Dec. 24, 1940. F. P. LASSETER 2,226,170

FLOTATION OF MATERIALS

Filed Jan. 13, 1938 5 Sheets-Sheet 1

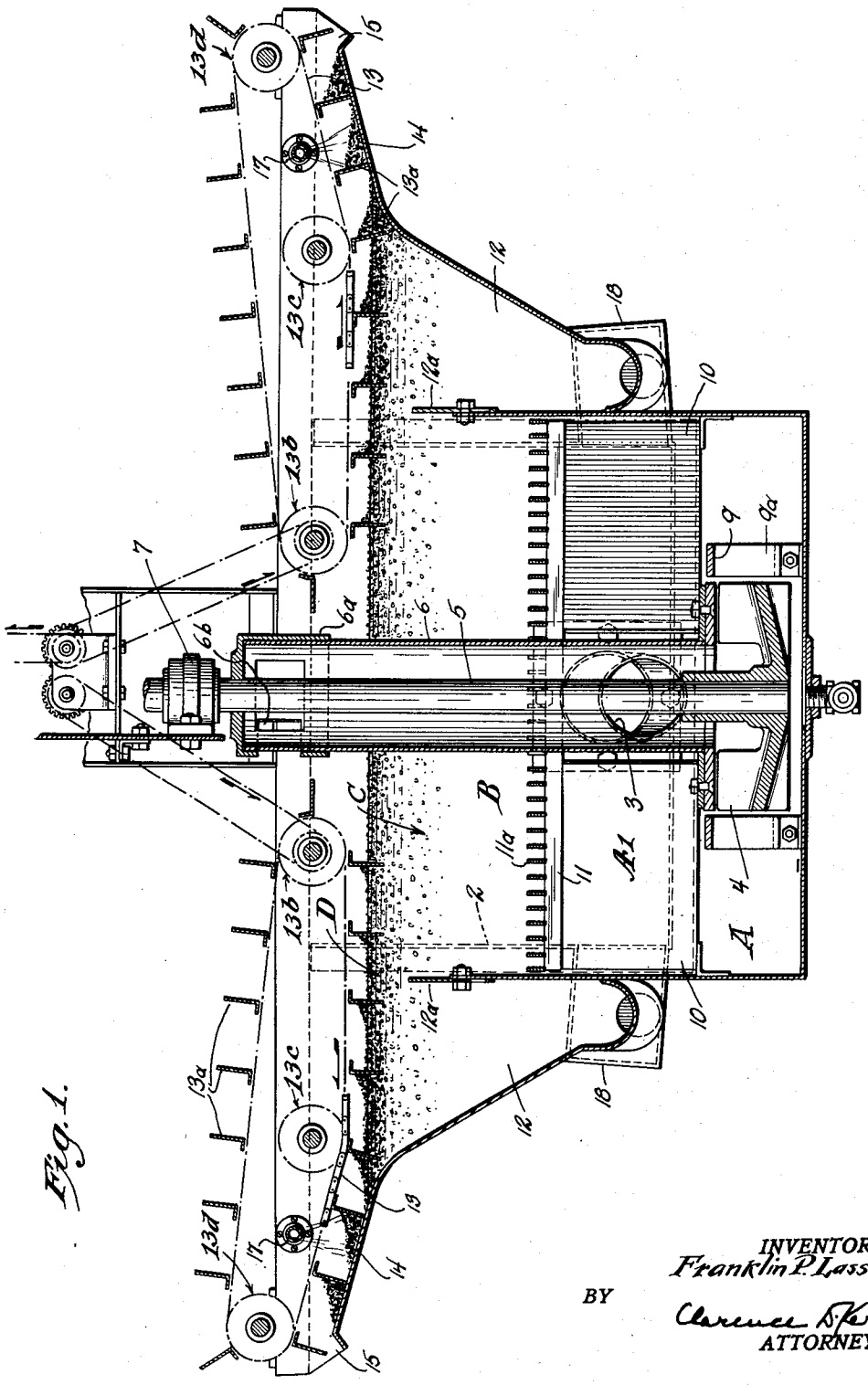


Fig. 1.

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FLOTATION OF MATERIALS

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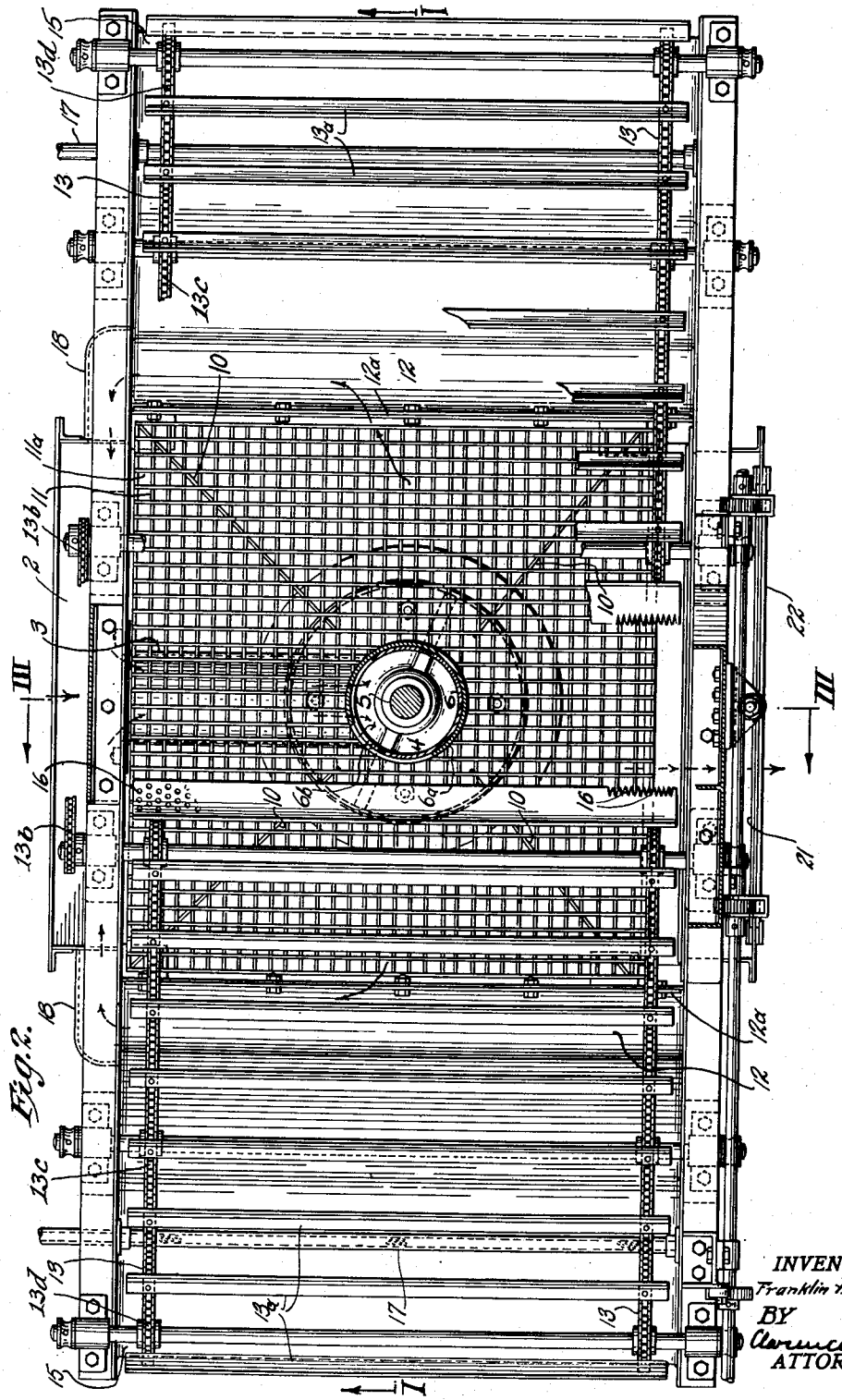


Fig. 2.

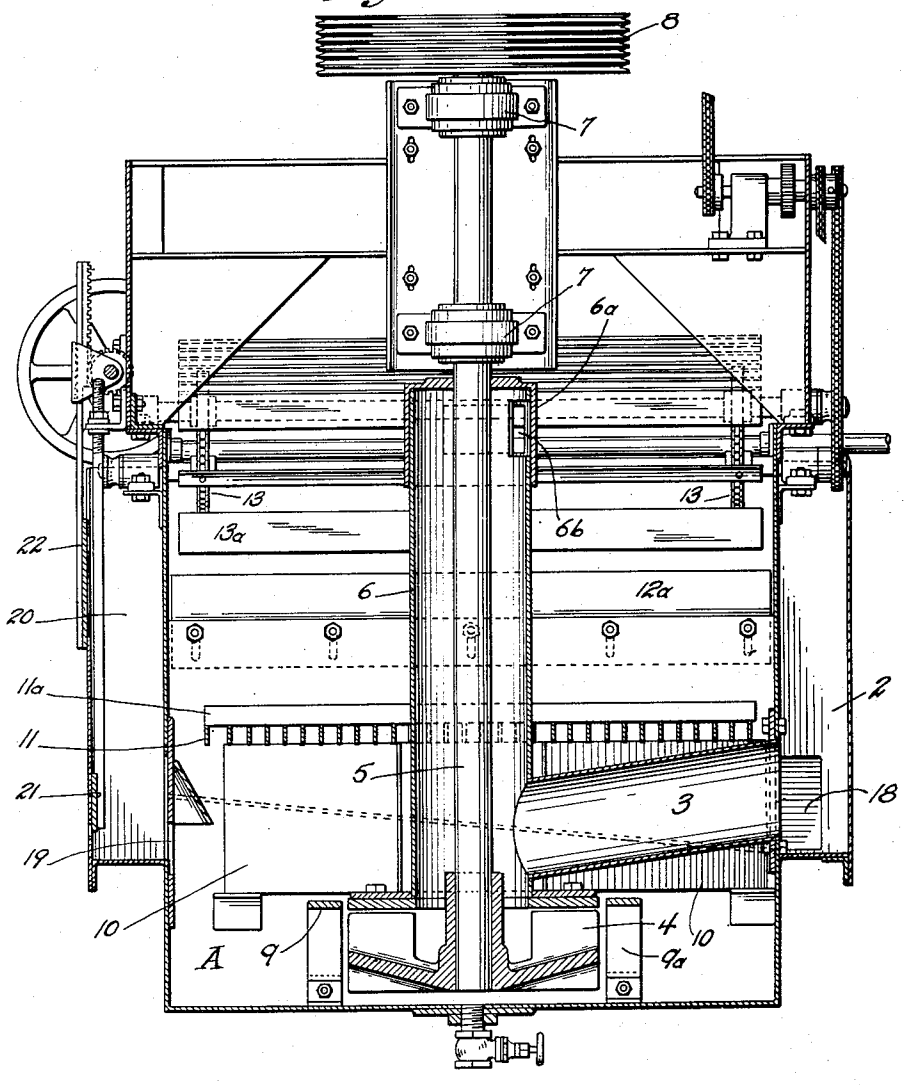
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FLOTATION OF MATERIALS

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Fig. 3.



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FLOTATION OF MATERIALS

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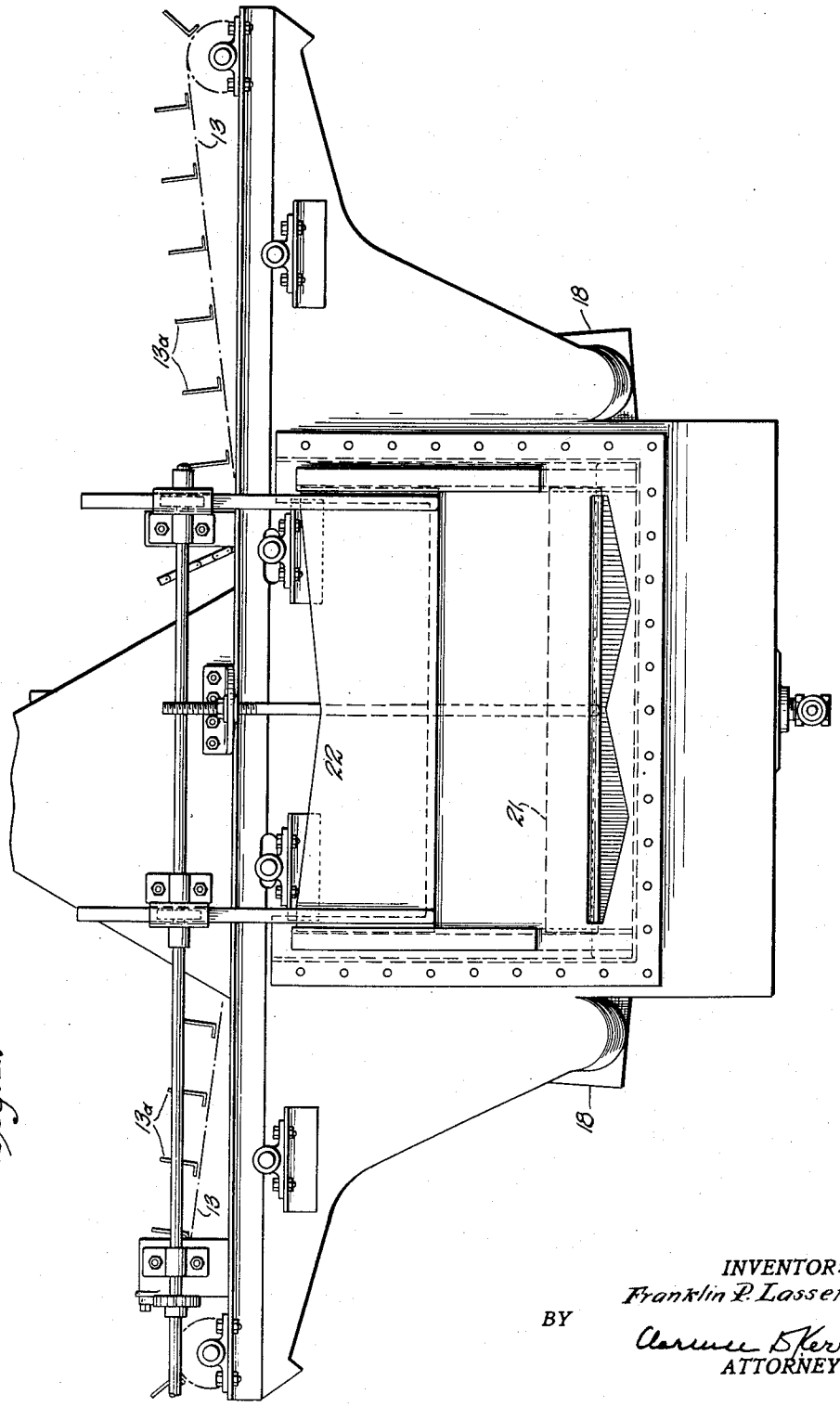


Fig. 4.

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Dec. 24, 1940. F. P. LASSETER 2,226,170

FLOTATION OF MATERIALS

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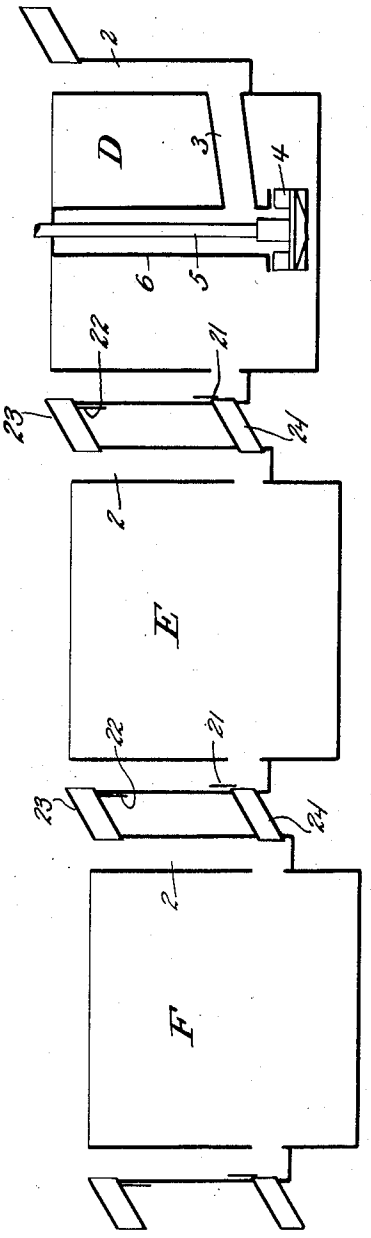


Fig. 5.

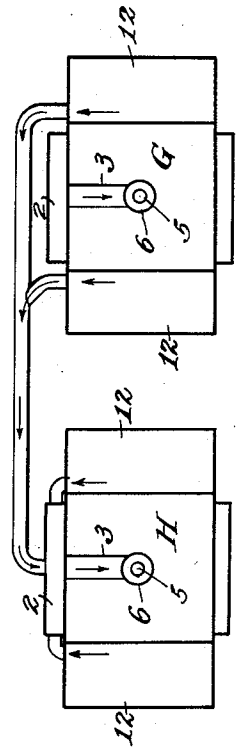


Fig. 6.

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Patented Dec. 24, 1940 2,226,170

UNITED STATES PATENT OFFICE

2,226,170

FLOTATION OF MATERIALS

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Application January 13, 1938, Serial No. 184,753

18 Claims. (Cl. 209—165)

My invention relates to a new and improved process and apparatus for the separation of high and intermediate values from materials, employing the flotation principle. It is particularly well adapted for use in treating relatively coarse, as well as fine, materials which are difficult to separate and recover by the usual flotation process.

My invention is further especially adapted for treating materials from which large bulk concentrates are to be removed. This is accomplished by floating the floatable particles as a stabilized or coherent matte having a minimum of contamination with non-floating particles, the matte subsequently to be removed in a substantially dewatered condition. It is also applicable for the efficient cleaning and recovery of relatively coarse, as well as fine, substances in cells having a large tonnage capacity with little size degradation and without the necessity of recleaning the concentrates thus obtained. It is especially useful in the separation and recovery of relatively coarse high carbon values from coal slush culm or silt, which is usually a waste product of large coal preparation plants.

I have also found, particularly where the values to be separated do not differ widely in specific gravity from the refuse, that the formation of the normal flotation froth in cells of the usual construction tends to float fine refuse with substantial proportions of fine values and to reject very substantial proportions of the coarse values with the refuse. In my process, however, the successive steps hereinafter described promote a more exact and complete separation and elevation of the coarse floatable particles desired to be recovered, and when these collect in the stabilized matte at the liquid surface they are not disturbed by agitation before removal.

Where I designate materials as "coarse" or "relatively coarse" herein it is to be understood that I am referring to materials coarser than 28 mesh.

Although designed primarily for separating coarse values, my invention may be used in separating values in either fractional sizes or en masse. For instance, I have obtained favorable results in cleaning coal particularly in sizes between 8- and 28-mesh, 8- and 150-mesh, and even finer, and also with everything plus 3/32 and up to 3/16 of an inch. I have found that results are improved in treating sizes under 3/32 of an inch if the percentage of solids in the pulp is approximately between 15 and 30 per cent. In general when treating larger sizes the percentage of solids should be at a maximum.

In carrying out my invention the material to be be recovered is preferably and successively passed in the form of a conditioned pulp through a very turbulent mixing, agitating and aerating zone, a refuse removal zone, a relatively quiet teetered classifying zone of substantial vertical extent, in which the floatable and partly floatable particles are classified and separated, a quiet flotation zone in which the floated particles collect as a cohesive matte for removal, and a flotation concentrate removal zone. The "middlings" or partially floating particles may also be collected in a separate removal zone. My invention may be carried out either in a single or in a series of cells, the latter being particularly effective when the recovery of products of differing grades or sizes is desired.

In the accompanying drawings I have shown appratus suitable for carrying out my invention, in which Fig. 1 is a vertical section taken through my improved cell on lines I—I of Fig. 2; Fig. 2 is a plan thereof; Fig. 3 is a section on lines III—III of Fig. 2; Fig. 4 is an elevation of the discharge end of the machine; Fig. 5 shows diagrammatically in partial section a group of my improved cells arranged for series operation; and Fig. 6 shows in plan another series arrangement of cells.

My improved flotation cell, which is best shown in Figs. 1 to 4, inclusive, is particularly adapted for carrying out the process hereinafter described. The material to be treated is introduced into the feed box 2, from which is passes through an inlet pipe 3 and the lower end of the hollow center column 6 to the upper face of the impeller 4, which is mounted on the bottom of the driving shaft 5 in the column 6. The shaft 5, which is arranged on the axis of the column 6, is suitably mounted in bearings 7 and is driven through the pulley 8 by any suitable source of power (not shown). Air or gas may be admitted into the column 6 through an air control cap 6^a, which may be rotated to vary the size of the air ports 6^b and thus regulate the amount of fluid drawn down by the impeller 4 for mixture with the material under treatment. Arranged about the periphery of the impeller 4 is a ring 9 with vertical slots 9^a therethrough for the discharge of the material by the impeller into the agitation zone A.

To break up the whirling motion of the pulp, to reduce its turbulence and to change the direction of flow to an essentially upward motion, and

thus divert the particles to be recovered into the separating zone B, are the vertical baffles 10, which are preferably arranged diagonally of the cell in the form of a cross, and a grid of vertically disposed bars 11 and 11a above the baffles 10. The zone B is preferably of sufficient depth or vertical extent to permit teeter classifying action, hereinafter described.

On opposite sides of the cell are the middlings pockets 12, which have adjustable lips or baffles 12a to control the flow of the material into the pockets 12. Above the zones B and C and operating transversely through the concentrate removal zone D, I have shown two endless drag conveyors 13 with conveyor blades 13a mounted upon them. The conveyors are mounted on gears 13b, 13c and 13d, the intermediate gears 13c being so located that the conveyor blades 13a, the lower edges of which extend into the stabilized matte and an appreciable distance below the surface of the liquor, travel through a path parallel to its surface from the gears 13b to 13c, and then up an incline from the gears 13c to 13d parallel to and over the drainboards 14. Thus the blades 13a propel the floated cohesive matte or concentrate laterally in the zone D and up along the incline of the drainboards 14 at the sides of the cell and discharge such concentrate through the openings 15.

The conveyor blades 13a preferably have perforations or recesses 16 to permit the entrained liquid to flow backward down the drainboard into the cell. The cleansing function of this drainboard operation may be amplified by using fine clear-water sprays from the pipes 17.

The pockets 12, at the sides of the cell, are inclined from the discharge end to the feed end so as to direct the middlings, which sink down in such pockets, through the middlings return pipes 18 to the feed box 2, and thence through the inlet pipe 3 and impeller 4 to the agitation chamber A for re-treatment. The tailings are discharged from the zone A' of the cell through the adjustable opening 19 into the discharge compartment 20, from which they pass out of either the bleeder gate 21 or weir gate 22 in accordance with what has heretofore been the usual practice. The height of the liquor in the cell is controlled by the height of the weir gate 22, the degree of opening of the bleeder gate 21 and the pulp feed.

In carrying out my invention the material to be treated should be properly conditioned. Usually the following additions are made: water to give it fluidity; a selective collecting agent such as a mineral oil; and a frother to give mechanical strength to the minute air bubbles which perform an important function in carrying out my invention. The amount and character of the reagents vary with the kinds and sizes of materials under treatment. Preferably, the conditioning operation is effected before the material is introduced into the treatment cell, but, if desired, the material and the conditioning agents may be separately introduced into the feed box, in which event the mixing will be effected by the impeller 4.

When my invention is applied to the separation of coal from impurities I preferably use a small amount of a collector oil with or without a very small amount of frothing agent. For instance, a suitable quantity of oil, such as kerosene, used may be of the order of .2 to .5 per cent of the weight of the concentrate, and as little as .012 per cent of a frothing agent, such as American Cyanamid Frother No. 40, may be used with beneficial results.

In my process the material to be treated, which thus may previously have been conditioned with the oiling and frothing agents, if any frothing agent is used, is introduced into the feed box 2 and from there is drawn into the impeller 4, which at the same time draws air or gas down the column 6, mixes it with the pulp, and drives the mixture outwardly and radially into the mixing, aerating and agitation zone A, so that the entire fluid mass is of even density and thoroughly mixed with air in as minute bubbles as mechanical means will produce. Limiting the amount of air to a minimum tends to the production of minute bubbles which form an important element in high percentage recoveries of values.

I have discovered that where the material being treated contains relatively coarse particles the agitation and aeration of the material in the manner described cause the adherence of air bubbles materially smaller than the particles. Such small air bubbles thereby render the coarse as well as the fine particles buoyant and separable from the low and non-value particles by flotation. As a result the subsequently formed matte or concentrate exhibits an absence of the usual froth (which is characterized by large bubbles carrying small particles of values) since the minute air bubbles are scarcely noticeable in the concentrate.

The pulp, as it is driven outwardly by the impeller 4, is strongly agitated and a whirling turbulent motion is set up through the zone A and the zone A' immediately above it, and if such motion was not controlled it would keep the whole mass in the cell in agitation. The diagonal vertical baffles 10, and the vertically disposed grids 11 and 11a, serve to break up this whirling motion and confine it largely to the zones A and A'. The main current flow, which carries with it most of the non-floating particles, is thus confined to the agitation zone, and flows outwardly through the discharge opening 19.

A certain amount of the fluid mass, which consists in water, solid particles, minute air bubbles and any added conditioning material, will pass upwardly through the grids 11, 11a, with a relatively slow and essentially upward flow into the classifying zone B. The solids, where coal is being treated, are high carbon particles which, because of their affinity for the oil, are entirely or almost entirely coated with oil; low carbon particles partially coated with oil; and substantially non-carbon particles with practically no oil upon them. The air bubbles, strengthened by the frothing agent, as they begin to rise have an affinity for and attach themselves to the oiled particles, which the oil coating has already made more buoyant. Thus the combined action of the upward current flow, the oil and the attached air bubbles causes substantially all except the heaviest particles to be carried upward through the grids 11, 11a into the classifying zone B, where the slow upward and outward current flow over the walls 12a into the pockets 12 sets the whole mass in a teeter and permits the selective movement of the entrained air bubbles (rising like bubbles in highly charged soda water), which attach themselves preferentially to the surfaces of the high values particles they meet. If such particles are not oiled any substantial movement may break the adhesion of bubbles and particle and leave the particles unsupported. The high carbon, and therefore the most completely oiled,

particles will hold the bubbles attaching to them and will be carried upwardly through the quiet zone C to form a stabilized matte in the removal zone D. The particles of lower carbon and therefore having less oiled surfaces will also collect sufficient bubbles to be carried upwardly but not so buoyantly, and the particles of lesser carbon will proceed upwardly more slowly and may rise into the zone D or may be carried in suspension in the current over a baffle 12a into a pocket 12.

The floatable particles collect in a cohesive matte or matted concentrate of substantial thickness, bound together and stabilized by the conditioning reagents and supported by the minute air bubbles, in the zone D at the surface of the liquid in the path of the conveyor blades 13a, which move at a speed least likely to disturb the particles and effect a separation between them and the supporting bubbles, in which event the particles would tend to sink. The blades 13a carry the stabilized matte transversely of the tank without substantial agitation or disturbance and then out of the liquor and up the drainboards 14. The cohesive character of the matte is destroyed as the matte travels along the drainboard, permitting substantially all of the entrained liquid to drain away from the particles and run back into the cell, while the concentrate is carried along the drainboards and is discharged from the openings 15. The substantial absence of froth and the arrangement of the drainboards permit the liquor to drain away readily from the concentrate, so that it is discharged in substantially a dewatered condition. Where the matted concentrate carries very minute non-floating particles, or it is desired to partially remove the conditioning agents, water sprays 17 may be employed to clean the concentrate.

By "stabilized matte," "cohesive matte," etc., is meant the condition of the floated product resulting from a property or characteristic of the system which causes the floatable particles, the added reagents and the attached minute air bubbles to gather at the liquid surface as a coherent mass or layer of substantial thickness the floated mineral constituting a large percentage of the total matte volume while air bubbles, because of their extremely small size, constitute a relatively small percentage thereof. Limiting the air employed to a minimum enables the formation of a blanket or matted concentrate at the quiet pulp surface and when formed appreciable turbulence is required to destroy its stability.

As the stabilized matte is continuously and steadily removed from the zone D along the drainboards 14 by the blades 13a other particles floating upward through the various zones previously described replace those removed and the matte or concentrate is thus continuously formed, there being no substantial diminution or change in the matted concentrate as it is thus formed and removed as long as fresh conditioned material continues to be fed into the cell.

The absence of a froth, in the sense that the term is used in the usual flotation practice, is a characteristic of my invention, and the formation of the matted concentrate results in the collection and recovery not only of the fine floatable particles but also of the coarse floatable particles, which the usual froth can not support at the surface of the pulp and which in the usual cell are caused by turbulence to bleed back into the body of the pulp and to pass out with the refuse.

The movement of the concentrate toward the sides of the cell and over the top of the pockets 12 induces a drift or current flow of the liquor in the main body of the cell toward the pockets, which carries any particles suspended in the liquor or which have become dislodged from the bottom of the matte into the pockets 12. These particles may be returned from the pockets to the main body of the cell for further treatment, as in Fig. 1, or carried to a separate cell for further treatment, as in Fig. 6.

Any of the refuse or larger non-floating particles which may have been carried upward into the classifying zone B will be rejected by the classifying action, as the air bubbles usually do not have sufficient affinity for the particles to buoy them up and they will sink down and eventually find their way out through the sand gate 21 or over the weir 22. Where the values in the material under treatment are particularly difficult to separate, or it is desired to recover different grades or sizes of values, a series arrangement of cells such as is shown in Fig. 5 may be employed. In that arrangement I have shown an assembly of my improved cells in which the tailings of the cell D are treated in cell E and the tailings of the cell E are treated in the cell F, the concentrate of each cell being floated as a stable matte and removed in the manner described above. The residue passing over the weir gate 22 of D runs down a trough 23 into the top of the feed box 2 of E, while that passing through the bleeder gate 21 runs through the pipe 24 into the bottom of the feed box of E. In the same way the discharge from E runs into the cell F. The bulk of the finer floatable particles will be recovered in the cell D and the products of the cells E and F will be progressively coarser in size and tend to run higher and higher in non-floating particles. If desired, additional reagents may be added before or in the cells E and F.

Where the material contains a substantial proportion of "middlings" which it is desired to recover, an arrangement of cells, such as is shown in Fig. 6, may be employed. In that arrangement is an assembly of two cells similar to that shown in Fig. 1, except that the discharge from the middlings pockets 12 in the cell G is carried by the pipes 25 to the feed box 2 of the cell H. Thus the middlings separated in the cell G are treated in the cell H; the floatable particles are separated as a stable matte and skimmed off the surface, and the partly floatable middlings are carried into the pockets 12 and returned to the main body of the cell for retreatment and further separation.

I have found that it is desirable to keep the quantities of oil and frother at an extremely small percentage of the weight of the material being treated, as otherwise these reagents would tend to support non-floating material and thereby prevent recovery of a clean concentrate. For instance, I have found that if 1 per cent of oil is added it usually results in distinct over-oiling, or if a percentage of frother is added comparable to amounts used in ordinary froth flotation work, the concentrate will contain an unduly large proportion of non-floating particles. Keeping the percentage of the reagents down as specified above results in a much cleaner concentrate and minimizes the tendency of non-floating particles to collect in it.

The terms and expressions which I have employed are used as terms of description and not of limitation, and I have no intention, in the use of such terms and expressions, of excluding any equivalents of the features shown and described, or portions thereof, but recognize that various

modifications are possible within the scope of the invention claimed.

What I claim is:

1. A flotation cell having agitating and aerating mechanism for the pulp in the lower portion of the vessel, means in the vessel adapted to confine the agitation and resulting turbulence of the pulp substantially to its lower portion, means for creating a slow upward flow of the portion of the pulp containing the floatable particles to the upper part of the vessel, means for forming a matted concentrate of said floatable particles at the surface of the pulp as a body of solid particles with interstices sufficiently filled with air to render said body floatable, conveying mechanism arranged in the upper part of the vessel substantially parallel to the surface thereof adapted to carry the matted concentrate transversely of the vessel, said vessel having an inclined surface at a side thereof, said conveying mechanism being also arranged to carry the said floated material out of the liquid without breaking up said body and up said surface and out of said vessel.

2. A flotation process which comprises flowing relatively coarse material of particles sizes up to about $\frac{3}{16}$ of an inch containing recoverable values and conditioning material including a collecting agent and a frother in the form of a pulp into a vessel, agitating the pulp and introducing into it a controlled air or other gas supply insufficient to cause a froth on the surface of liquid in the vessel, uniformly impregnating the pulp with minute bubbles the films of which are strengthened by the conditioning material which gives the surfaces of the selective particles a greater affinity for the bubbles, thereby making them floatable, removing the non-selected particles from the agitation zone of the vessel, elevating the floatable particles out of the agitation zone by the joint action of an upwardly directed current and the attached air bubbles into a relatively quiet classifying zone thereabove, separating the floating and non-floating particles in such zone, collecting the floating particles at the surface of the pulp in a compact body of solid particles with interstices containing sufficient gas to render said body floatable, and removing said body of particles from the vessel without agitation.

3. A flotation process as defined in claim 15 in which the body of coal particles is moved laterally as it is continuously formed and elevated at an incline away from the liquid surface to discharge said body from the vessel.

4. A flotation process which comprises introducing material to be treated and a collecting agent into the lower portion of a cell, providing a quiet zone comprising a body of liquid substantially free from turbulence above said lower portion, agitating and aerating said material in said lower portion with an amount of gas sufficient to elevate floatable particles into said quiet zone but insufficient to agitate the surface of said quiet zone, withdrawing the main flow of liquid from the cell below said quiet zone, collecting the flotable particles in the upper portion of said quiet zone as a compact body of solid particles with interstices sufficiently filled with air to render the body floatable, and removing said body of solid particles from the cell.

5. A flotation process as defined in claim 4 in which only a portion of the non-floating particles is recirculated through a similar cycle for further recovery of floatable particles.

6. A flotation process as defined in claim 4 in which non-floating particles passing up into the quiet zone are separately collected and treated by a similar cycle for further recovery of floatable particles.

7. A flotation process as defined in claim 4 in which only a selected portion of the non-floating particles is returned to the cell and re-introduced with fresh material to be treated.

8. A flotation process which comprises introducing material to be treated and a collecting agent into the lower portion of a cell, providing a quiet zone comprising a body of liquid substantially free from turbulence above said lower portion, agitating and aerating said material in said lower portion with an amount of gas sufficient to elevate floatable particles into said quiet zone but insufficient to create a froth on the surface of liquid in the cell, withdrawing most of the non-floating particles from said agitation zone, collecting the floating particles in the quiet zone as a floating compact body of solid particles with gas in the interstices, separately collecting non-floating particles that rise into said quiet zone, and returning said last mentioned non-floating particles for re-introduction into the agitation zone of the cell.

9. A flotation process which comprises introducing material to be treated and a collecting agent into the lower portion of a cell, providing a quiet zone comprising a body of liquid substantially free from turbulence above said lower portion, agitating and aerating said material in said lower portion with an amount of gas sufficient to elevate floatable particles into said quiet zone but insufficient to create a froth on the surface of liquid in the cell, collecting the floatable particles as a compact body of solid particles with interstices containing gas to float said body at the liquid surface, and removing said floating body without agitation thereof by raking said body with means extending below the liquid surface laterally across the liquid surface and out of said cell.

10. A flotation process as defined in claim 4 in which the body of solid particles is removed from the liquid surface at such a rate that it undergoes no substantial diminution in depth while it is being formed continuously at said liquid surface.

11. A flotation process as defined in claim 15 in which the body of coal is removed from the liquid surface without substantial agitation at such a rate that it undergoes no substantial diminution in depth while it is being formed continuously at said liquid surface.

12. A flotation process which comprises the steps of agitating material in a cell to aerate it uniformly, passing the floatable and entrapped non-floating particles through a classifying zone to separate the floatable and non-floating particles, collecting the floatable particles in the form of a body of solid particles with interstices sufficiently filled with air to render said body floatable on a quiet liquid surface of the cell, removing the body of particles while allowing any liquid entrained therein to drain back into the cell, and spraying a cleaning liquid on the body of particles while it is being removed from the cell.

13. A flotation process which comprises flowing relatively coarse material including material coarser than 28 mesh and containing recoverable values and conditioning material including a selective collecting agent and a frother in the form of a pulp into a vessel, agitating the pulp and introducing into it a limited air or other gas

supply insufficient to form a froth on the surface of liquid in the vessel, uniformly impregnating the pulp with minute bubbles the films of which are strengthened by the conditioning material which gives the surfaces of the particles carrying the higher values a greater affinity for the bubbles, flowing the particles with low- and non-values from the agitation zone directly out of the vessel, elevating the particles with higher values out of the agitation zone by the joint action of a slowly moving upwardly directed current and the attached air bubbles into a relatively quiet classifying zone in said vessel, separating the floating and non-floating particles in such zone, collecting the floating particles in a quiet zone at the surface of the pulp in a body of solid particles with interstices sufficiently filled with gas to be floatable in the liquid and removing the body without agitation.

14. A flotation process which comprises flowing material including relatively coarse coal particles and a selective collecting reagent in the form of a pulp into a vessel, agitating and aerating the material therein with a sufficiently limited quantity of air to cause the adherence of air bubbles materially smaller than the particles to the particles of coal and to prevent the formation of substantial quantities of froth at the surface of the liquid in said vessel whereby such small air bubbles render the coarse as well as any fine coal particles buoyant and separable from the very low-carbon and non-carbon particles by flotation, separately removing the coal particles and the low- and non-carbon particles from the agitation zone, classifying the coal particles into floating and non-floating particles in a body of liquid above the agitation zone that is sufficiently free from turbulence to allow said floating coal particles to collect at the liquid surface as a body of coal with interstices containing enough air to render said body floatable, and removing said body from the liquid without agitation.

15. A flotation process which comprises flowing material including coal particles and a selective collecting reagent in the form of a pulp into a vessel, agitating and aerating the pulp while flowing it through and out of the lower part of the vessel, confining the relatively violent agitation to the lower portion of the vessel, controlling the quantity of air supplied to the vessel to a sufficiently limited quantity to prevent formation of froth and to elevate the coal particles out of the agitation zone substantially entirely by the action of air bubbles attached thereto into a quiescent body of liquid above the agitation zone of sufficient depth to allow the coal particles to collect at the liquid surface as a body of coal having interstices sufficiently filled with air to render the body floatable, and removing said body from the vessel.

16. In flotation cells, a vessel embodying an inlet for the pulp, an outlet for non-selected particles in the lower portion of the vessel, agitating and aerating mechanism, means for confining the whirling motion and turbulence in the pulp substantially to the lower portion of the vessel, means for converting the whirling turbulence to an essentially upward motion in the intermediate portion of the vessel, the means for confining the turbulence to the lower portion of the vessel and the depth of the vessel above such means comprising also means for permitting a teetered upward current classifying action in the intermediate to upper portion of the vessel and a quiet flotation assembly of the floatable particles into a matted concentrate at the surface of the pulp, a drainboard, means for removing the concentrate laterally without agitation and without substantial diminution onto said drainboard, and means for draining entrained liquid from the concentrate whereby a substantially dewatered concentrate is discharged from the vessel.

17. A flotation cell having mechanism for agitating and aerating pulp therein, means for limiting the quantity of gas supplied for aeration, means above said mechanism for confining agitation and turbulence to the portion of the cell therebelow, means below said confining means for discharging tailings, means above said confining means providing a quiescent zone for the flotation of floatable material in the form of a relatively solid body of particles with interstices sufficiently filled with gas to render said body floatable, discharge means above said confining means and operating across the surface of the liquid in the cell for positively moving said floatable material laterally across the cell, a pocket at the side of the cell toward which the floatable material is moved to receive floatable material that sinks in the liquid as said material is moved laterally, and means for withdrawing from the pocket material collected therein, said pocket being substantially closed at its lower end to prevent rapid circulation of liquid therethrough.

18. In a flotation cell having an inlet for pulp, means for agitating and aerating said pulp, an outlet for tailings, and means providing a quiescent zone in an upper portion of the cell for the flotation of floatable material in the form of a relatively solid body of particles floating at and just below the surface of liquid in the cell, an inclined discharge surface for such floating material at one side of the vessel extending below the liquid surface at least to the lower edge of said floating body of material, and cenveyor elements for moving successive batches of said floating material across the surface of the liquid in the cell and up said discharge surface.

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