Dec. 19, 1939. H. W. COKE 2,184,115

APPARATUS FOR FLOTATION CONCENTRATION OF ORES

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Fig. 1.

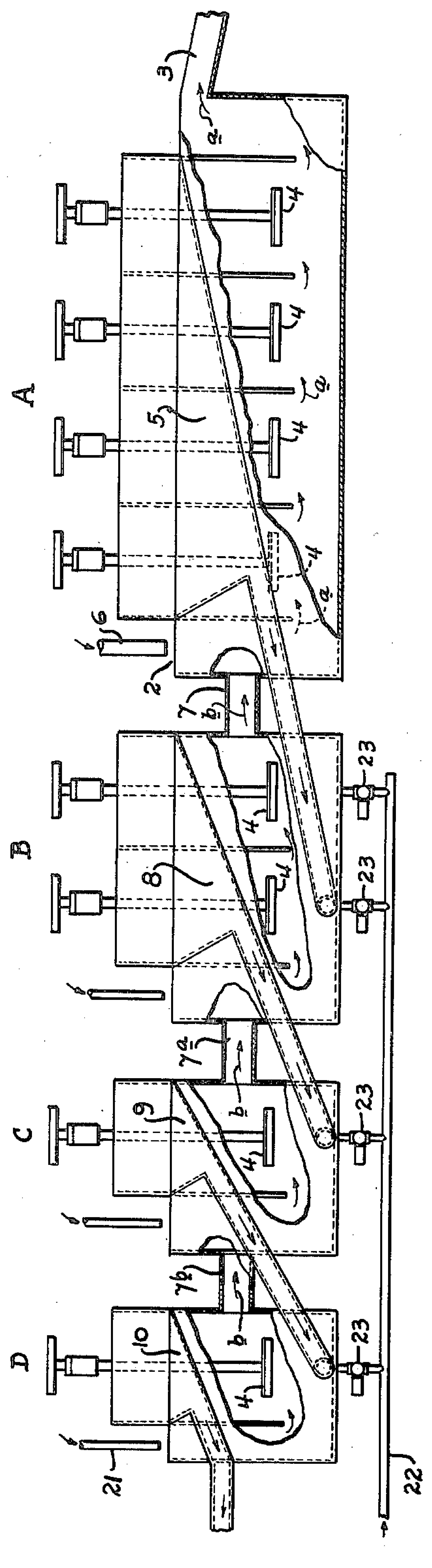

Fig. 2.

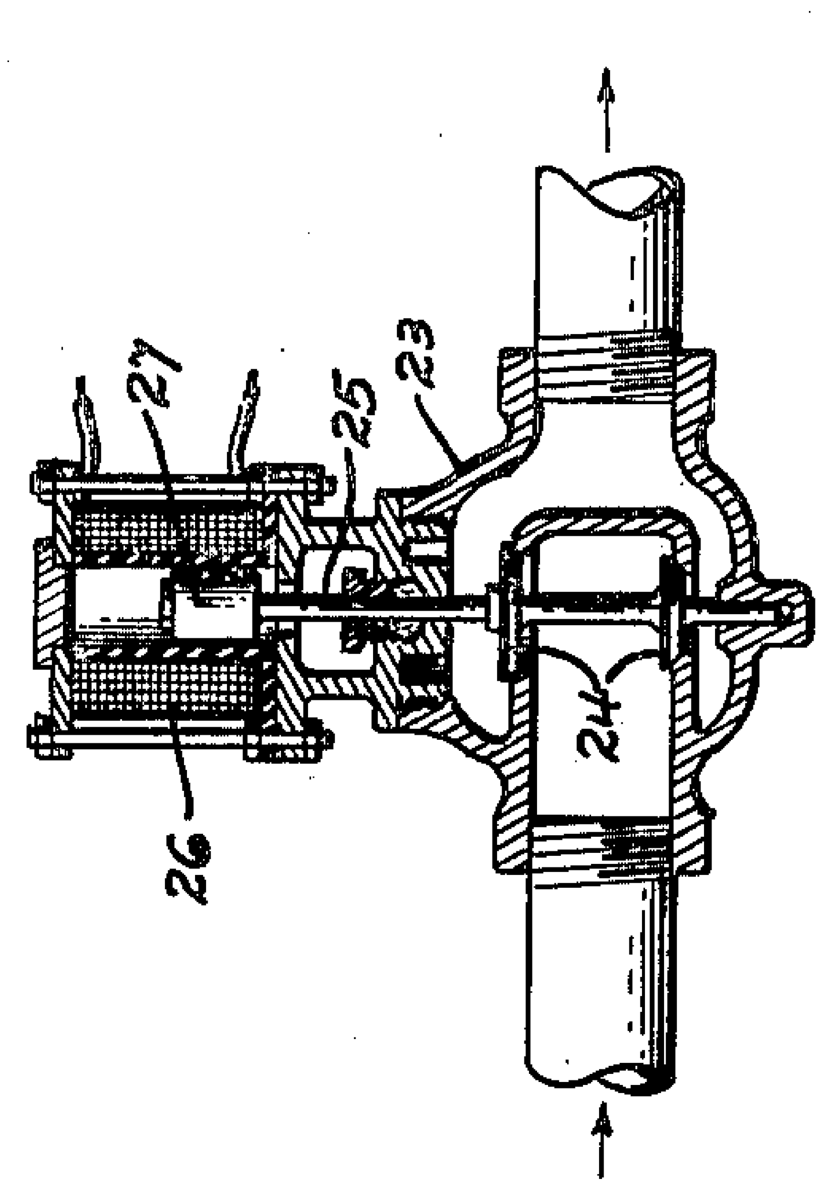

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Fig. 3.

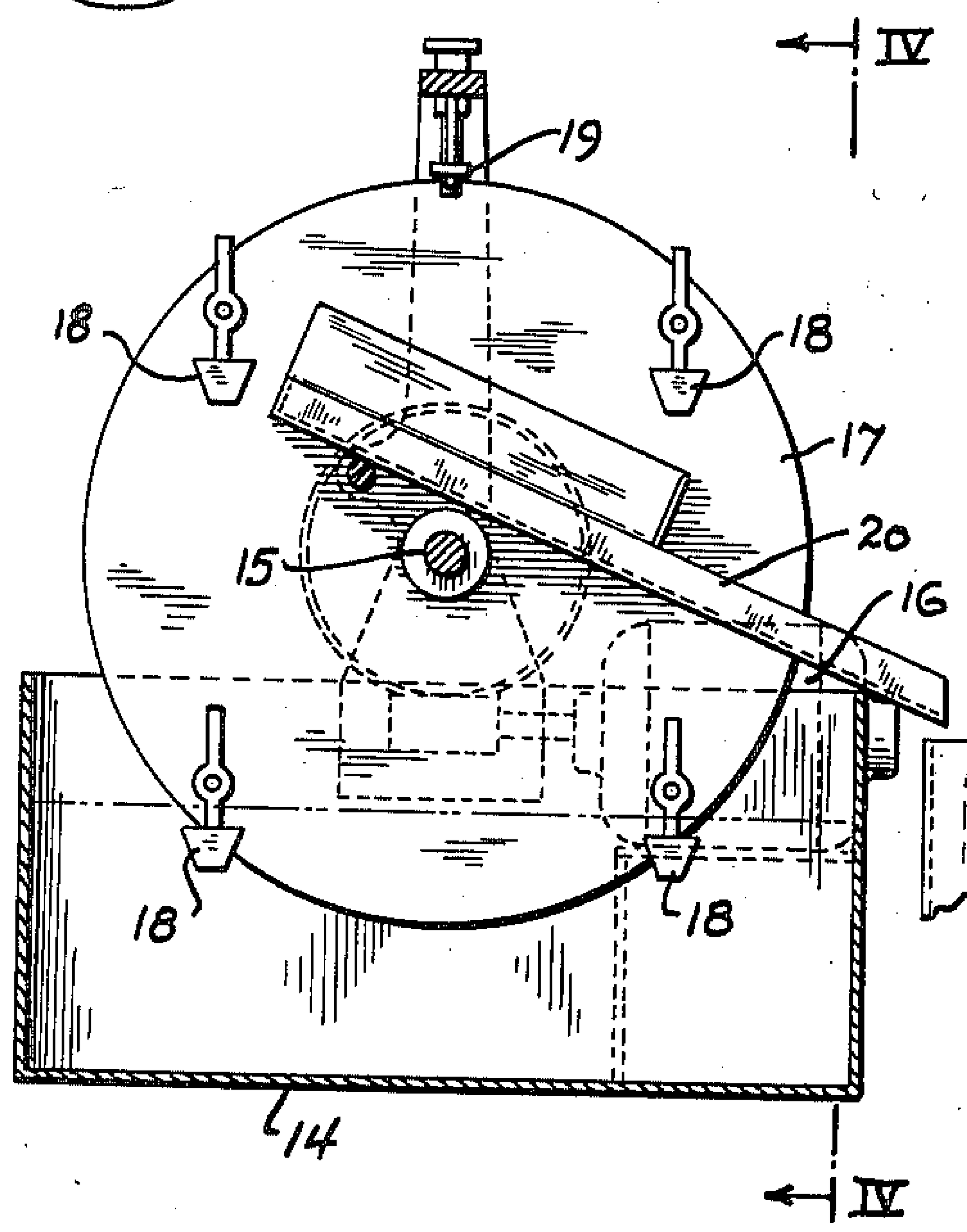


Fig. 4.

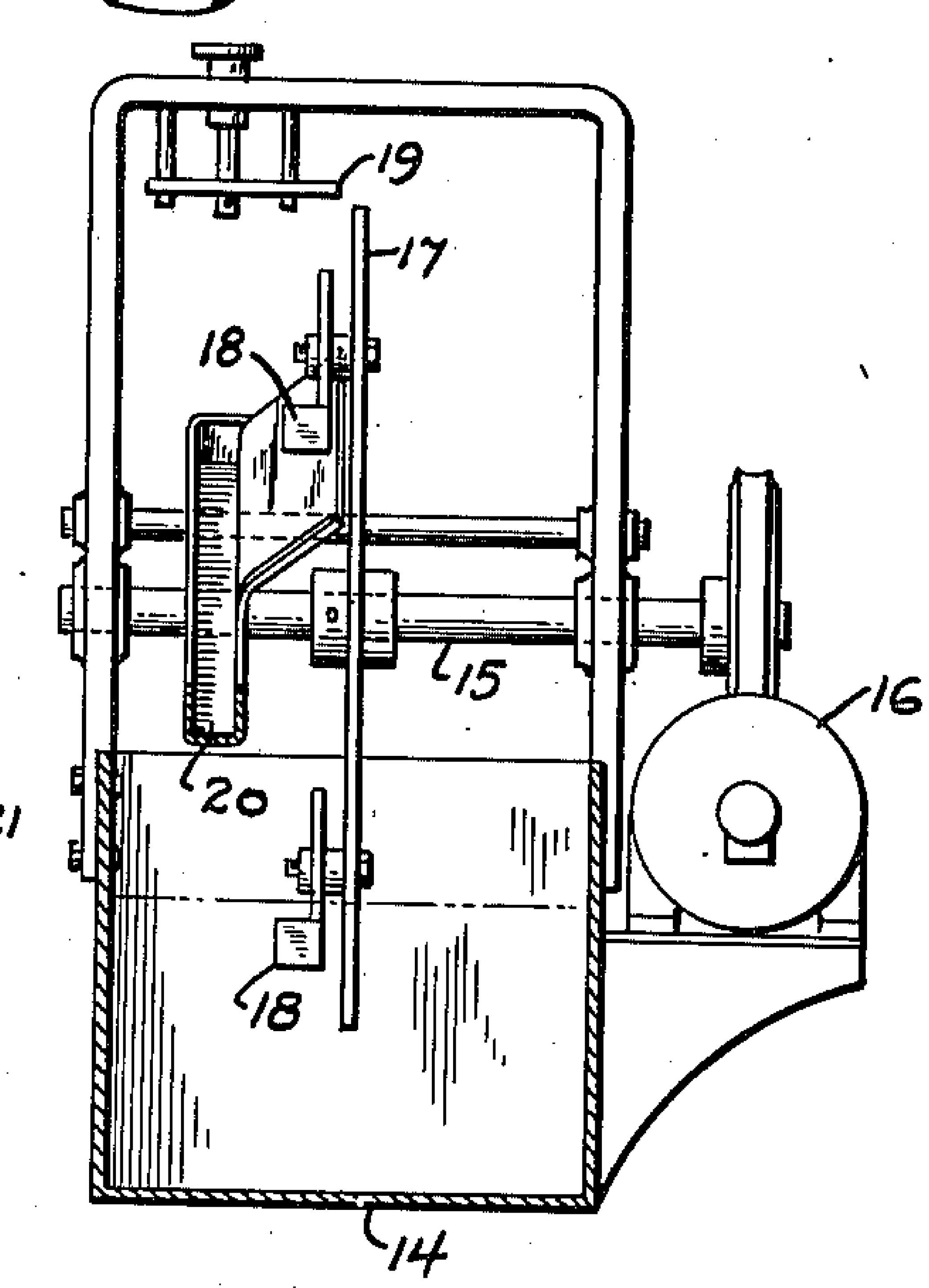
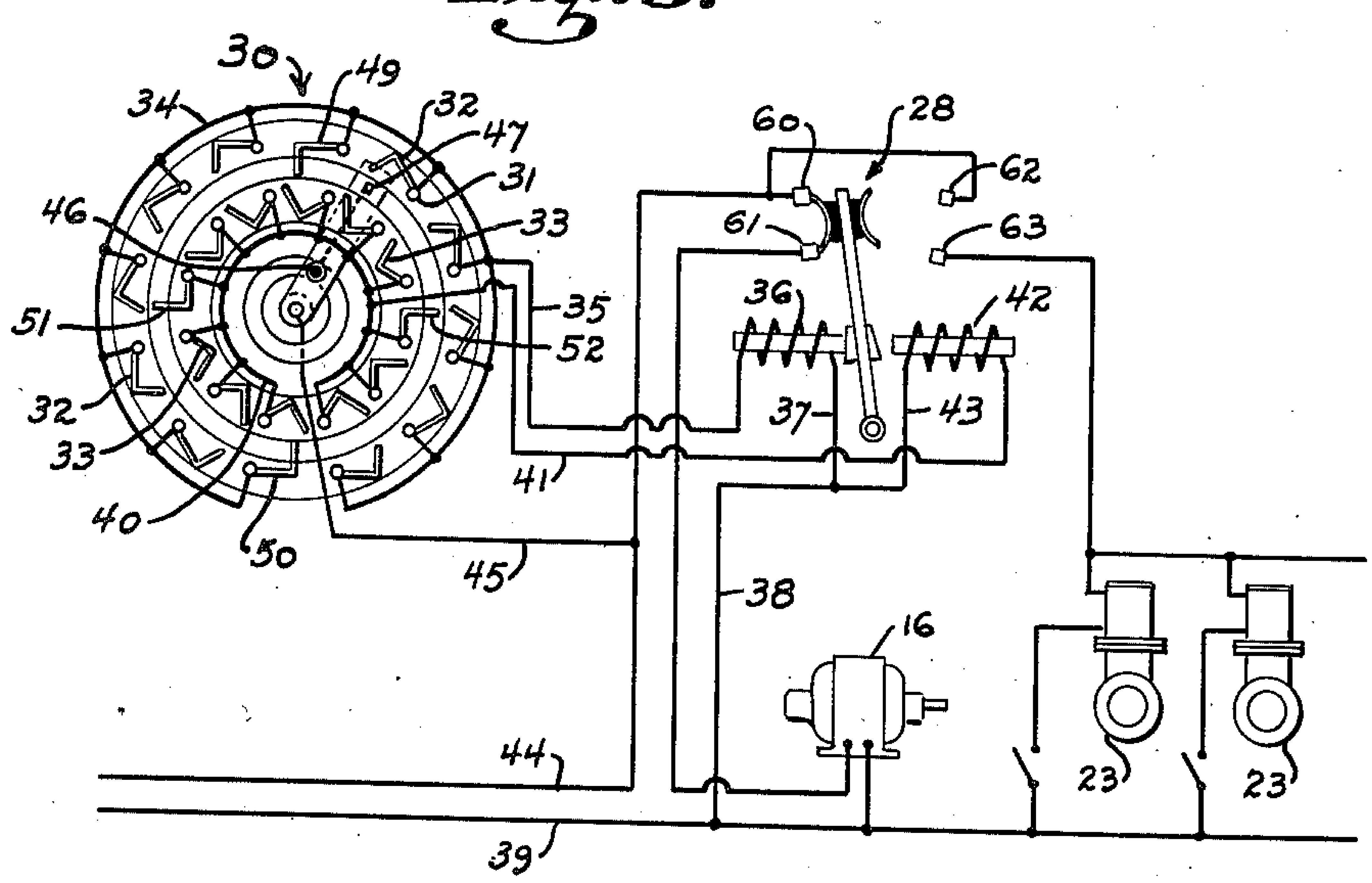


Fig. 5.



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APPARATUS FOR FLOTATION CONCENTRATION OF ORES

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Application September 27, 1938, Serial No. 231,891

4 Claims. (Cl. 209—168)

In the concentration by flotation of certain minerals, and more especially those containing precious metals, it is usually essential that the grade of the precious metal concentrate be raised to the highest point consistent with good recovery. In this manner only can the expenditures for freight and smelting charges be reduced and the price per ounce paid for the gold be increased.

There often occurs with precious metal and other ores certain minerals which are readily floatable by usual methods, but are frequently without sufficient value to be permissible in the concentrate. In one particular ore which may be cited as an example there are present the following minerals, all of which are floatable by the usual methods, and thus may be separated from the rock or gangue minerals; these are, listed in the order of their relative quantities:

1. Carbon
2. Pyrrhotite
3. Pyrite
4. Chalcopyrite
5. Argentiferous galena
6. Elemental gold

Of the above minerals (1) carbon is entirely barren and (2) pyrrhotite sufficiently low in precious metals to be discarded as unprofitable. The others (3) to (6) are of value and must be saved.

A common method of preventing these comparatively valueless minerals from floating and thus from lowering the grade of the concentrate is to add reagents, known as conditioning agents or depressants, which decrease the floatability of these minerals while not appreciably decreasing the floatability of the more valuable minerals; but the action of such depressants is not, unaided, so exact as to eliminate all the undesirable minerals and retain those that are desirable. Both the quantities of depressant reagents and the time of treatment have marked effects, as too large a quantity depresses the more valuable material and gives a tailing too valuable to discard, while a decrease generally results in a concentrate containing an undue quantity of waste material, and thus relatively less profitable.

I have discovered a method whereby both the quantity of the reagent and the time of treatment may be so varied at the will of the operator and the necessity of the ore, that substantially all the barren and depressible minerals are eliminated, and the more valuable minerals concentrated into a very high grade product.

Briefly stated, I provide a method and apparatus whereby the cleaning cell or cells of a flotation circuit are intermittently operated in cycles of accumulation of rich concentrates with elimination of unwanted barren minerals, and cycles of discharge of the rich concentrates. This is accomplished by the intermittent feeding of depressant reagents, the effect of which is to cause accumulation of those minerals least affected by the depressants due to the weakened froth structure produced during the feeding of the depressants, and when the depressant feed is stopped, the froth builds up rapidly with undepressed minerals and discharge of the accumulated rich concentrate commences and continues until minerals of the lower order of floatability begin to appear, when the accumulating cycle is repeated by again applying the depressants.

The method and apparatus employed is described in more detail in the accompanying specification, and is shown by way of illustration in the drawings, in which

Fig. 1 is a diagrammatic view showing the cleaning cells of a flotation circuit;

Fig. 2 is a central vertical section of an electromagnetically actuated air controlling valve;

Fig. 3 is a side elevation, partly in section, of a reagent feeder;

Fig. 4 is a cross section taken on line IV—IV of Fig. 3; and

Fig. 5 is a diagrammatic wiring diagram showing a timing switch, a double-throw magnetic switch actuated thereby, and an electric motor and valves which are controlled by the double-throw switch.

Referring to the drawings in detail, and particularly to Fig. 1, which diagrammatically indicates a roughing and cleaning circuit, A indicates the flotation tanks or cells forming a roughing circuit, and B, C and D the cells forming the cleaning circuit. The ore or pulp to be treated, together with the flotation agents employed are delivered to the roughing cells at the point indicated at **2**, and flow through the cells to the tailing launder **3**. The cells may be of any standard type, and may be aerated by suction or pump, as desired. The pulp is agitated throughout the circuit by impellers **4**, and the rougher concentrates are discharged in the usual manner into a launder **5** which delivers the concentrates to the first set of cleaning cells B.

In the diagram submitted, gravity flow is indicated, but pumps may be substituted wherever necessary or desirable. Again, the reagents may be introduced, if and when necessary, at the point 6, or at any other point where most convenient. The path of the pulp through the cells is indicated by the arrows *a*, and connecting ports or pipes 7 are provided to permit the middlings to pass, as indicated by arrows *b*, from cell to cell back into the roughers A.

The concentrates from the cleaner cells B overflow into a launder 8, and by this are delivered to the recleaning cell C. This cell is similar in construction and operation to the preceding cells B. The middlings from the cell C flow to cell B through pipe 7*a*, and the overflowing concentrates are received in a launder 9, and by this are delivered to the final cleaner cell D. This cell is also similar to the preceding cells, and is provided with a pipe 7*b* for return of middling, and it is also provided with an overflow launder 10 which receives and discharges the finished concentrates.

It will be observed that the flow of concentrates is counter to the flow of middlings, pulp and final tailings. I have shown four stages, A, B, C, and D, which have been found most desirable for a high concentration ratio of low-grade heads, but two or three stages may be all that is required for higher grades of crude ores.

It is in the operation of the final stage D, or, by option, also stages C and B, that I find intermittent operation and accumulation of concentrates most desirable; and while manual control of the intermittent operation is feasible, I prefer automatic control and timing, as will now be described.

The depressant to be intermittently applied may be fed by any suitable feeder, or the type of feeder shown in Figs. 3 and 4. This feeder comprises a tank 14 above which is journaled a shaft 15 driven through reduction gears by an electric motor 16. Secured on the shaft is a disc 17, and pivotally mounted on one side thereof is a plurality of buckets 18 which dip into the reagent or depressant contained in the tank once during each revolution of the shaft and disc. These buckets are tilted to discharge all or a part of their contents by engagement with an adjustable cross-bar 19. The buckets when tilted discharge into a trough 20, and this empties into a feeder pipe 21 which delivers the depressant to cell D. If it is desired to feed the depressant to the cell C also, and possibly to cell B, a second or third feeder will be employed.

To simplify the diagrammatic illustration shown in Fig. 1, air under the required pressure is delivered from a suitable pump or other source to a pipe 22, and directed thereby into the bottom of each cell. A valve 23 is interposed between the air delivery pipe and each cell, and as the valves are identical in construction and operation, the description of one will suffice. A type of valve which may be employed is shown by way of illustration in Fig. 2. It comprises a valve body 23 having two balanced valves 24 secured on a stem 25 which projects through the upper end of the body. A solenoid magnet 26 is mounted above the valve body and supported thereby, and as the core 27 of the solenoid is secured to the valve stem, the valves will open when the magnet is energized, and will close by gravity when the circuit through the magnet is broken. An electromagnetically controlled double-throw switch 28 is employed for the purpose of alternately making and breaking an electric circuit through the motor 16 and the solenoid-operated valves 23, and a timing switch, generally indicated at 30, is employed to actuate the double-throw switch 28.

Any suitable type of timing switch may be employed. In this instance one form of switch is diagrammatically illustrated. It comprises a circular disc-shaped member, on which is pivotally mounted as at 31 a set of adjustable switch arms 32. These arms are arranged in circular formation. A similar set of adjustable switch arms is indicated at 33 and is also arranged in circular formation and concentric with the arms 32. All the switch arms 32 are connected to a wire 34 which in turn is connected to a wire 35. This wire is connected with one terminal of a magnet 36. The opposite terminal is connected with a wire 37, and this is in turn connected, through a wire 38, with one side of a power circuit indicated at 39. The switch arms 33 are similarly connected to a common wire 40. This is connected, through a wire 41, with one terminal of a magnet 42. The opposite terminal is connected, through a wire 43, with the wire 38 and the side of the power circuit indicated at 39. The opposite side of the power circuit or wire 44 is connected through a wire 45 with a contact arm 46. This arm is driven by a telechron motor, or may be driven by a wound-up clock spring. The contact arm will make one revolution an hour, and it carries a brush 47 which is adapted to engage any one of the switch arms 32 or the switch arms 33.

Before proceeding with the description of the operation, let it be assumed that the particular ore being treated has been thoroughly tested, and that it has been found that cycles of intermittent operation having an approximate timing of fifteen minutes are desirable. If that is the case, two of the outer switch arms, indicated at 49 and 50, are moved inwardly, and so are two of the inner switch arms, which are indicated at 51 and 52. The several switch arms are thus set at fifteen-minute intervals. When the contact arm 46 passes the contact 49, the brush 47 on arm 46 will engage the contact 49 and will close the circuit which energizes the magnet 36, thereby energizing the same and causing the double-throw switch arm 28 to assume the position shown in Fig. 5. In this position it closes the circuit through the contacts 60 and 61. This circuit when closed passes through the motor 16 and starts it in operation. This motor, as previously stated, drives the depressant feeder shown in Figs. 3 and 4, and the depressant reagents will thus be applied, through pipe 21, to the cell D, weakening the froth structure to such an extent that only the minerals of high floatability may be retained, while those of lower floatability will be carried over to the cell C. The concentrates of highest value will thus continue to accumulate while the lower values or undesirable minerals will be discarded. At the end of fifteen minutes, the brush 47 will engage the switch arm 52 and will close the circuit through the magnet 42, thereby energizing the same and causing the double-throw switch arm 28 to swing over and engage the contacts indicated at 62 and 63. The circuit through the motor 16 will thus be broken, and the feed of the depressant reagents will be stopped. The circuit established through the contacts 62 and 63 will close the circuit through the solenoid-actuated valves 23, energizing the same and opening the valves. Air will thus be introduced, and froth will gradually build up and begin to overflow. Concentrates of high floatability will thus be discharged into the launder 10, and a highly concentrated rich concentrate will thus be obtained. This cycle will continue for the next fifteen minutes, as brush 47 will then move into engagement with the switch arm 50 and again close the circuit through the magnet 36, thus swinging the double-throw switch back into engagement with the contacts 60 and 61, and closing the circuit through the motor. This in turn starts operation of the feeder shown in Figs. 3 and 4, and the depressant reagents will again be applied.

While I have specifically described the application of the reagent to the cell D, I may, as previously stated, apply it to the cell C and also to the cell B; and while fifteen-minute periods have been described, timing will be varied depending on the problems encountered, such as grade of the ore being treated and ratio of concentration desired. Hence, the periods of concentrate accumulation may range from a checking effect to periods up to an hour or more, if this is found desirable.

When using a reagent for the purpose of depressing unwanted material by standard methods, the continuous application of reagent to a cleaning circuit has invariably a very detrimental effect on recovery of values, if used in sufficient quantity to develop a froth condition giving the highest possible grade of concentrate. By the present method, it is possible to feed the reagent in excess quantities during short periods, allowing for recovery from the effect of the reagent during the periods when no reagent is being fed. By this method, the detrimental effect of continuous feeding of a reagent is avoided. In addition, time is allowed for the accumulation of values and the production of concentrate is regulated and permitted only under the most ideal front conditions.

The time-actuated switch 30, as previously stated, has numerous switch arms such as indicated at 32 and 33. It is accordingly possible to arrange the time cycles as desired. The whole cycle, or any of the elements of the cycle, is thus in the control of the operator by the setting of the switch arms, and they will automatically maintain the proper timing until a change in quantity or character of the ore may require adjustment. Suffice it to say that in actual operation the time switch 30 will become actuated and will start up the reagent feeder, which will send the depressant to the cell D or to any number of additional cells as desired. At the same time, the time switch will cut off the air supply to the cells under treatment, and the cells will continue to operate without producing froth. Conditioning the pulp already in the cells and the concentrates received from the roughers will follow. In this manner, the cleaner cells will build up full of conditioned and partially concentrated pulp, which will circulate within and between the cells until the time determined by the setting of the time switch. The time switch will then stop the reagent feeder, whereby no further depressant is sent to the cell or cells. At the same time the time switch will open the air valves, and aeration and production of froth will commence. The froth, having been preconditioned by the excessive depressant, now discontinued, will contain only the valuable minerals, and the barren or low-grade minerals will, by means of the reverse flow of the middlings, be sent back to the roughers and be there rejected in the rougher tailings. The discontinuance of aeration by closing the valves 23 through means of the time switch will signal the beginning of a new accumulation cycle, and each cycle will thus be automatically repeated and repeated without any attention on the part of the operator. The only time a change in the setting of the time switch will be required is when different ore conditions or problems are encountered.

An Alaskan gold ore containing silver and galena contained:

1. Carbon, barren of precious metals but under usual conditions floating with the sulphide minerals.
2. Pyrrhotite, too low grade in precious metals to be of value.
3. Pyrite, of value for its gold content.
4. Chalcopyrite, of value for gold and copper.
5. Argentiferous galena.
6. Elemental gold.

All of the above exist in a mixture with quartz and slate.

When treated by the usual continuous process, selective flotation, with cleaning and recleaning of the concentrate, gave a concentration of about 380 into one, and a product having

Gold	ounces per ton	3.3
Silver	do	14.0
Lead	per cent	15.0

The present method resulted in an equal total recovery with a ratio of about 1000 into one and a grade of

Gold	ounces per ton	8.6
Silver	do	48.0
Lead	per cent	50.0

Since freight and treatment were approximately the same per ton in both cases, the saving is very appreciable.

Ratios of concentration of 1000 to 1500 into one have been obtained with low grade gold ores containing less than .1% Pb. by using periods of thirty minutes for accumulation and 10- to 15-minute periods of discharge.

Far higher grades of concentrate can be obtained with the described method than by any of the methods commonly employed in the art of flotation.

Differentiation between minerals is developed to a very high degree. Sharp selection of one or more minerals of a group is possible according to the order of their floatabilities.

Soluble starch, sodium silicate, etc. have been used and found suitable as depressant reagents, but other depressants may obviously be employed where other conditions are found. A number of different frothing and collecting agents may be employed in connection with an ore of the type described above. Among the frothing agents which may be used are crysilic acid, pine oil, etc.; among the collecting agent which may be employed are xanthates, for instance pentasol and amyl xanthate. While this and other features of my invention have been more or less specifically described and illustrated, I nevertheless wish it understood that changes may be resorted to within the scope of the appended claims.

Having thus described and illustrated my invention, what I claim and desire to secure by Letters Patent is:

1. In a flotation apparatus including a plurality of cleaner cells, a feeder for feeding a selective flotation reagent to one or more of the

cleaner cells, an electric motor for driving the feeder, means for delivering air to aerate the cells, a valve for each cell to control the delivery of air thereto, means for opening the circuit through the motor to intermittently stop the feed of the reagent to the cells, and means for closing the air controlling valves during the feeding of the reagent and for opening the valves when the motor circuit is open.

2. In a flotation apparatus including a plurality of cleaner cells, a feeder for feeding a selective flotation reagent to one or more of the cleaner cells, an electric motor for driving the feeder, means for delivering air to aerate the cells, a valve for each cell to control the delivery of air thereto, means for opening the circuit through the motor to intermittently stop the feed of the reagent to the cells, means for closing the air controlling valves during the feeding of the reagent and for opening the valves when the motor circuit is open, and means for automatically controlling the opening and closing of the valves and the circuit through the motor.

3. In a flotation apparatus including a plurality of cleaner cells, a feeder for feeding a selective flotation reagent to one or more of the cleaner cells, an electric motor for driving the feeder, means for delivering air to aerate the cells, a valve for each cell to control the delivery of air thereto, means for opening the circuit through the motor to intermittently stop the feed of the reagent to the cells, means for closing the air controlling valves during the feeding of the reagent and for opening the valves when the motor circuit is open, and a block-actuated switch controlling the opening and closing of the valves and the circuit through the motor.

4. In a flotation apparatus including a plurality of cleaner cells, a feeder for feeding a selective flotation reagent to one or more of the cleaner cells, an electric motor for driving the feeder, means for delivering air to aerate the cells, a valve for each cell to control the delivery of air thereto, means for opening the circuit through the motor to intermittently stop the feed of the reagent to the cells, means for closing the air controlling valves during the feeding of the reagent and for opening the valves when the motor circuit is open, a clock-actuated switch controlling the opening and closing of the valves and the circuit through the motor, and means on the clock-actuated switch for varying the length of time of reagent feed and aeration of the cells.

HUGH W. COKE.