

D. COLE.
 APPARATUS FOR SEPARATING OR CONCENTRATING ORES.
 APPLICATION FILED AUG. 3, 1915.

1,375,211.

Patented Apr. 19, 1921.

5 SHEETS—SHEET 1.

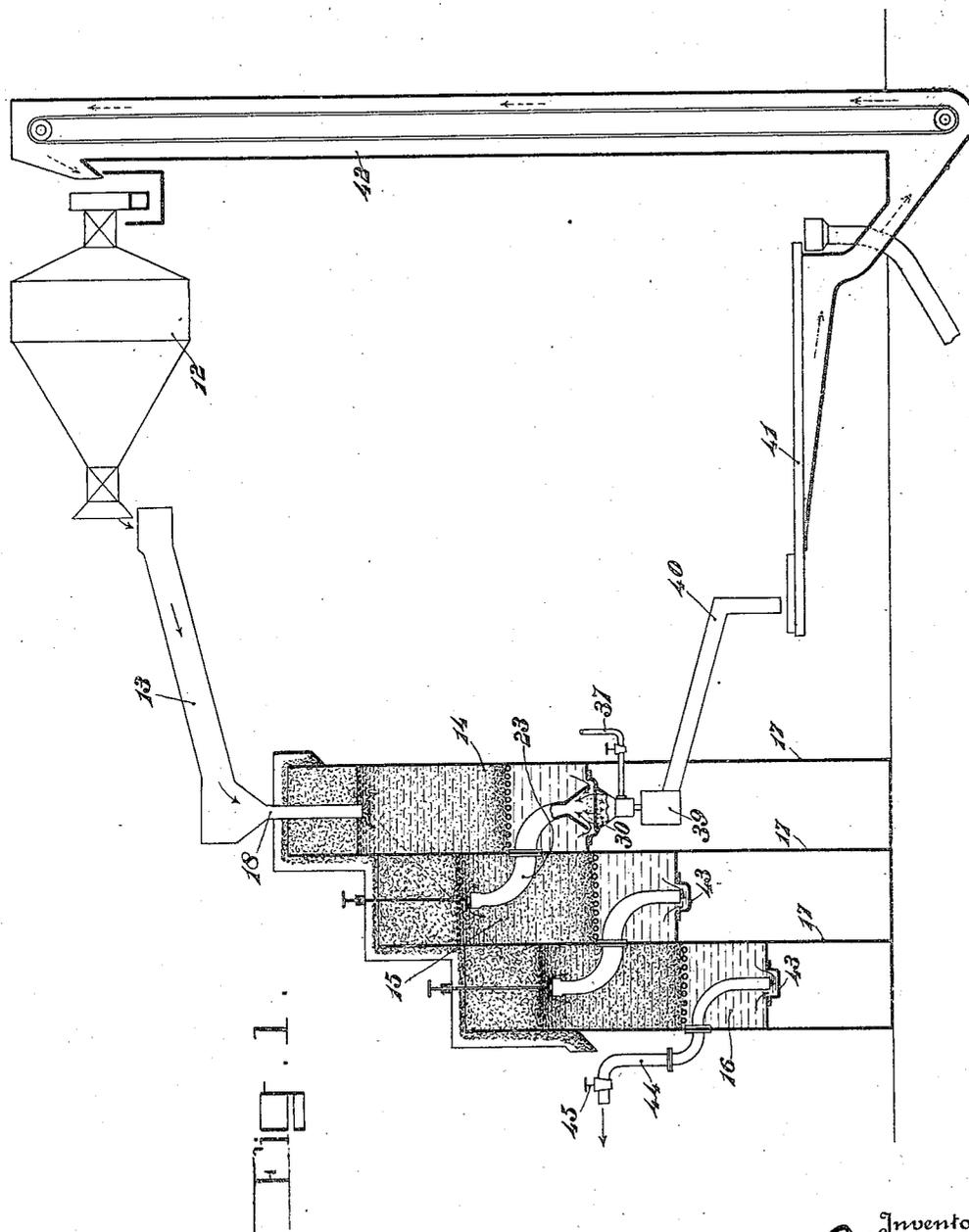


FIG. 1.

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5 SHEETS—SHEET 2.

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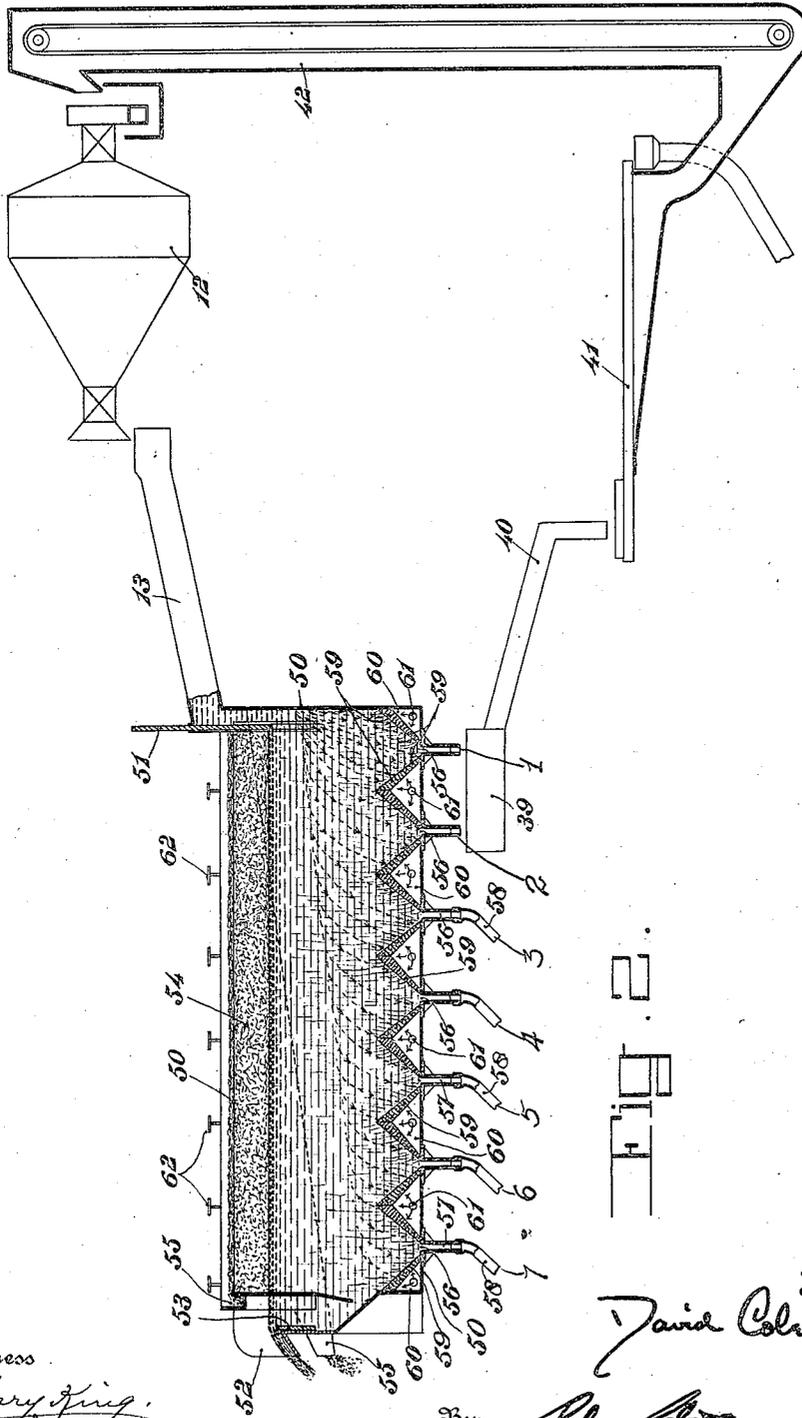


FIG. 2.

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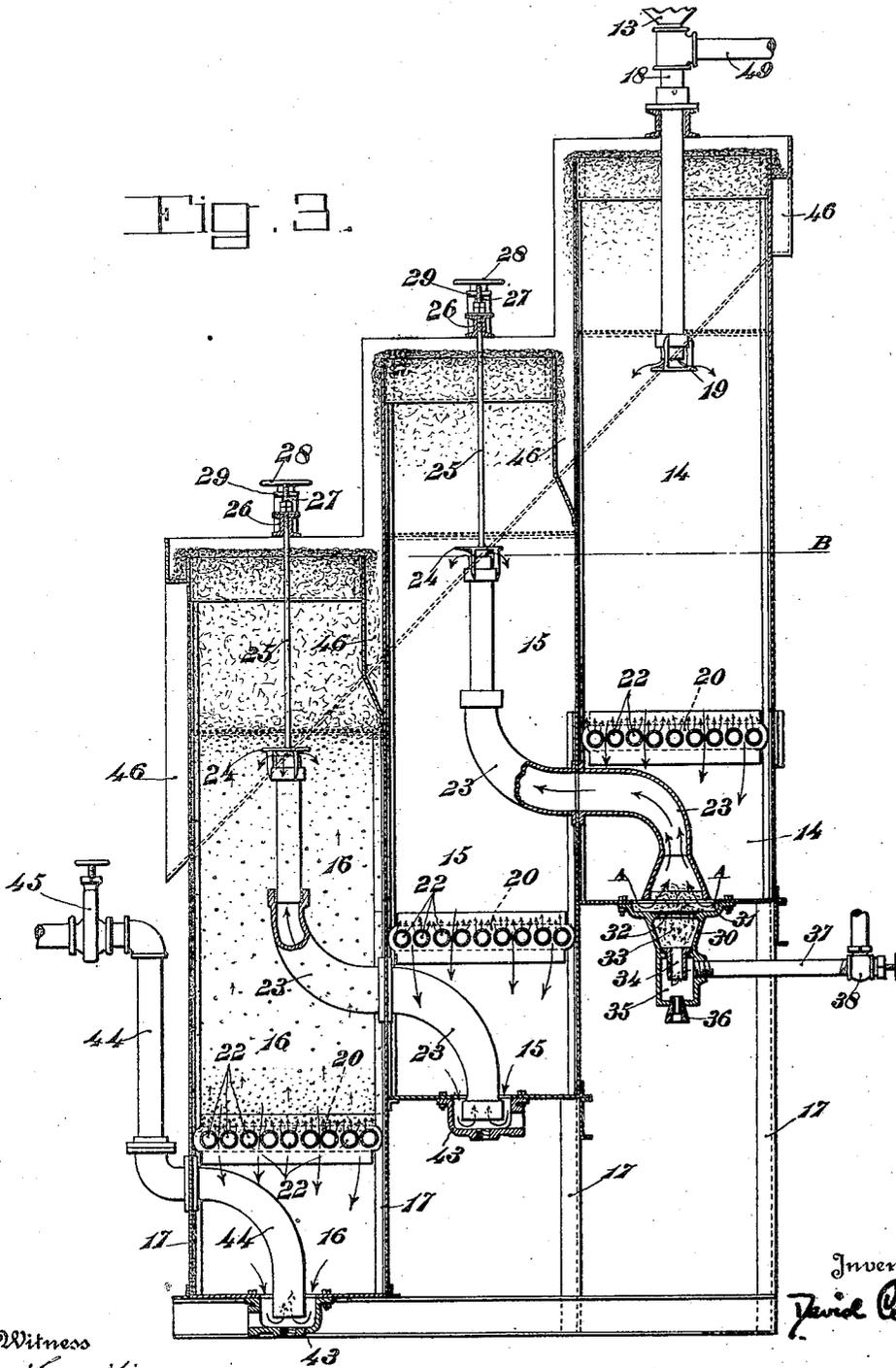
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5 SHEETS—SHEET 3.

Fig. 3.



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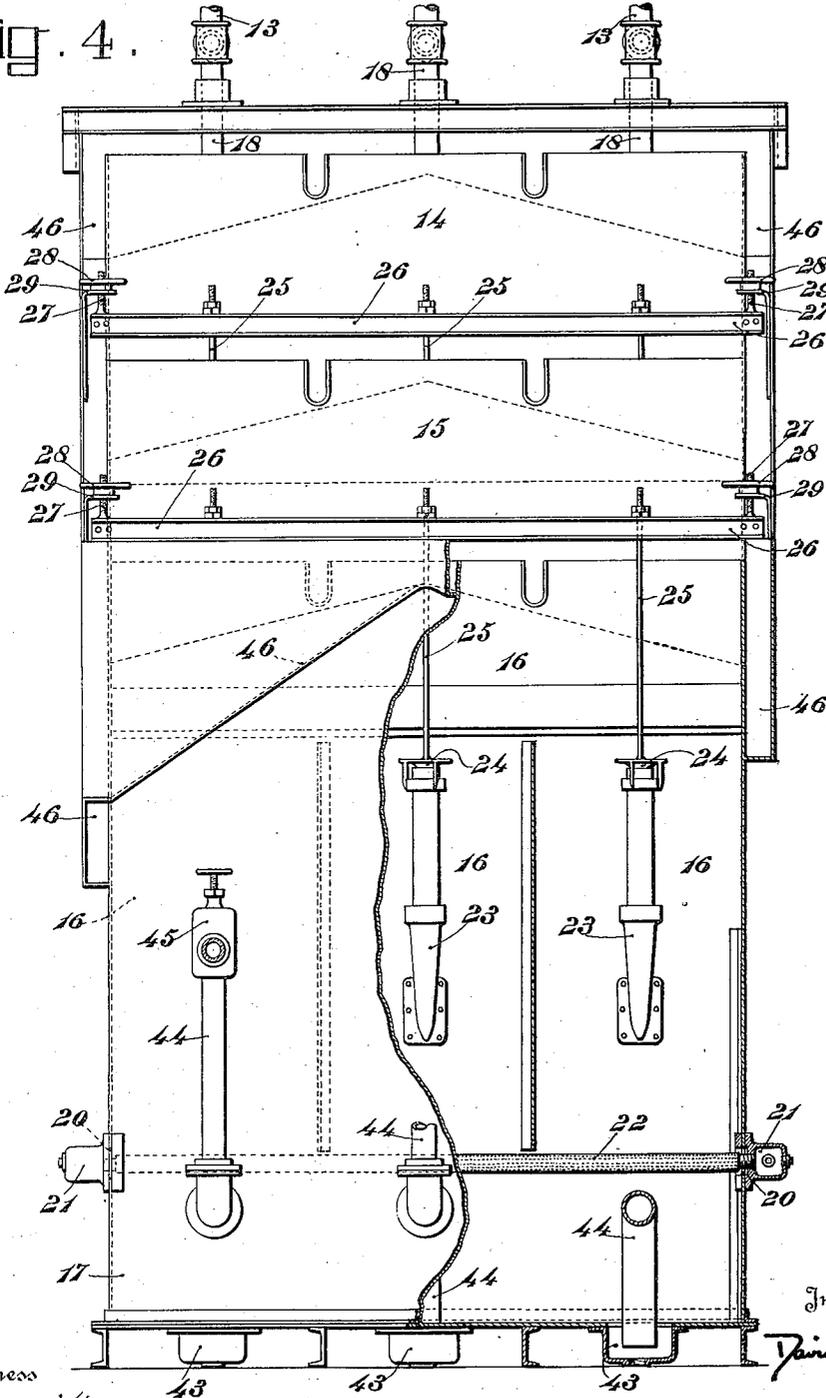
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5 SHEETS—SHEET 4.

Fig. 4.



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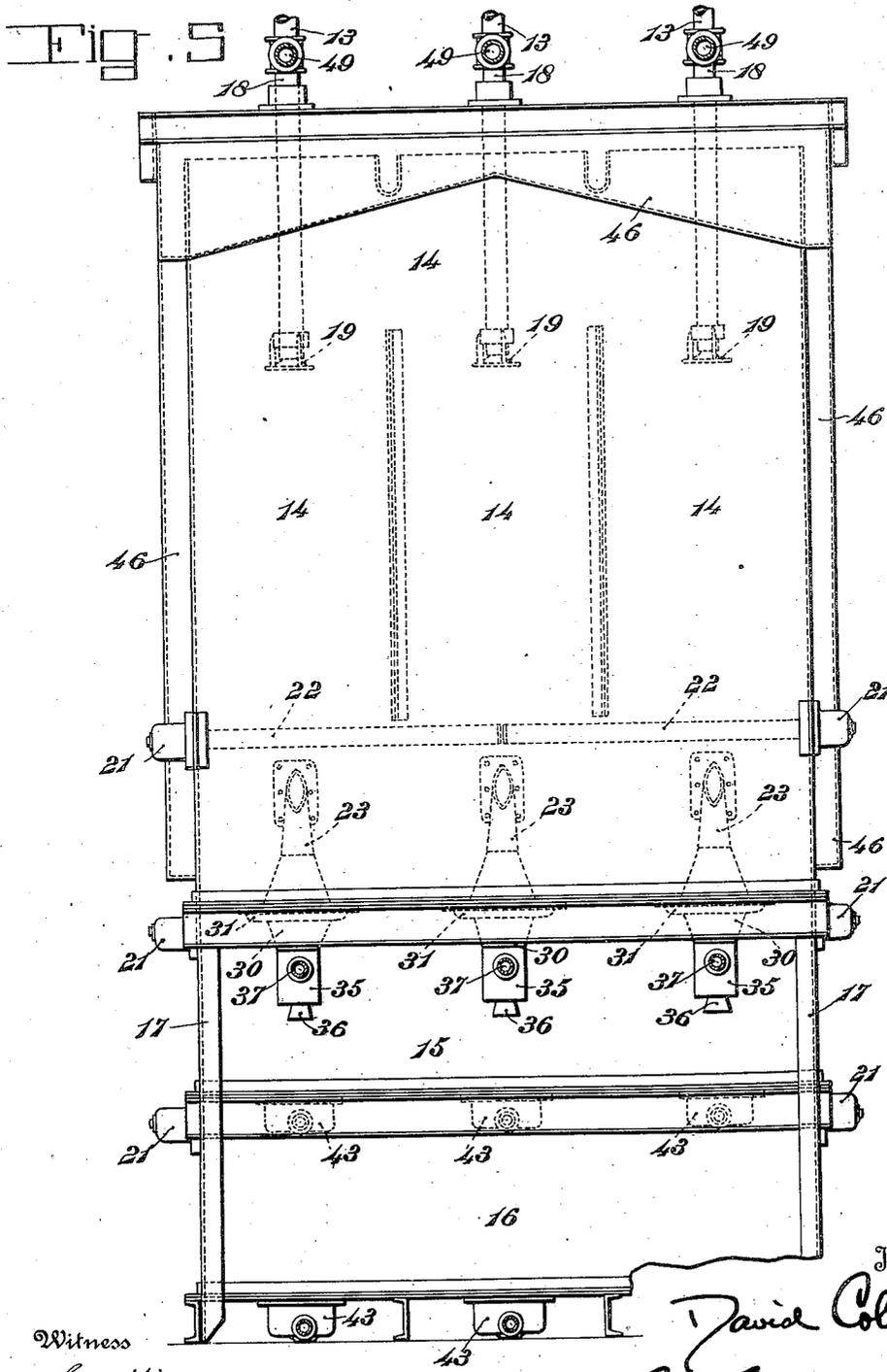
Attorneys

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5 SHEETS—SHEET 5.



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UNITED STATES PATENT OFFICE.

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APPARATUS FOR SEPARATING OR CONCENTRATING ORES.

1,375,211.

Specification of Letters Patent. Patented Apr. 19, 1921.

Application filed August 3, 1915. Serial No. 43,442.

To all whom it may concern:

Be it known that I, DAVID COLE, a citizen of the United States, residing at Morenci, in the county of Greenlee and State of Arizona, have invented or discovered certain new and useful Improvements in Apparatus for Separating or Concentrating Ores, of which the following is a specification, reference being had therein to the accompanying drawings.

This invention relates to the hydraulic classification, separation, and concentration of ore and the like by what is known as the flotation method, and more particularly to that branch of the process known as frothing classification, the latter being an amplification of the "flotation" method, having for its object the preparation of the rejections of the flotation treatment in such a way that maximum recoveries may be made by the usual gravity methods upon the grains and sizes in the pulp which were not within the range of, and were not susceptible to, recovery by flotation treatment. Grains which will pass a screen having ten thousand openings per square inch will be within the possible range of flotation recovery, but substantially all grains coarser than this size will not be within the range of recovery by flotation.

The mineral grains constituting the product separated and recovered by flotation methods are so fine that substantially ninety-five per cent. of them will pass through a screen having forty thousand apertures per square inch. Therefore the range of flotation sizes is substantially limited to the minus one hundred mesh sizes (*i. e.*, ten thousand holes per square inch above referred to) and since it is impracticable commercially to reduce all of the ore to be treated to this very fine state of division it is necessary either to separate the flotation treatment sizes from the gravity treatment sizes and treat them separately, or to so prepare the combined sizes during flotation treatment that the gravity treatment to follow will not be embarrassed in making maximum recoveries upon the sizes of grains in the pulp which are amenable to gravity treatment, this preparation constituting the frothing classification process.

In accordance with the last named process the material to be subjected to the treatment is pulverized in the presence of water and

usually also small amounts of oils and the like to a size which will yield the best commercial recovery, and the resulting "pulp" is introduced into a suitable tank provided with means in the lower part of same for liberating air in a finely divided state through a suitable porous medium, said air forming very numerous streams of very small bubbles which expand in size as they rise toward the surface of the pulp in the tank, carrying with them the particles of mineral which have greater affinity for air than for water, and which are sufficiently finely divided to be enveloped in the film of the bubble and be carried by the rising air, thereby forming a mineral froth above the surface of the pulp in the upper part of the tank, which froth, with its load of mineral, builds a column high enough to overflow the edges of the top of the tank; while the particles of ore which have more affinity for water than for air, together with the particles too large to be lifted by the bubbles, will find their way to the bottom of the tank and be withdrawn therefrom.

The process is usually carried on continuously, the pulp flowing into the tank at a suitable rate, the froth with its content of fine mineral being continuously discharged in the "mineral froth" at the top of the tank, and the water and coarser material being continuously discharged at the bottom of the tank.

In order that such apparatus of the previous art may operate properly and not become clogged it is necessary that the ore or other material being treated be all of a certain degree of fineness. It is therefore necessary that said material be either carefully pulverized primarily to a very even degree and sufficiently fine, or else that said material be screened or receive other previous treatment for removing the coarser particles, or "oversize," which would embarrass the apparatus and would tend to clog it. It is one of the objects of the present invention to provide means, associated with a flotation or frothing classifier itself, for automatically removing the oversize, such removal being effected during and in connection with the normal operation of the apparatus, thus preventing embarrassment to the operation and making it possible to apply the flotation or frothing process primarily in the treatment of ores in a much

coarser state of reduction, that is to say, to the ordinary mill run, without subjecting the same to previous screening or other treatment for the purpose of protecting the
 5 frothing machine. In carrying out this feature of the invention the separating tank is preferably provided with one or more classifying cones each having an outlet and an inlet through which "hydraulic" water
 10 is introduced, said water driving or holding back material of a predetermined fineness (depending upon the form of chamber and pressure or velocity of the water so admitted) and permitting the oversize to
 15 pass out through the outlet.

In preparing ore for flotation treatment it is customary to reduce said ore in so-called "tube mills", such mills having been
 20 found in practice to be the most efficient and economical for this purpose. In order to operate such mills at their maximum capacity (that is to say with the greatest efficiency) it is necessary to feed material there-
 25 to in quantities which result in the discharge of a large amount of oversize, and said oversize must be returned to the mill for regrinding. If the feed to the mill is so regulated in quantity that no oversize is dis-
 30 charged, then the work of grinding will be greatly hampered, the amount handled will be greatly reduced, and the cost per ton for grinding will be greatly increased. Con- sidering which and as a second object of
 35 the invention a combined apparatus is provided whereby the regular run of a tube mill may be directly discharged into a frothing classifier, the oversize being automati-
 40 cally separated out in said classifier and returned to the mill for regrinding, thereby permitting both the mill and the classifier to be operated at their maximum efficiency
 45 and without interruption in closed circuit, eliminating the usual step of mechanical screening or other preliminary classifica-
 50 tion, and generally simplifying the apparatus and operation, correspondingly reducing the cost. The separation of the oversize is preferably effected by means of hydraulic
 55 classifying cones as above described, so that, by regulating the amount of hydraulic water admitted, the size and quality of material escaping the closed circuit may be controlled and varied, thus accomplishing, by the mere regulation of an inlet valve, a result which, in the case of mechanical separation, would require the complete chang-
 60 ing of screens or other troublesome operations.

In the usual practice of the frothing process considerable difficulty is encountered by
 65 reason of the tendency of the coarser material to lodge upon the porous medium, thereby obstructing the outlet of air, and also by reason of the tendency on the part of
 the liquid passing to the restricted outlet

at the bottom of the tank to form a vortex, the effect of which is to suck down and carry away the bubbles, all of which, in order to secure proper operation, should be allowed
 70 to pass freely upward through the liquid in the tank. The present invention has, therefore, for another object to provide, in a frothing classifier, air admission means which will effect a more thorough aeration
 75 of the liquid than any similar means heretofore devised, which is not subject to clog-
 80 ging by sediment accumulating thereon or finding its way thereinto, and which, at the same time, provides for the efficient withdrawal of the liquid and coarser material
 with a minimum tendency to interfere with the free upward passage of the bubbles.

In the flotation separation of ores and the like it is found to be advantageous to sub-
 85 ject the material under treatment to more than one passage through the apparatus, and the present invention accordingly has for a further object the provision of a frothing classifier which provides in a simple
 90 and efficient manner for the repeated treatment of the material, said apparatus comprising a series of tanks or compartments and means whereby the material is auto-
 95 matically transferred from one of said tanks or compartments to the next by gravity and without the necessity of pumping, said transferring means being of such a nature
 100 as not to interfere with the efficient operation of the apparatus. In carrying out this feature of the invention the transferring
 105 means is constructed and arranged to cooperate with the classifying cones in such a manner as to materially assist the operation of the latter and to reduce materially the amount of hydraulic water required for the
 proper separation of the oversize and returnable portion.

The foregoing and other objects of the invention, together with means whereby the
 110 same may be carried into effect, will best be understood from the following description of certain forms or embodiments thereof illustrated in the accompanying drawings. It will be understood, however, that the particu-
 115 lar constructions described and shown have been chosen for illustrative purposes merely, and that the invention, as defined by the claims hereunto appended, may be otherwise practised without departing from the spirit and scope thereof. 120

In said drawings:

Figure 1 is a partly sectional diagrammatic view illustrating an apparatus constructed and arranged in accordance with the invention. 125

Fig. 2 is a similar view showing a different form of separator or classifier.

Fig. 3 is an enlarged vertical sectional view of the classifier shown in Fig. 1.

Fig. 4 is an end elevation partly broken 130

away of the apparatus shown in Fig. 3, as viewed from the left in the latter figure.

Fig. 5 is an end elevation partly broken away of the apparatus shown in Fig. 3, as viewed from the right in the latter figure.

Referring first to Fig. 1, 12 denotes a tube mill of any suitable or well known form for reducing the ore or other material to be treated. Said reduced material, containing a certain amount of oversize incidental to the efficient operation of the mill, is discharged from said mill into a chute 13 leading to the frothing classifier.

The frothing classifier shown in Figs. 1, 3, 4 and 5 comprises a series of tanks or compartments 14, 15, 16 supported by suitable uprights 17, said tanks or compartments being of any desired number (herein shown as three) and being located immediately adjacent one another and in stepped arrangement, as shown, each succeeding tank or compartment being at a somewhat lower elevation than the preceding one. The chute 13 delivers the comminuted material, together with an amount of water (introduced through branch pipes 49) sufficient to produce a mixture of proper consistency, into one or more feed pipes 18 which discharge into the first tank or compartment. The feed pipes 18 are preferably provided at their lower ends with deflectors 19 which cause the streams to spread out into thin sheets for the purpose of preventing the formation of violent currents in the tank 14.

At a proper distance above the bottoms of each of the tanks 14, 15, 16, slots 20 are formed in the ends of said tanks, and secured to said ends adjacent said slots are manifolds 21 communicating with a suitable source of compressed air. The manifolds 21 of each tank support and communicate with a series of horizontally disposed tubes 22 which extend throughout the length of the corresponding tank and form a tubular grating substantially covering the entire horizontal cross-sectional area of said tank at a point suitably elevated above the bottom thereof. The tubes 22 are so constructed as to have a finely porous air emitting surface, as by forming said tubes of a porous material, such as carborundum, or by covering the same when perforated with filtering fabric or the like, whereby the compressed air supplied to the manifolds 21 is discharged through said tubes into the tanks in the form of numerous streams of fine bubbles. The pores of the tubes 22 are too small to allow solids to enter from the outside, under hydraulic pressure when the air pressure is cut off, as would occur in the case of a perforated pipe or the like, thereby preventing the internal clogging of said tubes. The tubes 22 of each grating are spaced from one another a sufficient dis-

tance to permit easy downward passage between them of the pulp and water under treatment, while being sufficiently close together to provide for the thorough aeration of the contents of the tanks above them. The outlet from each tank, as will presently be more fully described, is at the bottom thereof, while the tubes 22, as above explained, are located some distance above the bottom. By this arrangement, as also by reason of the spacing of the tubes 22 as above described, all violent downward currents or vortices in the vicinity of said tubes, tending to draw the bubbles downwardly, are avoided, and all possibility of improper discharge of the finer material from the bottom of the tank reduced to a minimum. The construction of the tubes 22 is preferably such as to permit a discharge of air throughout their circumference, thereby providing a greatly increased air emitting surface, and, at the same time, free downward passages for the liquid, as above explained. By virtue of this form and arrangement all possibility of such accumulation of sediment as would clog the exterior of the tubes and interfere with the proper discharge of air therefrom is prevented, it being obvious that, even though the entire upper surfaces of the tubes were covered by deposits, there would still be left a total unobstructed air emission surface equal to or greater than the entire transverse area of the tank, notwithstanding the passages between the tubes.

The bubbles from the tubes 22 pass upwardly through the tanks, combing out and carrying with them the finer particles of material, particularly metallic sulfid, and form in the upper part of said tanks bubble or froth columns which overflow into a launder 46 arranged to discharge the froth with its content of fine material at any suitable point.

For the purpose of leading the material from one tank or compartment to the next for successive treatment the transfer tubes 23 are provided. Said transfer tubes are preferably of the S-shaped form shown, pass through the wall separating adjacent tanks or compartments at points below the tubes 22 of the upper tank, and are preferably flattened laterally, as shown in Figs. 4 and 5 in order to oppose the least possible resistance to the upward passage of the bubbles in the lower tank. Each tube is arranged with its inlet adjacent the bottom of the tank from which it discharges and with its outlet in the upper portion of the next adjacent tank, the difference in elevation of succeeding tanks providing a sufficient hydrostatic head to force the material from the lower part of one tank to the upper part of the next succeeding tank by gravity.

Arranged adjacent the outlet of each

transfer tube 23 in each of the tanks 15 and 16 is a valve 24 carrying a deflector similar to the deflector 19. The deflector valves 24 are adjustable with respect to the outlets of the tubes 23 and are carried by stems 25 supported at their upper ends by beams 26. As shown in Figs. 4 and 5 a plurality of transfer tubes 23 is preferably provided for discharging material from each tank to the next succeeding, and the deflector valves 24 in each tank are supported from a single beam 26. Each of the beams 26 is provided at each end with a threaded stem 27 cooperating with a hand wheel 28 supported by a bracket 29 suitably secured in stationary position, as to the launder 46. By operating the hand wheels 28 of any pair the deflector valves 24 of any tank may be simultaneously adjusted, thereby providing for an even flow through all of the transfer tubes 25 discharging into said tank.

Secured to the bottom of the tank 14 adjacent the inlets of the corresponding transfer tubes 23 are classifying cones 30, said classifying cones being preferably in the form of separate castings bolted in position to the bottom of said tank adjacent suitably formed openings in said bottom. Each of the classifying cones 30 is formed at its top with a depression 31 into close proximity to which extends the inlet end of the corresponding transfer tube 23, said end being preferably of the flaring or conical form shown and of a diameter at its bottom slightly less than the diameter of the depression 31. The bottom of the depression 31 is provided with an opening in which is located a coarse screen or perforated plate 32, said opening leading to a chamber 33 which communicates through a bushing 34 with a second chamber 35 provided with an outlet 36. Communicating with the chamber 35, preferably at a point above the bottom of the bushing 34, is an inlet pipe 37 for hydraulic water, said pipe being controlled by a suitable valve 38.

In the operation of the apparatus, considered with respect to each classifying cone and the corresponding transfer tube, the water in the tank 14, together with the material not carried away by the bubbles, reaches the bottom of said tank and is discharged through the transfer tube 23 to the next adjacent tank or compartment 15, as indicated by the full line arrows on Fig. 3. Hydraulic water entering the chamber 35 through the pipe 37, under a predetermined pressure regulated by the valve 38, passes upwardly through the bushing 34, chamber 33 and perforated plate 32 (said plate diffusing the upward current), a part of said water, of course, passing downwardly and being discharged through the outlet 36. The adjustment of the valve

38 is such that, in addition to the hydraulic water discharged through the outlet 36, a sufficient quantity of said water passes upwardly through the bushing 34 with the proper velocity to prevent slime or fine sand from descending in opposition thereto, but to allow the oversize to pass downwardly, as indicated by the dotted line arrows on Fig. 1 said oversize being discharged at the outlet 36. This operation is greatly facilitated by the construction and arrangement of the transfer tubes 23 with reference to the classifying cones. The material in the tank 14 gravitates to the points indicated by A in Fig. 3 where the swift current due to the constricted opening carries the same horizontally toward the center of the funnel-shaped inlet of the transfer tube and upwardly into said tube upon reaching the enlarged chamber in the bell mouth of the transfer tube. The oversize tends to separate out and fall into the chamber 33. This tendency is opposed by a gentle upward current composed in part by the hydraulic water flowing upwardly through the bushing 34 and perforated plate 32, and in part by the lessened speed of upward flow into the transfer tube, caused by its bell shaped construction so that said material, minus its oversize particles, after more or less circulation, passes upwardly into the mouth of the transfer tube 23. By this arrangement of parts, enabling the transfer tubes 23 to assist the hydraulic water in carrying away the finer material, very much less hydraulic water is necessary than would otherwise be required, this being a very desirable feature inasmuch as the hydraulic water tends to dilute the pulp and to interfere with the frothing operation in the next tank. It will of course be understood that the size of material discharged through the outlet 36 will be dependent upon the pressure at which the hydraulic water is admitted through the pipe 37, and this may be regulated at will, and in accordance with requirements, by means of the valve 38.

The outlets 36 of the classifying cones 30 discharge into a tank or trough 39 from which a conductor 40 leads to a concentrating table 41 of any suitable or well known form. The material rejected by the concentrating table 41 is delivered to an elevator or conveyer 42 which returns the same to the mill 12. If desired the concentrating table 41 may be omitted and the conductor 40 arranged to discharge the oversize directly to the elevator or conveyer 42.

It will thus be seen that the classifying cones 30 operate to remove the oversize discharged into the tank 14, which oversize is returned to the mill for regrinding. Ordinarily one set of classifying cones will accomplish this result satisfactorily, as substantially all of the oversize will pass

out therethrough, practically none passing through the transfer tubes 23 into the next tank. For this reason, as herein shown, the first tank 14 only is provided with classifying cones, the other tanks 15, 16 etc. being provided at the corresponding points with normally closed cup-shaped castings 43 into which the inlet ends of the corresponding transfer tubes 23 depend. If desirable, however, any or all of the tanks 15, 16, etc. may be provided with classifying cones 30 in place of the castings 43. In the latter case, by varying the pressure of the hydraulic water admitted to the classifying cones of succeeding tanks, material of different and successively graded sizes may be removed from the successive tanks.

The tailing leaving the last tank 16 through the last transfer tube 23 is discharged to any suitable point through a pipe 44 controlled by a suitable valve 45.

The complete operation of the apparatus thus far described is as follows. In starting the operation clear water is first introduced into the apparatus through the feed pipes 18. As soon as the water in the first tank or compartment 14 reaches the level indicated by the dotted line B the second tank or compartment 15 will commence to fill through the first set of transfer tubes 23, and when this compartment is filled to the level of the outlets to the transfer tubes leading therefrom, the third compartment will fill, and so on until the level of the mouth of the final outlet from the last compartment is reached in that compartment. Compressed air is then admitted through all of the grates 22. The consequent aeration of the water in all of the compartments causes the level thereof to be raised, and by adjustment of the deflector valves 24 through the wheels 28 as well as by adjustment of the valves 45 of the final outlets, the surface of the liquid is caused to rise above the deflector valves 24 to or adjacent the tops of the tanks as may be desired. After a proper balance has been established the mill 12 is started and substantially the same volume of pulp to be treated is substituted for the clear water. On account of the presence of the solids transported by the water, and because of the colloidal and other matter in the pulp which will produce froth, additional adjustments, such as the opening or closing of the deflector valves 24 and discharge valves 45, the admission of a greater or less amount of air through the tubes 22, etc., are usually necessary in order to establish a new condition of equilibrium after which no other adjustments are necessary under normal and even conditions for use. The finest particles of metallic sulfids in the pulp are discharged with the froth from the top of the tanks into the launder 46, the coarser particles both silicious and metallic

find their way to the bottoms of the tanks, are transferred through the tubes 23 from one tank to the next for successive treatment, and are finally discharged through the pipes 44, while the oversize is discharged through the classifying cones 30, and, after passing from the concentrating table 41, is returned to the mill 12 for regrinding, all as above described in detail.

The apparatus shown in Fig. 2, as to its general combination and arrangement, is substantially similar to that shown in Fig. 1, a different form of frothing classifier being, however, employed. This frothing classifier comprises a single tank 50 having an inlet provided with a baffle plate 51, and with which the chute 13 communicates, and an outlet 52 provided with an adjustable slide 53 for controlling the level of discharge and consequently the level of the liquid in the tank. The bottom of the tank is provided with a series of transversely arranged slots 56 communicating below the tank with hoppers 57 from which lead outlet pipes 58, the several outlets being numbered from 1 to 7, inclusive, in Fig. 2, although the precise number of these outlets may be in accordance with the requirements. Adjacent each of these slots 56 is a pair of downwardly converging porous plates 59, said plates inclosing air chambers 60 to which compressed air is admitted through inlets 61 controlled by valves, not shown, which are operated by hand wheels 62.

Compressed air in the chambers 60 is admitted to the tank 50 through the porous plates 59 and passes upwardly through the liquid in the tank in the form of numerous streams of fine bubbles, carrying with them the finer material and forming a froth column 54 above the level of the liquid, the froth overflowing the sides of the tank into suitably disposed launders 55 which discharge the same at any desired point, the operation in this respect being substantially similar to that of the frothing classifier first described. Also, as in the apparatus first described, it will be seen that the outlets 56 are disposed at a lower level than that at which the air is introduced, so that the tendency for the bubbles to be drawn downwardly into said outlets is very slight. Moreover the elongated slots constituting these outlets are of such a form as to provide for a slow, gentle and even downward passage of the water without the formation of vortices, thereby further minimizing all tendency to draw the bubbles downwardly. Furthermore by the inclined arrangement of the porous plates 59, collection of sediment on these plates and consequent clogging of the air orifices is prevented. On account, however, of this inclined arrangement, resulting in a difference in hydrostatic pressure at different points in the plates, there

would be a tendency, were these plates of constant thickness throughout, for the air to pass through the portions of the plates in greatest quantities at points of least hydrostatic pressure, namely, at the upper edges of the plates. To compensate for this, and provide for even aeration of the liquid by causing the air to pass through said plates in equal volume from top to bottom, said plates are formed slightly tapering or wedge-shaped in cross-section with their thickest portions at the top, the difference in thickness between the upper and lower edges being just sufficient to compensate for or balance the difference in hydrostatic pressure, so that the air passes through said plates with equal facility and in equal quantities throughout their area.

Of the solid matter not carried upward by the bubbles and passing into the launder 55 with the froth, the coarsest particles and oversize will sink to the bottom of the tank first, and the successively smaller particles at successively later periods. Therefore as the liquid passes through the tank 50 longitudinally from end to end the coarser material and oversize will be discharged through the outlet 1 and the successively smaller sizes through the outlets 2, 3 and 4, etc., so that only the solid particles of smallest size will pass out with the tailing through the outlet 56. The outlets 1 and 2, in accordance with the arrangement shown, are therefore arranged to discharge into the trough or tank 39 from which the material is discharged, through the conductor 40, to the concentrating table 41, and thence returned by the elevator or conveyer 42 to the grinding mill 12 for regrinding, as in the apparatus above described. The pipes 58 leading from the outlets 3, 4, 5, etc., convey the otherwise classified material to any suitable or desired points.

While, as herein shown, the material discharged from the outlets 1 and 2 is returned to the mill 12 for regrinding, it will be obvious that the material from outlet 1 only might be so disposed of, or that additional outlets might be arranged to discharge into the trough or tank 39 in accordance with requirements or conditions of operation.

The trough or tank 39 is merely shown herein as illustrative of convenient means for receiving the oversize to be returned to the mill for regrinding, and it will be obvious that other means might readily be employed for conducting the material to the concentrating table 41 or elevator 42, as, for example, in the arrangement shown in Fig. 2, by connecting the conductor 40 directly with the outlet 1.

The particular frothing classifier shown in Fig. 2 is not claimed herein, being covered by the claims of other Patents No. 1,243,814 of October 23, 1917, and No. 1,351,096 of

August 31, 1920. Also certain features of the classifying apparatus shown in Figs. 1, 3, 4 and 5 *per se*, are covered by the claims of Patent No. 1,319,208 of October 21, 1919, issued upon an application divisional hereof, and are therefore not claimed herein.

Having thus described my invention, I claim:

1. The combination with a grinding mill, of a frothing classifier into which the comminuted material from the mill is discharged and means for returning the coarse material separated out by said classifier to said mill for regrinding.

2. The combination with a grinding mill, of a frothing classifier into which the comminuted material from the mill is discharged, means associated with said frothing classifier for removing oversize material delivered thereto, and means for returning said oversize material to said mill for regrinding.

3. The combination with a grinding mill, of a frothing classifier into which the comminuted material from the mill is discharged, said classifier being provided with a classifying cone for removing oversize material, and means for returning said oversize material to said mill for regrinding.

4. The combination with a grinding mill, of a frothing classifier into which the comminuted material from the mill is discharged, a concentrator to which coarse material separated out by said classifier is delivered, and means for returning the material rejected by said concentrator to said mill for regrinding.

5. The combination with a grinding mill, of a frothing classifier into which the comminuted material from the mill is discharged, an elevator for supplying material to said mill, and means for delivering the coarse material, separated out by said classifier to said elevator.

6. The combination with a tube mill, of a frothing classifier into which comminuted material from the mill is discharged, and means for returning the coarse material separated out by said frothing classifier to said mill for regrinding.

7. The combination with a tube mill, of a frothing classifier into which comminuted material from the mill is discharged, means associated with said frothing classifier for removing oversize material delivered thereto, and means for returning said oversize material to said mill for regrinding.

8. The combination with a tube mill, of a frothing classifier into which the comminuted material from the mill is discharged, a concentrator to which coarse material separated out by said classifier is delivered, and means for returning the material rejected by said concentrator to said mill for regrinding.

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9. The combination with a tube mill, of a frothing classifier into which comminuted material from the mill is discharged, a classifying cone associated with said frothing classifier for removing oversize material delivered thereto, a concentrator to which said oversize material is delivered, and an elevator for supplying material to said mill and to which the material rejected by said concentrator is delivered.

10. The combination with a grinding mill, of a frothing classifier into which substantially all of the material discharged from said mill is received, said frothing classifier having provision for removing, during the frothing operation therein, oversize material delivered thereto, and means whereby said oversize material may be returned to said mill for regrinding.

11. A frothing classifier comprising a plurality of vessels each provided with means for admitting air thereto at the lower part thereof, and means for connecting adjacent vessels consisting of a laterally flattened transfer tube leading from the bottom of one vessel and extending into the next adjacent vessel above the air admitting means thereof.

12. A frothing classifier comprising a plurality of vessels each provided with means for admitting air thereto at the lower part thereof, and means for connecting adjacent vessels consisting of a laterally flattened S-shaped transfer tube leading from the bottom of one vessel and extending laterally into the next adjacent vessel above the air admitting means thereof.

13. A frothing classifier comprising a plurality of vessels each provided with means for admitting air thereto at the lower part thereof, and means for connecting adjacent vessels consisting of a laterally flattened transfer tube leading from one vessel underneath the air admitting means thereof and extending into the next adjacent vessel above the air admitting means thereof.

14. The combination with a grinding mill, of a frothing classifier comprising a vessel into which comminuted material from the mill is discharged, a classifying cone communicating with said vessel and having a water inlet and an outlet, a discharge tube for said vessel having its inlet arranged adjacent said classifying cone, and means for returning material discharged by the outlet of said classifying cone to said mill for regrinding.

15. In a frothing classifier, a vessel, means

for admitting air to said vessel at the lower part thereof, a classifying cone at the bottom of said vessel and communicating therewith, said classifying cone having a water inlet and an outlet for oversize, and an upwardly directed tailings discharge tube for said vessel having its inlet arranged adjacent said classifying cone and below said air admitting means.

16. A frothing classifier comprising, in combination, a plurality of vessels, means for admitting air to all of said vessels, a classifying cone at the bottom of one of said vessels and communicating therewith, said classifying cone having a water inlet and an outlet for oversize, and a transfer tube leading from said last named vessel, at a point adjacent said classifying cone, to the next adjacent vessel.

17. The combination with a grinding mill, of a frothing classifier comprising a plurality of vessels disposed in stepped arrangement at successively lower levels, means for discharging comminuted material from said mill into the uppermost of said vessels, air tubes supported at their ends in the walls of said vessels at points above the bottom thereof and collectively forming tubular gratings extending over substantially the entire horizontal cross-sectional area of said vessels, a classifying cone communicating with the bottom of said uppermost vessel and having a water inlet and an outlet, transfer tubes leading from the bottoms of said vessels at points below said tubular gratings to the upper parts of the next adjacent vessels, the transfer tube leading from said uppermost vessel having its inlet arranged adjacent said classifying cone, and means for returning the material discharged from the outlet of said classifying cone to said mill for regrinding.

18. A frothing separator comprising a vessel, means for admitting air to said vessel to produce froth at the top thereof, a hydraulic classifying cone at the bottom of said vessel for separating out and removing oversize from said vessel, and means for otherwise discharging from said vessel material smaller than oversize but too coarse for frothing treatment.

In testimony whereof I affix my signature, in presence of two witnesses:

DAVID COLE.

Witnesses:

W. L. DU MOULIN,
J. P. MONTER.