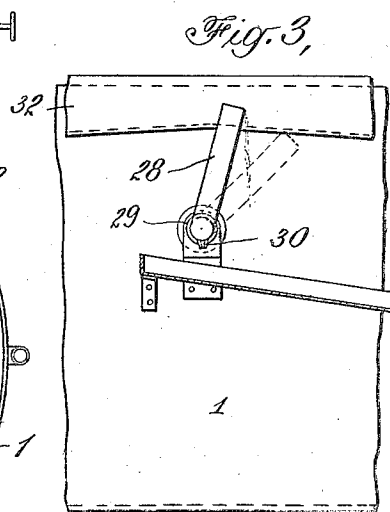
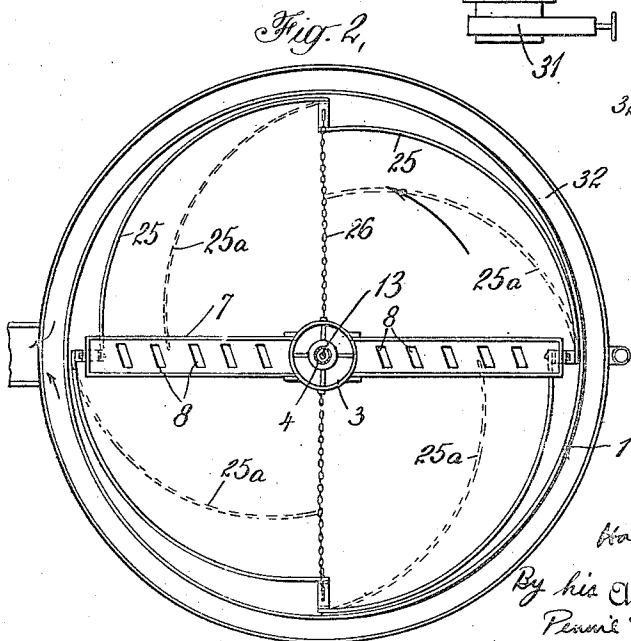
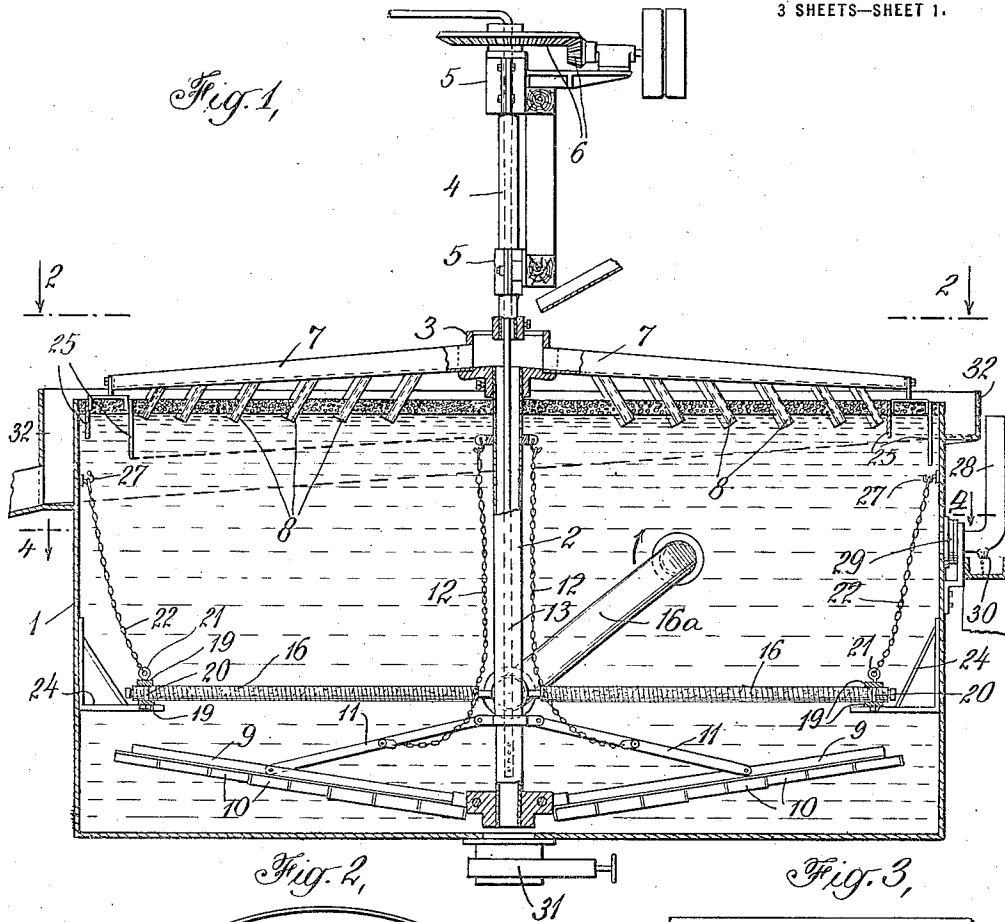


H. R. ROBBINS.
METHOD OF CONCENTRATION OF ORES.
APPLICATION FILED OCT. 21, 1919.

1,398,394.

Patented Nov. 29, 1921.

3 SHEETS—SHEET 1.



Walter Rice Robbins, Inventor

By his Attorneys
Perrin Davis, Marvin & Edmunds

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Fig. 4.

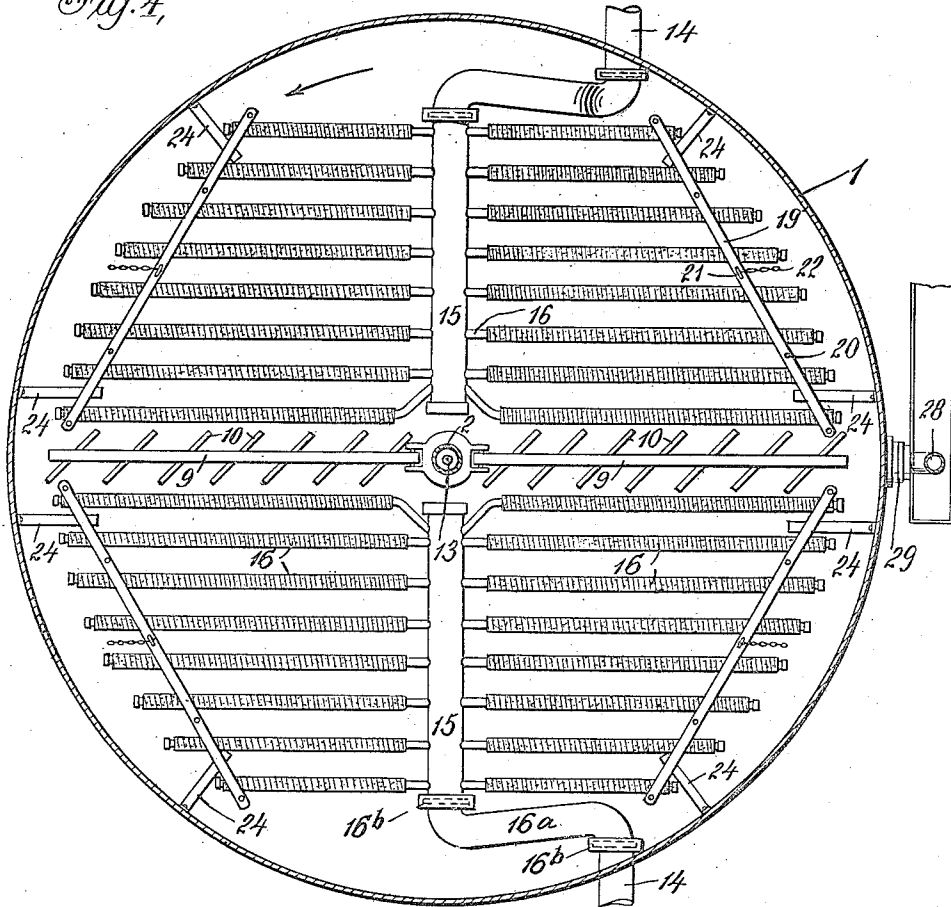


Fig. 5.

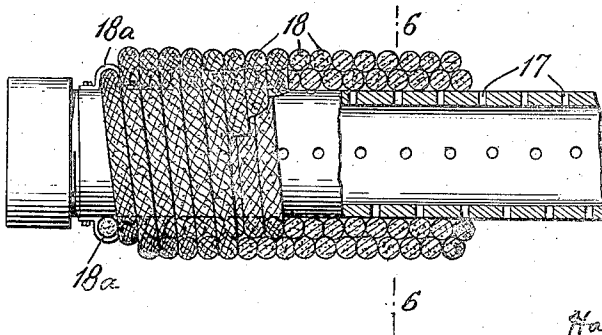
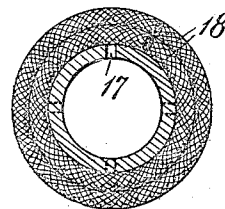


Fig. 6.



Hallet Rice Robbins Inventor

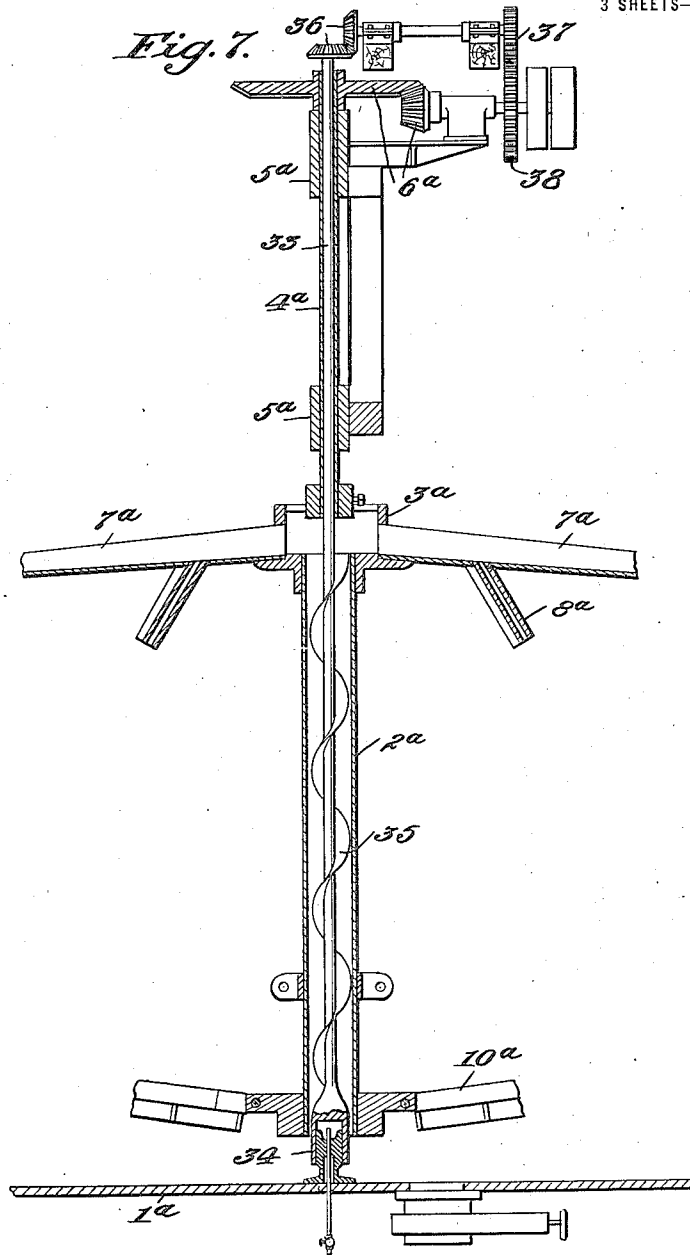
By his Attorneys
Bernie Davis Morris & Edmunds

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3 SHEETS—SHEET 3.



Inventor:
Hallet R. Robbins,

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UNITED STATES PATENT OFFICE.

HALLET RICE ROBBINS, OF MANCHESTER, NEW HAMPSHIRE.

METHOD OF CONCENTRATION OF ORES.

1,398,394.

Specification of Letters Patent.

Patented Nov. 29, 1921.

Application filed October 21, 1919. Serial No. 332,345.

To all whom it may concern:

Be it known that I, HALLET RICE ROBBINS, a citizen of the United States, residing at Manchester, in the county of Hillsborough, State of New Hampshire, have invented certain new and useful Improvements in Methods of Concentration of Ores; and I do hereby declare the following to be a full, clear, and exact description of the invention, such as will enable others skilled in the art to which it appertains to make and use the same.

My invention relates particularly to a process for the concentration of ores by the froth flotation process, in which the constituents of ores are separated as a froth formed by the aeration of a liquid pulp consisting of the finely-ground ore and water, modified by the presence of a flotation agent, such as finely-divided emulsified or dissolved oils, or dissolved organic compounds or inorganic salts; but is also well adapted for other chemical, physical or metallurgical operations requiring efficient circulation and aeration of liquids or semi-liquids.

Among the objects of my invention are the provision of an apparatus and process which will be cheap both to install and to operate; efficient mechanically and metallurgically; adjustable to the varying conditions demanded by ores of differing physical and chemical characteristics; or by substances other than ores; and suited to the economical handling of large tonnages; and which has advantages in these respects over methods and apparatus for the flotation treatment of ores or for similar purposes known or used at the present time.

The flotation process is now practised in apparatus consisting of comparatively small units, each of which requires individual attention and adjustment. So far as I am informed this is true of both the mechanical agitation method of introducing air and of the method of introducing air through a permeable medium. In the latter method, especially when minerals of high specific gravity are treated, particles of mineral become embedded in the porous medium thus increasing any initial variations in the degree of permeability of different parts of the medium and causing an uneven distribution and waste of air. This, in connection with an uneven and irregular circulation of the pulp in those instances where the pulp is circulated, prevents that maximum contact

between ore particles and bubbles which forms one of the principal objects of my invention.

Among the characteristic features of my invention are (1) a positive circulation of the pulp through the zone of aeration; (2) a substantially uniform distribution throughout the body of the ore pulp of a very large number of extremely fine air bubbles; (3) provision for skimming the froth, where this is necessary or important; (4) an arrangement such that there is a minimum delay and inconvenience in restarting, after a sudden and unexpected failure of the power or air supply; (5) economy in power required; (6) economy in air, due to increased depth of pulp through which the air passes; (7) cheap installation, with a minimum number of moving parts, and no parts moving at high speeds; (8) operation not requiring close and constant attendance; (9) economy of treatment of large tonnages of low grade ores; and (10) adaptation to either continuous treatment of ore pulp by flotation, or operation on the intermittent or charge system. The importance of these advantages will be apparent from the following discussion.

1. A positive circulation of the pulp through the zone of aeration should be provided, for two principal reasons: First, to insure that all particles of the ore shall be presented to flotative tendencies as many times as possible, as the forces causing the flotation of minerals are extremely small, and it has been found absolutely necessary to present many of the ore particles to these forces a large number of times in order to insure this flotation. In an apparatus not provided with positive circulation, it is inevitable that many particles will not be exposed to flotative forces a sufficient number of times, resulting in their loss in the tailings, or in the necessity of using additional units of the apparatus to save them. If the ore contains a considerable amount of mineral of high specific gravity, or in coarse particles, unless positive circulation is provided, parts of the apparatus will sooner or later become choked with settled mineral.

2. There should be distributed throughout the body of the pulp, as uniformly as possible, a very large number of extremely fine air bubbles, which collect the mineral to be floated and raise it to the surface, where the bubbles form a froth which holds

the floated mineral until it overflows or is skimmed. If the distribution of the air bubbles is not uniform, or if the bubbles are too large, violent eruptions of the surface of the pulp are caused, which break down the froth, and contaminate it with minerals which it is not desired to float.

A principal object of my invention is to cause a uniform distribution of minute bubbles without incurring the expense of mechanical agitation or the irregular action incident to the use of porous blankets, and to accomplish these results in such a way that the necessary apparatus for introducing air may be removed and replaced for inspection, cleaning and repair without emptying the cell or otherwise seriously interfering with the operation of the plant.

3. Provision should be made for skimming the froth in most cases. In existing forms of apparatus in common actual commercial use this is found only, so far as I am aware, in machines using violent mechanical agitation for beating air into the ore pulp. In apparatus using direct aeration through porous blankets, air-tubes, etc., the froth must be formed rapidly enough to overflow before it breaks down, and no skimmers are commonly used on such apparatus, nor can they be so used without adding materially to the complexity and cost of the apparatus, and interfering with its operating adjustments. I have found that a cleaner concentrate and higher ratio of concentration is obtained when the froth is restrained from a free overflow, and time given for a coalescence of the bubbles, which permits the dropping out of the froth of mineral and gangue accidentally and mechanically entangled with it. With some ores containing a small percentage of high-grade mineral like chalcocite, a dirty concentrate, containing 40% "insoluble" may be made, and yet contain 40% copper, and be an acceptable product for the smelter, and show a high ratio of concentration; and with such ores the imperfection of existing pneumatic flotation apparatus does not fully appear. In the case of ores, however, containing large percentages of low-grade mineral, such as cupriferous pyrite, together with considerable amounts of other mineral differing only slightly from the cupriferous pyrite in its flotative properties, such for example as non-cupriferous pyrite or pyrrhotite, then it is necessary to restrain the froth and permit it to clean itself by coalescence of the bubbles, skimming it from the apparatus by mechanical means, otherwise the ratio of concentration will be found excessively low, so much so in some cases as to make the entire scheme of concentration unadvisable and uneconomical.

4. My improved process may be practised with apparatus so arranged that the mini-

mum delay and inconvenience in re-starting is caused by a sudden and unexpected failure of the power or air supply. In substantially all types of existing apparatus, it is necessary to empty them immediately such a sudden stoppage occurs, thus throwing away all the mineral in the apparatus at the time; or, if not emptied promptly, then they must be dug out with a shovel, or sluiced out with a hose before operations can be resumed, and every such interruption causes a certain period of poor metallurgical results, while the different units of the apparatus are being refilled, and smooth and suitable operating adjustments are being restored, which cannot usually be done in less than an hour under the most favorable conditions.

5. The apparatus necessary for my improved process is economical of power. Power is required for two principal purposes in a flotation machine, first, to keep the pulp in circulation, and, second, to compress the air used for forming the collecting and froth-building bubbles. In all types of machines employing mechanical agitation, a very high percentage of the power used is wasted. In the apparatus employing straight pneumatic flotation, much more air than required for the froth must be used, in order to cause a sufficient agitation of the pulp to prevent its excessive settlement on the porous blanket during its passage through the apparatus.

6. The apparatus used in the practice of my process is economical of air, and hence of power required to compress the air used. If the air can travel upward through six feet of pulp, the bubbles will come in contact with roughly three times as many ore particles as would be the case with a body of pulp only two feet deep, or in other words the air considered as a collecting and separating medium would be used about three times more efficiently in the former case than in the latter. In few if any forms of existing apparatus is it possible to use a depth of pulp over the porous blankets of more than two or three feet, owing to the difficulty in preventing settlement of the heavy ore particles. Air should not be used for agitation to prevent settlement, nor should more air be used than is required to form a froth of the proper texture.

7. The necessary apparatus is cheap to install, and contains a minimum possible number of moving parts, and no parts moving at high speeds. The parts are, moreover, of simple construction, readily assembled, and accessible for inspection and repair.

8. My process is cheaply operated and not dependent for good metallurgical results on close and constant attendance.

9. The process is adapted to the economical treatment of large tonnages of low-

grade ores, which is equivalent to the statement that the necessary apparatus may be provided in units of large size.

10. My improved process and the apparatus 5 used in practising it are adapted to the treatment of ore pulp by flotation on the intermittent or charge system. While in most cases this system is unnecessary, nevertheless there are cases, particularly of difficult 10 differential separations, where it gives better results than continuous treatment, so that any process or apparatus to be of universal application must be suited to the use of the intermittent system if desired. In no form 15 of existing flotation process or apparatus, so far as I am aware, is it possible to carry on a commercial flotation operation on the intermittent system.

The nature and advantages of the invention 20 will be further described and illustrated by the accompanying drawings and the following description illustrative of the preferred embodiment thereof and of the preferred construction and operation. It 25 should be clearly understood, however, that I do not limit myself to the precise form of apparatus shown in the drawings and described below, but may use other apparatus of different proportions, and with different 30 details, operating on similar principles and accomplishing its results in substantially the same manner.

In the accompanying drawings—

Figure 1 illustrates a preferred construction and embodiment of the invention, in 35 central vertical section;

Fig. 2 is a top view taken on the line 2—2 of Fig. 1;

Fig. 3 is a detail view showing the tail- 40 ings outlet;

Fig. 4 is a horizontal section taken on the line 4—4 of Fig. 1;

Fig. 5 is an enlarged view illustrating a preferred embodiment of the air distributing 45 pipes; and

Fig. 6 is a sectional view taken on the line 6—6 of Fig. 5.

Fig. 7 is a vertical central sectional view illustrating modified means for elevating the 50 pulp.

Referring to the accompanying drawings, and the reference numerals thereon:—

1 is an ordinary tank, of approximately cylindrical shape, with a flat bottom, and of 55 relatively larger size than any container heretofore used for a flotation separation, in so far as I am aware. A suitable size would be about 18 feet in diameter, and about 10 feet deep. The tank may be made of wood- 60 staves, steel plate, concrete or other suitable material. This tank 1 is provided with a hollow vertical conduit, 2 open at the bottom and top, and suspended from a connecting casting 3 which in turn is fastened to a 65 vertical shaft 4 provided with suitable bear-

ings 5 and driving mechanism 6 for imparting a comparatively slow rotary movement to the same. To the connecting casting, 3 are fastened two distributing launders 7 in the bottom of which are several short pipes 70 or launders 8. To the bottom of the hollow vertical conduit are fastened inclined arms 9 provided with diagonal rabblies 10 and supported by the hinged links 11 to which are attached the chains 12. The inclined arms 75 9 are fastened to the hollow conduit 2 by means of hinged connections, about which they are free to rotate. A pipe 13 is provided for the introduction of air under pressure within the hollow conduit 2 near 80 the bottom of the same.

14, 14 are air mains for conveying air under suitable pressure to the manifolds 15. The air mains are connected to the manifolds through the swivel joints 16^b and the swivel 85 pipes 16^a. Into the manifolds 15 are screwed, or to them are otherwise suitably connected, the air-tubes 16 an enlarged detail of which is shown in Fig. 5. These air- 90 tubes 16 are closed at the outer ends, and consist of ordinary hollow pipes, with small perforations 17 and tightly wrapped with one or more coils of rope 18, preferably woven of some material such as cotton which 95 shrinks in length and increases in diameter when wet. The ends of the rope are firmly anchored by the clamps 18^a.

The outer ends of the air-tubes are held in place by the bars 19 fastened together at suitable intervals by the bolts 20 and provided with the eye-bolts 21 and lifting chains 100 22. The entire tube-grates, consisting of the manifolds and air-tubes are supported on the brackets 24 fastened to the sides of the tank 1. The tube-grates are not fastened to 105 the brackets 24 but simply rest upon them.

25, 25 are a number, such as four, froth skimmers, consisting of light sections of sheet metal or other suitable substance, curved as shown, and with a sloping bottom 110 edge, so proportioned that at its lowest point it is at or slightly below the pulp-level, and at its highest point it is about on the same level with the top of the tank 1. The froth skimmers may be supported 115 substantially as shown, from the revolving launders 7 and from the shaft 4 through the chains 26. The action of the skimmers is supplemented by the action of the diagonally arranged distributing pipes 8. The 120 inner ends of the skimmers 25 may be adjustable to different positions, to increase the skimming effect, *e. g.* to positions indicated in dotted lines at 25^a.

27 are hooks, so positioned as not to be 125 interfered with by the froth skimmers, for supporting the ends of the lifting chains 22 attached to the tube-grates. 28 is a short piece of pipe, open at the end, and rotatable about the swivel joint 29 and provided 130

with a small outlet 30 at its lowest point. The bottom of the tank is provided with an outlet in which is a gate valve 31. 32 is a launder surrounding the tank, sloping uniformly each way, substantially as shown, to a discharge point.

The operation of the apparatus is as follows: The tank 1 having been filled with pulp, the feed may be discharged continuously from a pipe or launder into the connecting casting 3 in which it joins and mixes with the stream of circulating pulp coming up the conduit 2 under the action of the air discharged from the pipe 13. The new feed and circulating pulp, mixed together, pass through the revolving launders 7 and pipes 8 which pass through the bed of froth, and discharge at or slightly beneath the pulp-level. In this way the pulp is uniformly distributed, over the surface of the contents of the tank beneath the froth, and hence without objectionable disturbance of the froth. As the ore particles in the pulp settle downward, they are exposed to the floatative action of the fine air bubbles emitted from the air-tubes, and those which are not floated eventually pass down between the air-tubes, and then are moved gradually toward the center of the tank by the rabblies 10 on the slowly-revolving arms 9. At the center, they are drawn up into the vertical hollow conduit 2 to replace the pulp forced upward therein by air discharged from the pipe 13. It is seen that a positive circulation of the entire pulp is insured, regardless of the size or weight of any individual particles therein.

The air discharged from the air-tubes 16 is brought into the apparatus by the fixed air main 14 and passes through the swivel pipe 16^a and the manifold 15 into the air-tubes 16 and from them is discharged into the body of pulp, in the form of extremely fine bubbles, forced through the rope 18. The air bubbles travel a longer distance vertically than in existing forms of apparatus, due to the increased depth of the tank and of the pulp therein, and consequently have more opportunity to pick up floatable mineral. The bubbles form a froth on the surface of the pulp, which is not disturbed by the passage of the circulating pulp through the pipes 8. The froth is forced to the edge of the tank by the curved skimmers and by the diagonally arranged pipes 8 and is propelled by them over the edge into the collecting launder 32 from which it passes away from the apparatus as the finished product, or to a place of further treatment. The form of the skimmers, as well as the character of the curve and shape and form of the lower edge, may be varied to suit different conditions. In certain cases it is even feasible to dispense with the

froth skimmers altogether, and permit the froth to overflow freely.

When the apparatus is used in a continuous process, there will usually be several units in series, and the tailings may be continuously withdrawn through the pipe 28 discharging into a launder leading to the next machine, or to waste, as the case may be. The pulp level in the tank is regulated by the position of the end of the pipe 28 and this position may be simply and readily adjusted by rotating the pipe 28 around the swivel joint 29. In order to prevent the choking of the pipe 28 by particles too heavy to be carried upward by the velocity of the pulp-stream therein, the small hole 30 is provided through which heavy and coarse particles may pass directly out of the machine. The size of this hole is such as to limit its capacity as a discharge orifice to less than the product of the apparatus, and in that way it cannot affect the pulp-level, which will be dependent solely on the vertical position of the end of the discharge-pipe.

If it is desired to use the apparatus on the charge or intermittent system, the discharge pipe 28 may be dispensed with, or raised to an inoperative position, the tank 1 filled by any convenient means, the charge being circulated through the zone of aeration provided by the air discharged through the tubes 16 until the proper separation has been made, when the remaining material may be drawn off through the gate-valve 31. In order to combine the advantages of intermittent and continuous operation, an even number of units of the apparatus may be used, and at any given moment half of them would be in process of being filled or emptied, and the other half would be under circulation and aeration. The removal of the froth would be similar in intermittent or continuous operation of the apparatus.

The quantity of air discharged through the end of the pipe 13 should and need be no more than just enough to impart the desired upward velocity to the pulp in the hollow conduit 2 on the principle of the air-lift, well recognized as one of the most economical methods for the elevation of liquids through small differences of elevation. This air is not used to agitate the pulp, nor as a source of collecting and froth-forming bubbles, and practically all of it escapes directly into the atmosphere from the top of the connecting casting 3 as soon as it has fulfilled its sole function of elevating the pulp within the hollow conduit 2. The quantity of air discharged through the air-tubes 16 should and need be no more than enough to furnish the bubbles to collect the mineral and form the froth. No agita-

tion is required, as choking of the apparatus by settled mineral is prevented by the rabblers 10 which keep everything in constant motion toward the entrance of the vertical conduit. The function of the rabblers 10 is solely to move the settled pulp slowly toward the center of the apparatus, and they move far too slowly to "agitate" it in the slightest degree.

Should occasion require the raising of the arms, without emptying the apparatus, this may be readily accomplished by turning the rotating shaft 4 by hand power if necessary, as the power required is very small, until the arms 9 are directly beneath the clear space provided between the two tube-grates when nothing will interfere with the raising of the arms 9. In the event of a sudden failure of the power supply, and consequent stoppage of the revolving arms 9 the pulp will immediately begin to settle on the bottom of the tank, and if the delay in re-starting should be considerable, and if the apparatus is not emptied, the tube-grates may advantageously be lifted all or part way out of the tank. This may be accomplished without delay or difficulty of any kind, and without disconnecting any pipes, by simply turning the vertical shaft until the launders 7 are directly over the clear space between the two tube-grates, then attaching the ends of the lifting chains 22 which are maintained within easy reach, on the hooks 27, to blocks conveniently suspended from the roof overhead, and hoisting the tube-grates as high as desired, the air connections merely turning on the swivel joints 16. This procedure for removing the tube-grates from the tank may be used in case of necessity for repairing or renewing the air-tubes 16 obviating any necessity for emptying the apparatus, and reducing the effects of the interruption to the continuity of its operation to a minimum. In restarting after a considerable period of delay with the tank full of pulp, the arms 9 should be lowered until the chains 12 are slack, the vertical shaft 4 should be caused to rotate, and air turned on through the pipe 13. When the arms 9 have worked their way down to their normal position, the tube-grates should be lowered into their position, when the air may be turned into them, the feed to the apparatus turned on, and normal operation resumed. As an alternative to the use of an air-lift for elevating the pulp in the hollow conduit, mechanical means may be used if desired, such as a boat propeller, or Archimedean screw or other device not wasting power in violent agitation of the pulp. In Fig. 7 of the drawing I show an Archimedean screw, 35, within casing, 2^a, for elevating the pulp. The shaft, 33 of the screw extends upwardly through a sleeve, 4^a, held in supports, 5^a, the sleeve, 4^a, carry-

ing the pulp distributor and scraper, 7^a and 10^a. The screw is driven by the bevel gears 36 and the sleeve by the bevel gears 6^a, the latter being mounted on the shaft of the spur gear 38 which meshes with spur gear 37 on the shaft of one of the bevels 36. The lower end of the screw shaft is mounted on a step-bearing, 34, in connection with which means may be provided as illustrated for supplying water under pressure for lubrication.

It is to be understood that other forms of tube-grate may be used, differing from that particularly described herein, all that is necessary being some device for emitting fine air-bubbles, uniformly distributed, and through which the pulp can pass in its path of circulation, although I consider the specific construction of the tube-grate illustrated and described as novel and advantageous.

The apparatus disclosed is not claimed herein but forms the subject matter of a divisional application filed December 21, 1920, Ser. No. 432,291.

I claim:

1. In a flotation process the operations of maintaining throughout the entire horizontal cross-sectional area of a body of freely-flowing ore pulp a substantially uniform ascending column of minute gaseous bubbles, maintaining throughout said area a substantially homogeneous descending column of pulp, elevating pulp from the lower part of said body of pulp and discharging it substantially uniformly throughout the horizontal cross-sectional area of the upper part of said body of pulp thereby causing circulation of said pulp in a homogeneous column, and separating the floated mineral from the remainder of the pulp.

2. In a flotation process the operations of maintaining throughout the entire horizontal cross-sectional area of a body of freely-flowing ore pulp a substantially uniform ascending column of minute gaseous bubbles, maintaining throughout said area a substantially homogeneous descending column of pulp, elevating pulp from the lower part of said body of pulp and discharging it substantially uniformly throughout the horizontal cross-sectional area of the upper part of said body of pulp thereby causing circulation of said pulp in a homogeneous column, keeping the part of said body of pulp through which said bubbles rise free from movement other than the ascent of the bubbles and descent of the pulp column, and separating the floated mineral from the remainder of the pulp.

3. In a flotation process the operations of maintaining throughout the entire horizontal cross-sectional area of a body of freely-flowing ore pulp a substantially uniform ascending column of minute gaseous bubbles, maintaining throughout said area a

substantially homogeneous descending column of pulp, pneumatically elevating pulp from the lower part of said body of pulp and discharging it substantially uniformly throughout the horizontal cross-sectional area of the upper part of said body of pulp thereby causing circulation of said pulp in a homogeneous column, and separating the floated mineral from the remainder of the pulp.

4. In a flotation process the operations of maintaining throughout the entire horizontal cross-sectional area of a body of freely-flowing ore pulp a substantially uniform ascending column of minute gaseous bubbles, maintaining throughout said area a substantially homogeneous descending column of pulp, pneumatically elevating pulp from the lower part of said body of pulp and discharging it substantially uniformly throughout the horizontal cross-sectional area of the upper part of said body of pulp thereby causing circulation of said pulp in a homogeneous column, the part of said body of pulp through which said bubbles rise being kept free from movement other than that due to the ascent of the bubbles and descent of the pulp column, and separating the floated mineral from the remainder of the pulp.

5. In a flotation process the operations of maintaining throughout the entire horizontal cross-sectional area of a body of freely-flowing ore pulp a substantially uniform ascending column of minute gaseous bubbles, maintaining throughout said area a substantially homogeneous descending column of pulp, permitting said pulp column to descend to a level below said ascending column of bubbles, elevating pulp from below said column of bubbles and discharging it substantially uniformly throughout the horizontal cross-sectional area of the part of the body of pulp traversed by said column of bubbles thereby causing circulation of said pulp in a homogeneous column, and separating the floated mineral from the remainder of the pulp.

6. In a flotation process the operations of maintaining throughout the entire horizontal cross-sectional area of a body of freely-flowing ore pulp a substantially uniform ascending column of minute gaseous bubbles, maintaining throughout said area a substantially homogeneous descending column of pulp, permitting said pulp column to descend to a level below said ascending column of bubbles, elevating pulp from below said column of bubbles and discharging it substantially uniformly throughout the horizontal cross-sectional area of the part of the body of pulp traversed by said column of bubbles thereby causing circulation of said pulp in a homogeneous column, the part of said pulp through which said bubbles

rise being kept free from movement other than that due to the ascent of the bubbles and descent of the pulp column, and separating the floated mineral from the remainder of the pulp.

7. In a flotation process the operations of maintaining throughout the entire horizontal cross-sectional area of a body of freely-flowing ore pulp a substantially uniform ascending column of minute gaseous bubbles, maintaining throughout said area a substantially homogeneous descending column of pulp, permitting said pulp column to descend to a level below said ascending column of bubbles, pneumatically elevating pulp from below said column of bubbles and discharging it substantially uniformly throughout the horizontal cross-sectional area of the part of the body of pulp traversed by said column of bubbles thereby causing circulation of said pulp in a homogeneous column, and separating the floated mineral from the remainder of the pulp.

8. In a flotation process the operations of maintaining throughout the entire horizontal cross-sectional area of a body of freely-flowing ore pulp a substantially uniform ascending column of minute gaseous bubbles, maintaining throughout said area a substantially homogeneous descending column of pulp, permitting said pulp column to descend to a level below said ascending column of bubbles, pneumatically elevating pulp from below said column of bubbles and discharging it substantially uniformly throughout the horizontal cross-sectional area of the part of the body of pulp traversed by said column of bubbles thereby causing circulation of said pulp in a homogeneous column, the part of said body of pulp through which said bubbles rise being kept free from movement other than that due to the ascent of the bubbles and descent of the pulp column, and separating the floated mineral from the remainder of the pulp.

9. In a flotation process the operations of maintaining throughout the entire horizontal cross-sectional area of a body of freely-flowing ore pulp a substantially uniform ascending column of minute gaseous bubbles introduced through the pores of a permeable medium, maintaining throughout said area a substantially homogeneous descending column of pulp, permitting said pulp column to descend through substantially uniformly distributed spaces between parts of said permeable medium, elevating pulp from beneath said permeable medium and discharging it above said medium substantially uniformly throughout the horizontal cross-sectional area of the part of the body of pulp traversed by said column of bubbles thereby causing circulation of said pulp in a homogeneous column, and separating the floated mineral from the remainder of the pulp.

10. In a flotation process the operations of maintaining throughout the entire horizontal cross-sectional area of a body of freely-flowing ore pulp a substantially uniform
 5 ascending column of minute gaseous bubbles introduced through the pores of a permeable medium, maintaining throughout said area a substantially homogeneous descending column of pulp, permitting said pulp column
 10 to descend through substantially uniformly distributed spaces between parts of said permeable medium, elevating pulp from beneath said permeable medium and discharging it above said medium substantially uniformly
 15 throughout the horizontal cross-sectional area of the part of the body of pulp traversed by said column of bubbles thereby causing circulation of said pulp in a homogeneous column, the part of said body
 20 of pulp through which said bubbles rise being kept free from movement other than that due to the ascent of the bubbles and descent of the pulp column, and separating the floated mineral from the remainder of the
 25 pulp.

11. In a flotation process the operations of maintaining throughout the entire horizontal cross-sectional area of a body of freely-flowing ore pulp a substantially uniform
 30 ascending column of minute gaseous bubbles introduced through the pores of a permeable medium, maintaining throughout said area a substantially homogeneous descending column of pulp, permitting said pulp column
 35 to descend through substantially uniformly distributed spaces between parts of said permeable medium, pneumatically elevating pulp from beneath said permeable medium and discharging it above said medium substantially
 40 uniformly throughout the horizontal cross-sectional area of the part of the body of pulp traversed by said column of bubbles thereby causing circulation of said pulp in a homogeneous column, and separating

ing the floated mineral from the remainder 45 of the pulp.

12. In a flotation process the operations of maintaining throughout the entire horizontal cross-sectional area of a body of freely-flowing ore pulp a substantially uniform
 50 ascending column of minute gaseous bubbles introduced through the pores of a permeable medium, maintaining throughout said area a substantially homogeneous descending column of pulp, permitting said pulp column
 55 to descend through substantially uniformly distributed spaces between parts of said permeable medium, pneumatically elevating pulp from beneath said permeable medium and discharging it above said medium substantially
 60 uniformly throughout the horizontal cross-sectional area of the part of the body of pulp traversed by said column of bubbles thereby causing circulation of said pulp in a homogeneous column, the part of
 65 said body of pulp through which said bubbles rise being kept free from movement other than that due to the ascent of the bubbles and descent of the pulp column, and separating the floated mineral from the remainder
 70 of the pulp.

13. A process for the concentration of ores and the like by froth flotation, which comprises maintaining a body of ore-pulp, introducing fine air bubbles initially too small
 75 to effect any substantial agitation into the pulp above the bottom thereof, collecting the froth formed above said pulp, and effecting circulation of the pulp without violent agitation by withdrawing pulp from below the
 80 zone of air introduction, elevating the withdrawn pulp, and discharging the elevated pulp into the body of ore pulp below the surface thereof and substantially uniformly throughout the horizontal sectional area of
 85 said body of pulp.

In testimony whereof I affix my signature.

HALLET RICE ROBBINS.