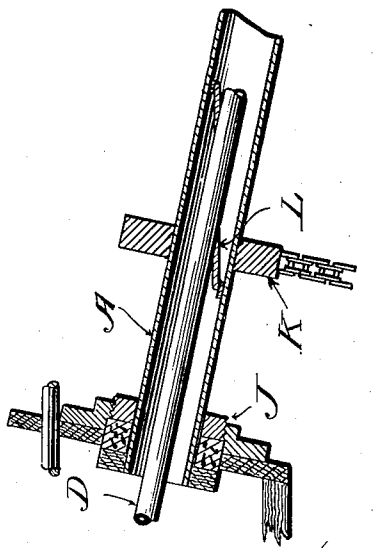


Fig. 2A

Inventor
Walter G. Clark,
By A. M. Houghton
his Attorney

Dec. 11, 1934. W. G. CLARK 1,983,968

ORE CONCENTRATION

Original Filed Jan. 22, 1931 3 Sheets-Sheet 3

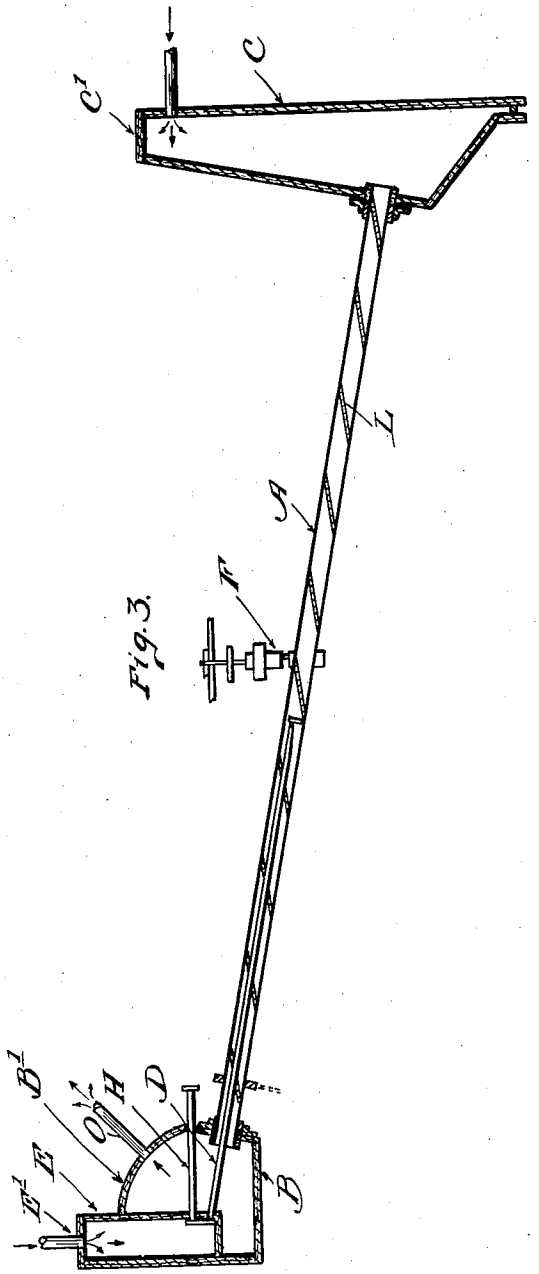


Fig. 3.

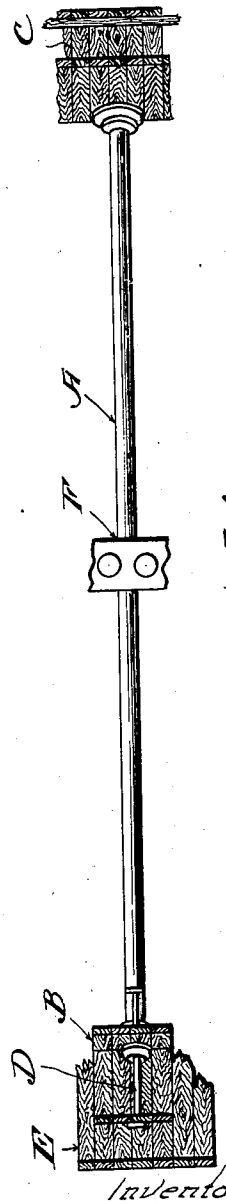


Fig. 3-A



Fig. 7.



Fig. 6.



Fig. 5.



Fig. 4.

Inventor
Walter G. Clark,
By A. M. Houghton
his Attorney.

Patented Dec. 11, 1934 1,983,968

UNITED STATES PATENT OFFICE

1,983,968

ORE CONCENTRATION

Walter G. Clark, Los Angeles, Calif., assignor to F. R. Feitshans, trustee

Application January 22, 1931, Serial No. 510,549
Renewed June 13, 1934

17 Claims. (Cl. 209—437)

This invention relates to ore concentration; and it comprises a method and means for separating solids of differing specific gravity wherein and whereby such solids in fine particles are fed into a receptacle inclined from the horizontal and the particles are subjected to vibration of the receptacle in a substantially transverse vertical direction in nodal waves while water or other carrier fluid is passed through the receptacle in a direction upward of the inclination of the receptacle substantially at right angles to the direction of vibration; all as more fully hereinafter set forth and as claimed.

Ore concentration by force of gravitation is usually accomplished in one of the three methods known as (1) jigging, (2) table concentrating, and (3) flotation.

In the first of these methods the materials to be separated are fed into a container having a perforated bottom and the container is given a reciprocating vertical motion while submerged in water caused to move through the materials in a direction usually approximately parallel to the reciprocating motion. In another of the jigging type of concentrators the water itself is pulsated while the container remains stationary.

In the second or concentrating table method the ore is fed onto an open inclined table or belt and thereon is subjected to a jarring or shaking motion in the presence of a downward flow of water over the table, the segregation or classification of the ore particles of different gravities being a function of the angle of inclination of the table and the velocity of water flow over the table.

In the third or flotation method the ore is treated with a liquid of specific gravity different from that of a carrier liquid and selective floating of individual particles coated by the treating liquid brings about the desired separation.

Sometimes the jig method and the table method are combined, the ore under treatment being subjected to a horizontal shaking motion while the carrier liquid is passed in a pulsating current upward through the perforations in the floor of the table. Here the action of the carrier liquid is similar to that in the jig method while the shaking motion is similar to that usually employed in the table method.

The above sketched devices leave much to be desired in sharpness of separation of ore constituents of different gravities, in simplicity and economy of operation, and in capacity per unit of installation cost.

In the present invention the desired separation is accomplished by subjecting the materials to controlled vibration in a substantially vertical direction in the presence of a carrier fluid such as water moving across the surface of the vibrating mass in a direction approximately at right angles to the direction of the force of gravity and to the direction of vibration. So doing, the ore, in particles desired to be separated, is introduced into one or more elongated receptacles such as a tube or trough inclined at a predetermined angle from horizontal and the receptacle is caused to vibrate sharply in a vertical direction, that is, transversely at right angles to its axis and to the surface of the ore mass therein, the vibration being transmitted in waves running along the length of the receptacle. During such vibration the carrier liquid, usually water, is caused to flow through the receptacle from the lower to the upper end. When the vibration of the receptacle is adjusted at the proper frequency and intensity, standing waves or mounds are produced in the finely divided ore under treatment, and the particles of higher specific gravity drop downward across the receptacle toward the bottoms of the mounds while the particles of lower specific gravity move transversely upward toward the tops of the mounds, this effect constituting the first stage of the separation. The mounds or piles of moving ore particles act in effect as a series of separate concentrating zones in which the particles are successively classified and reclassified with the heavier particles at the bottom and the lighter particles on top. As the lighter particles reach the surface of the wave mounds they are carried upwardly from mound to mound and thus along the length of the receptacle by the water current which moves in a direction opposite to the major movement of the heavier particles down the floor of the receptacle under the influence of gravity. Under the combined influences of the vertical vibratory waves, of gravity and of water current the lighter particles are propelled upward through the receptacle and are discharged from the upper end while the heavier particles travel downwardly and reach the lower end where they may be collected.

It will be understood that the movement of the individual particles is a resultant of the combined action of gravity and of the carrying power of the water current flowing upwardly through the receptacle. Particles of a specific gravity, size, and shape such that their fall under the influence of gravitational force is substantially modified in direction by the float-

ing power of the water current are carried upward of the receptacle inclination and particles not capable of being carried by the water current proceed downward. Successive impulses for the upward and downward particle movement along the length of the receptacle are given by the vertical movement imparted to the particles by the vibratory waves of the receptacle. The vibration overcomes the mutual hindrance of the particles and allows the heavier particles to move downward under the force of gravity overbalancing the carrying power of the water current while the lighter particles after being propelled upwardly across the receptacle by the vibration are carried up the inclination of the receptacle by the force of the water current. With the receptacle inclined at the proper angle and the flow of water adjusted to the proper velocity the ascending current of water picks up vibrating particles having a gravity below a predetermined maximum and carries them in progressive steps to the upper end of the receptacle from which they can be discharged for disposal as desired. The lighter and the heavier particles dance, so to speak, to the upper and lower ends of the receptacle, respectively.

The described invention is adaptable to the treatment of widely varying materials. The inclined vibrating receptacle may advantageously be in the form of a tube and the angle of inclination of the tube may be varied for the purpose of carrying particles of increasing or decreasing gravity upward through the tube. It has been found that for many materials an angle of about 12 to 15 degrees is suitable. For other materials requiring relatively high ratios of concentration the angle may be as low as 3 degrees. For materials where a lesser ratio of concentration is desired the angle may range up to 35 degrees. The length and size of the tube may be varied for different materials. Adjustment for treating different materials and for changing the concentration ratio is possible through regulation of the velocity of water flow upward through the tube. Usually a moderate lineal velocity of water flow is used and it may be varied as desired. The greater the velocity of water flow the greater is the proportion of material propelled to the upper end of the tube and the greater the concentration ratio resulting from the treatment. It has been found in concentrating ores of various kinds that the present invention effects a relatively high ratio of concentration with a high yield of values in the concentrates and at the same time a relatively high rate of throughput.

When a trough is used as the inclined vibrating receptacle it may have sides of such height as to permit passing water upwardly through the trough without spilling water at the lower end. In any case the floor of the receptacle should be longitudinally inclined from the horizontal, the flow of water is upward of this inclination and the vibration imparted to the ore particles is in a direction substantially at right angles to the floor.

My invention is particularly efficient in that the mass of particles is subjected to strong agitation in each of many internodes. The entering ore is first subjected to agitation in the center of the tube, the lightest particles rising towards the top of the mass and being carried upward in the tube by the current of liquid. The remaining mass then passes through a quiet node to another internode where the same process is repeated; separation and reconcentration taking place at a series of internodes extending both upwardly and downwardly from the center of the tube, the light particles concentrating at the top of the tube by the action of the liquid and the heavy particles concentrating at the bottom of the tube by the action of gravity.

I have found that many materials can be economically separated, as described, in a non-rotating, elongated vibrating tube while for other materials better results can be obtained by rotating the tube during its vibration. For materials containing clay or similar matter, it is desirable to rotate the tube and for some materials it is advisable to provide internal projecting fins or vanes or an angular or spiral flight to direct the movement of the materials, thereby increasing the area in contact with the carrier water and holding the materials in contact with the carrier water for a greater period of time.

It is also possible to adapt the cross-section of the tube to the physical characteristics of the materials under treatment. This cross-section may be oval or triangular or rectangular or a combination of angles or curves. When it is desired to rotate tubes of a cross-section other than circular, the ends of the tubes are made of circular section to permit of rotation in packing glands or in fluid tight bearings.

In the accompanying drawings I have shown more or less diagrammatically apparatus within my invention. In this showing,

Fig. 1 is a vertical longitudinal section partly in elevation of a tubular ore concentrator;

Fig. 1A is a detail of the upper end of the tube of the concentrator of Fig. 1 showing the ore feed pipe;

Fig. 2 is a view similar to that of Fig. 1 of a concentrator having a modified tube construction;

Fig. 2A is a detail of the upper end of the tube of Fig. 2;

Fig. 2B is a detail similar to Fig. 2A of the upper end of another tube modification showing vanes within the tube;

Fig. 3 shows a sectional elevation of an ore concentrator in a modification adapted to operation under substantial liquid pressure;

Fig. 3A is a plan view of an ore concentrator;

Figs. 4, 5, 6 and 7 are diagrammatic tube sections of triangular, oval, rectangular and hexagonal shape respectively.

Referring to the drawings, tube A is connected at its upper end with discharge box B and at its lower end with container C kept full of water to the level G which is higher than the water level in box B. Into tube A at its upper end ore feed pipe D extends, as shown, nearly half way through the tube or to a point somewhat above the center. Pipe D runs from ore receptacle E which contains water up to a level well above level G in container C. Receptacle E is provided with a valve H controlling the flow of water and ore into pipe D. At about half way between the ends of tube A is placed vibrator F which may be operated by a pulsating or alternating electric current generating intermittent magnetic impulses acting on tube A. If desired however vibration may be produced by means of a gear or a cam or hammer type of vibrator operating at a desired frequency. The vibration applied is transmitted in waves running along the wall of tube A and thus to the particles of material in all parts of the tube.

In operation, ground ore, or other finely divided material to be subjected to a separatory treatment, is fed into tube A through pipe D by means of a water flow introduced into receptacle E. At the same time the water flows from container C through the tube upwardly into discharge box B and with vibrator F in operation at a rate of vibration and with an intensity or length of vibration which may be controlled as desired, the ore particles vibrate vertically in a series of standing waves and during their vibrations the particles are classified and, as it were, dance upward and downward relative to the tube length, being thus propelled by the force of gravity modified by the force of the upward current of water in tube A. The lighter particles are propelled upwardly through the tube and are discharged into discharge box B while the heavier particles move downward under the force of gravity to the lower end of the tube and collect in container C. As is well known a rod or pipe fixed at each end vibrates in a manner similar to a wire under tension and such vibration in this instance takes place between fixed nodal points which are indicated by the location of the piles or mounds of material in the tube. In the described arrangement, the frequency and intensity of vibration set up by vibrator F, the angle of tube A, the feed through tube D, the velocity of the carrier current from container C to discharge box B, all are subject to control and the apparatus can be adjusted in design to the fineness of the material to be treated and to the variation in specific gravity of the constituent particles. This affords a high yield or a sharp separation on a small difference of specific gravity between constituents.

In Figs. 1 and 1A the feed pipe D is shown as entering the upper end of tube A at a small angle of inclination to the tube length.

In Fig. 2 tube A is shown as mounted in box B and container C through packing glands or stuffing boxes J—J and also as equipped with sprocket wheel, (or gear or pulley) K by means of which tube A may be caused to rotate while being vibrated. Tube A is here shown also as equipped with an internal spiral flight L which has the effect of extending the length of the path of travel of the materials under treatment, without adverse effect upon the arrangement of the material in piles under the influence of the vibratory nodal waves imparted to the tube by vibrator F. In Fig. 2B, tube A is shown as equipped with vanes M which may, as indicated, be either continuous or interrupted. In Figs. 2A the feed pipe D is shown as being concentric with tube A.

In the modification shown in Fig 3 container C is closed at the top and receptacle E and discharge box B are also closed so as to permit flowing of the water through the apparatus under pressure. In this modification the ore and water are forced through feed pipe D into tube A and water may be pumped under pressure into container C to produce any desired velocity of flow through pipe A, the water being discharged from the top of box B through pipe O.

The various cross-sectional shapes for tube A as shown in Figs. 4 to 7 are adapted to meet different conditions imposed by different materials. The triangular shape of Fig. 4 has been found to be a desirable tubular cross-section when separating materials carrying a small proportion of exceedingly heavy constituents such as gold or platinum in a large proportion of light alluvial or sedimentary matter. The oval shape of Fig. 5 has been found to be desirable when handling materials carrying approximately equal proportions of light and heavy constituents, that is when the relative proportions discharged into discharge box B and into container C are approximately equal. The rectangular and hexagonal sections of Figs. 6 and 7 have been found to be desirable when separating materials carrying clay, bentonite or similar adhesive matter requiring greater agitation while under treatment.

It will be understood that other carrier fluids than water can be used, for example, some materials can be subjected to treatment using a salt solution for carrying comparatively heavy particles upward through the tube. For some materials a light oil is a satisfactory carrier fluid. The apparatus modification illustrated in Fig. 3 is adaptable to use with a gaseous carrier fluid. A plurality of inclined tubes operated in parallel under pressure is often advantageous.

What I claim is:

1. In the separation of solids of differing specific gravity, an apparatus comprising an elongated open ended tube rigidly supported at each end and inclined at a predetermined angle from the horizontal, means for imparting to the tube axially transverse nodal wave vibrations, means for flowing water through the tube from the lower to the upper end and means for feeding said solids into the tube above its center.

2. In the separation of solids of differing specific gravity, an apparatus comprising an elongated open ended tube rigidly supported at each end and inclined at a predetermined angle from the horizontal, means for imparting to the tube axially transverse nodal wave vibrations, means for flowing water through the tube above its center from the lower to the upper end, means for feeding said solids into the tube, and means for rotating the tube about its axis.

3. Apparatus for separating solids comprising an open ended elongated tubular member inclined at an angle from horizontal and in communication at its lower end with a water container adapted to force water upwardly through the tubular member, a feed pipe for delivering solid material into said member between its center and its upper end and means for causing vertically transverse nodal vibrations in the tubular member.

4. Apparatus as specified in claim 3 in which the tubular member is provided with internal flights adapted to increase the surface of contact between the water and the tubular member.

5. Apparatus as specified in claim 3 in which the tubular member is provided with means for rotating the same about its longitudinal axis.

6. Apparatus as specified in claim 3 in which the feed pipe is arranged to deliver the solid material at a point near the center of the tubular member.

7. An ore concentrator comprising in combination an open ended elongated chamber member inclined at an angle from the horizontal, a water container in communication with said member at its lower end and adapted to force water through said member, a discharge box in communication with said member at its upper end, a vibrator near the center of said member

adapted to set up therein vertically transverse nodal vibrating waves and a feed pipe arranged in the upper portion of said member to deliver ore near the center thereof, said member being adapted to discharge the heavier and lighter ore particles respectively into the water container and the discharge box.

8. A method of separating particles of different densities from a mixed mass thereof which comprises establishing and maintaining an elongated mass at an angle to the horizontal, establishing and maintaining an upward current of liquid flowing over the surface of the mass, said current being of sufficient velocity to carry forward lighter particles with it while permitting heavy particles to move downward thereagainst, and vibrating the mass to produce a succession of fixed nodes and alternate internodes, the vibrations being sufficiently energetic to cause violent agitation of the mass with separation of denser and lighter particles in the internodes and re-collection in the nodes with the lighter components at the top of the path of the stream of liquid.

9. A method of separating a mixed mass of particles of different densities which comprises establishing and maintaining an elongated mass thereof at an incline from the horizontal, vibrating said mass by means of controlled waves establishing a series of fixed nodes and alternate internodes therein and establishing and maintaining a current of fluid over the mass, said current being of sufficient velocity to carry lighter particles without disturbing denser particles up the incline.

10. A continuous method of ore concentration which comprises establishing and maintaining an elongated mass of finely divided ore at an angle to the horizontal, flowing a current of liquid over said mass in an upward direction and vibrating said mass by means of controlled waves establishing a series of fixed nodes and alternate internodes, said current being of sufficient velocity to carry said lighter particles upward with it past the successive nodes and internodes and finally remove them at the top and said vibrations being of sufficient intensity to cause the heavier particles, under the influence of gravity, to move downward against the current through the series of alternate nodes and internodes to the bottom of the mass where they are removed.

11. A method of ore concentration which comprises establishing and maintaining an elongated mass of finely divided ore at an incline from the horizontal, vibrating said mass by means of controlled waves establishing a plurality of fixed nodes with alternate internodes therein so as to form nodal mounds of ore with lighter particles at the tops of the mounds and heavier particles at the bottoms and establishing and maintaining a current of liquid of predetermined velocity over said mass so as to carry lighter ore particles up the incline and to permit heavier particles to progress down the incline.

12. In a method of separating a mass of particles of different densities comprising agitating an enlongated mass thereof and removing the lighter particles by a stream of liquid, the step which comprises setting up fixed nodes and internodes of vibration in the mass by means of controlled wave vibrations so as to form mounds of ore at the nodes with segregation of denser particles at the bottoms of the mounds and particles of lesser density at the tops.

13. In a method of ore concentration comprising subjecting an elongated mass of finely divided ore to agitation and removing the lighter particles by a stream of fluid, the step which comprises vibrating the mass by means of controlled waves establishing a series of fixed nodes and alternate internodes in the mass.

14. A method of separating a mass of particles of different densities according to claim 8 in which the vibration of the particles takes place in a direction transverse to the length of the mass.

15. A method of ore concentration according to claim 10 in which the vibration of the particles takes place in a direction transverse to the length of the mass.

16. The process of separating particles of different densities which comprises establishing and maintaining an elongated, inclined mass thereof, subjecting such mass to vibratory action whereby the particles tend to move downwardly and also to separate with the lighter components at the top, simultaneously subjecting the particles of said mass to an upwardly moving current of fluid in such quantities and at such rate as to permit the heavier particles to travel downwardly and concentrate at a low point in said mass and to cause the lighter particles to travel in an opposite direction and concentrate at a high point in the mass, and separately collecting the heavier and lighter particles.

17. The process of separating particles of different density which comprises continuously feeding a mixture of such particles to establish a moving stream thereof, confining said stream to cause the particles to travel an inclined relatively narrow and elongated path, the tendency of the particles being to travel downwardly along said path, subjecting the moving mixture to vibratory action while simultaneously causing a current of fluid to flow upwardly along said path under conditions permitting progression of the heavier particles towards the lower end of the inclined pathway and causing progression of lighter particles towards the upper end of the pathway with consequent removal of the heavier particles from said path at a point below the point of feed and removal of lighter particles at a point above the point of feed.

WALTER G. CLARK.

CERTIFICATE OF CORRECTION.

Patent No. 1,983,968. December 11, 1934.

WALTER G. CLARK.

It is hereby certified that error appears in the printed specification of the above numbered patent requiring correction as follows: Page 3, second column, lines 42-43, strike out the words "above its center" and insert the same after "tube" and before the comma in line 9, of said claim; and that the said Letters Patent should be read with this correction therein that the same may conform to the record of the case in the Patent Office.

Signed and sealed this 12th day of February, A. D. 1935.

Leslie Frazer
Acting Commissioner of Patents.

(Seal)