Feb. 9, 1943. J. A. BRUSSET 2,310,894

DRY FLOTATION AND MEDIA AND APPARATUS THEREFOR

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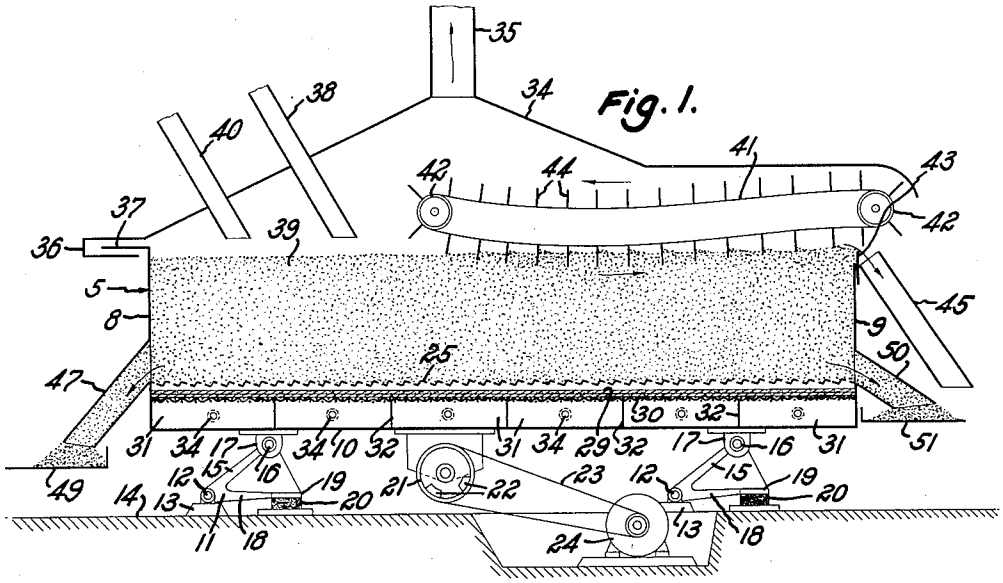


Fig. 1.

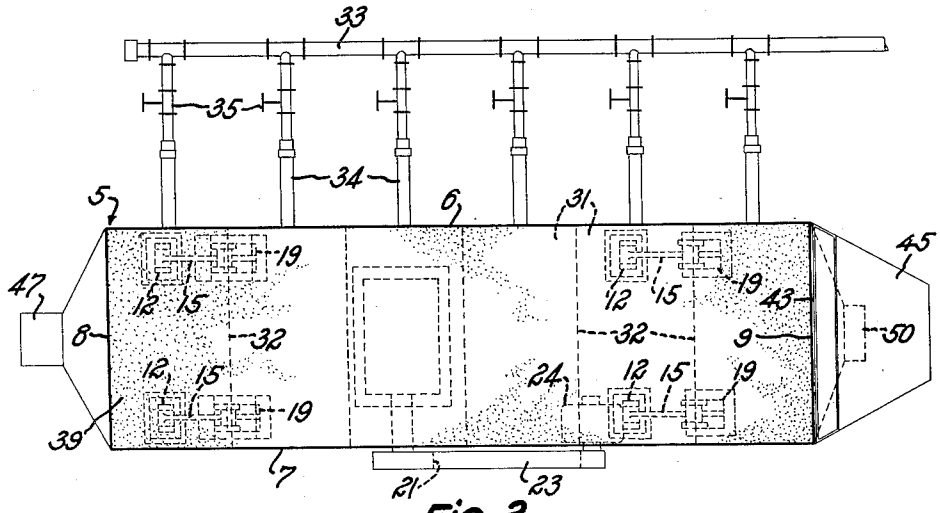


Fig. 2.

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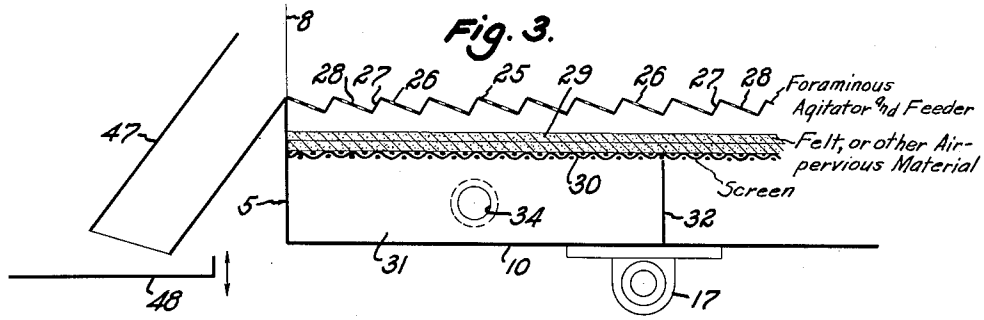
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Fig. 3.



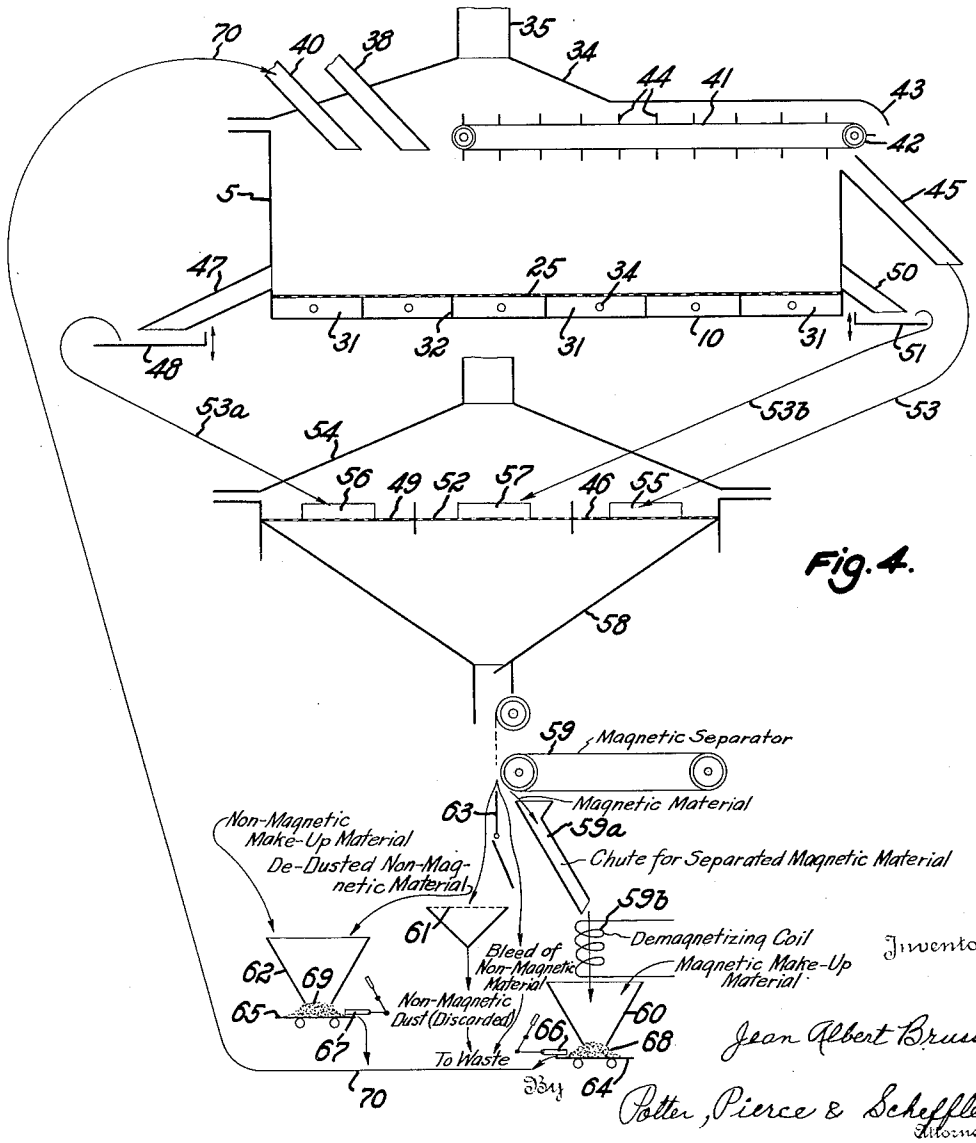


Fig. 4.

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UNITED STATES PATENT OFFICE

2,310,894

DRY FLOTATION, AND MEDIA AND APPARATUS THEREFOR

Jean Albert Brusset, Blairmore, Alberta, Canada

Application January 22, 1941, Serial No. 375,497

9 Claims. (Cl. 209—422)

This invention relates to the art of separating dry mixtures of materials of different specific gravities by selective flotation on or in a dry fluidic medium, and is particularly concerned with the provision of improved media for use in such "sink-and-float" process, with cyclical methods of using such media, and with improved apparatus for carrying out this type of separation involving the cyclical use of such media. While the concepts of the present invention are applicable to the dry separation of mixed materials generally, they will be described hereinafter with particular reference to the separation of a mixture of coal and refuse (e. g., rock).

It heretofore had been proposed to separate a dry mixture of solids of different specific gravities by producing a fluidic mass composed of dry fines of the materials constituting the mixture, said fines being mixed together in a proportion to yield a desired composite medium, introducing into the fluidic mass the mixture to be separated, aerating the resulting heterogeneous mixture so as to maintain it in fluidic condition whereby a heavier component of the mixture to be separated sinks through the fluidic mass while a lighter component of the same floats on the fluidic mass, continuously or intermittently removing so-separated heavier component from the fluidic mass, continuously removing floated component from the fluidic mass, and reforming the fluidic mass for re-use in the continued carrying out of the process. Thus, for separating coal from a mixture of coal and refuse, it had been proposed to produce a fluidizable mass composed of fine particles of coal and refuse screened from the total mixture, to aerate the mass to fluidic condition by means of upwardly directed currents of air under pressure, to deposit upon the mass, as the latter is aerated, the raw coal-refuse mixture, to remove from the mass refuse which has sunk thereinto, to remove from the mass coal which has floated thereupon, to separate the used mass into its components, and to reform the mass from selected portions of the so-separated components.

Alternatively it heretofore had been proposed to form the medium of sand, and to impart to said medium both (1) a fluidizing, internally vibratory, aerating movement and (2) an "en-mass" translating movement (such as, a horizontal flow of the medium).

Such previously proposed systems suffered from one or another of a variety of disadvantages. Thus, in the case where the bulk specific gravity of the material composing the fluidizable medium was considerably greater than that of the lighter component of the mixture undergoing separation it was necessary to blow a relatively intense current of air therethrough in order to effect the desired aerating movement and to insure the selective settling of the heavier component of the mixture: such relatively intense blowing, besides requiring a relatively large blowing equipment and consuming a correspondingly large amount of power, is not favorable to a clean-cut separation of the starting mixture, as is well known, because finer particles of the heavier component of the mixture are, by reason of such intense blowing, transported out of the medium and are added to the floated, lighter, component as a contaminant of the latter. Moreover, in systems requiring heavy blowing the influence of shape of particles is enhanced, it being a fact that relatively thin, flat particles of the heavier component tend to be selectively acted upon by the relatively intense air current and to be added to the floated, lighter component. It will be seen, therefore, that in systems requiring relatively intense air currents, emphasis of a predominant influence of size and shape of the particles obscures to a material extent the influence of gravity and results in a less clean-cut separation than is desirable.

It has now been found that the efficiency of the general dry separation process referred to above may be improved materially by the use of a composite fluidic medium consisting essentially of a homogeneous mixture of fine particles of two or more different materials of different specific gravities, the composite specific gravity of which mixture is closely adjustable, to the requirements of the particular separatory task, by adjustment of the proportion of the two ingredients of the medium. Preferably, the two ingredients essentially constituting the medium are subdivided to different degrees of fineness so that the particles of the one ingredient are "equivalent" to those of the other ingredient, the term "equivalent" here meaning that particles of the two would reach the same terminal velocity when allowed to fall freely in air. As a result of maintenance of this "equivalency," the improved medium of the present invention does not stratify, but rather remains perfectly homogeneous, under the action of a pulsating (and/or continuous) air current—save for the inevitable production of powdered material produced during use of the medium by reason of continued abrasion of the component particles, which powdered material from time to time (or better, continuously) must

be removed from the medium in order to maintain the latter at predetermined "composite specific gravity."

Preferably, also, the improved medium of the present invention consists essentially of a homogeneous mixture of "equivalently" sized particles of magnetic material (e. g., particles of magnetite, steel, ferro-silicon or the like) as the heavier ingredient and, as the lighter ingredient, of the lightest of the pure materials of the mixture to be separated (e. g., particles of coal, in the case of a coal-rock mixture to be separated). Each ingredient of the medium is so subdivided that the difference in specific gravity is equalized by the difference in particle size whereby the homogeneity of the medium is insured. The desired "composite specific gravity" of the medium is attained by close adjustment of the proportion of the two ingredients thereof. The composite specific gravity preferably is adjusted to a value only a little higher than the specific gravity of the lighter component of the mixture to be separated. For instance, for the separation of coal—of specific gravity 1.4—from a mixture of the same and rock, a preferred medium consists essentially of 150–300 mesh particles of magnetite and 16–48 mesh particles of coal, the composite specific gravity of the medium preferably being adjusted (by suitable proportioning of its ingredients) to about 1.5, so that by the relatively gentle aeration of the medium, in use, the medium expands sufficiently to give an effective specific gravity of 1.4. In general, the medium of the invention is prepared to such an apparent specific gravity that it can be brought to desired final or effective specific gravity, during use, by means of a minimum air current consistent with free motion of the particles (or, "fluidity" of the bed).

The preferred medium just described is strictly regeneratable—that is to say, it readily may be maintained at a constant, predetermined composite specific gravity for clean-cut separation. In use it requires only a relatively feeble blowing to effect the separatory treatment: thereby irregularities in composition (due to too vigorous agitation of the medium), formation of blowholes, and stratification of medium-ingredients are largely avoided, dust nuisance is minimized, and there is less recontamination of the floated component (by finer particles of heavier component or by relatively flat particles of heavier component) of the mixture undergoing the separatory treatment. Moreover, by reason of the fact that this medium requires only a relatively feeble blowing there results a minimization of abrasion of the medium-ingredients and of the components of the mixture being acted upon.

The cyclical process includes a regeneration phase, composed of the steps of withdrawing a portion of used medium from the separatory bed, passing the withdrawn portion of used medium through a zone of magnetic influence wherein particles of the magnetic ingredient of the (composite) medium are separated from the non-magnetic particles, and reforming from the so-separated ingredients—either directly or, after a dust-separating step—fresh composite medium by admixture of the magnetic and non-magnetic materials in suitable proportion to give the desired composite specific gravity, whereupon the so-prepared composite medium is returned to the separatory bed for use in the continued separatory process. Preferably, in each such cycle of the medium and during the regeneration phase thereof after the magnetic particles have been separated from the non-magnetic material of the mixture, a portion of the latter is discarded and is replaced by an equivalent amount of pure material: the purpose of this measure is the removal and discard of pollution material—that is to say, of powdered medium, powdered heavier component of the mixture undergoing treatment, and particles of such heavier component—whereby to hold pollution of the medium below an arbitrary value. Before the separate ingredients are remixed to yield regenerated medium, they may be screened or otherwise ridden of any associated dust, whereby further to depress dust nuisance.

The process and novel apparatus used in carrying out the same will be described with greater particularity with reference to the accompanying drawings which illustrate a preferred embodiment of the invention and in which:

Fig. 1 is a diagrammatic vertical longitudinal section through a treatment receptacle embodying the invention,

Fig. 2 is a plan view thereof with the hood and conveyor removed,

Fig. 3 is a diagrammatic fragmentary sectional view on an enlarged scale, and

Fig. 4 is a flow sheet illustrating the operation of the process and novel apparatus employed therein.

Referring more particularly to the drawings, the apparatus comprises a rectangular receptacle 5 having side walls 6 and 7, end walls 8 and 9 and a bottom wall 10. The receptacle is supported by four articulated bracket arms 11 in the nature of bell cranks pivoted at 12 on bearing brackets 13 mounted on a stationary base or chassis part 14. The arms 15 of the bell cranks extend from the pivot 12 at an angle of about 60° to the horizontal and are pivoted at 16 to the brackets 17 on the underside of the receptacle. The other arms 18 of the bell cranks extend substantially horizontally and at their ends are provided with pads or bearing plates 19 which rest on large resilient rubber blocks 29 on the frame or chassis 14.

By reason of the articulated resilient mounting, the receptacle can be submitted to controlled vibrations through the medium of a pulley wheel 21 mounted on the underside of the same, said pulley carrying a pair of adjustable eccentrically mounted weights 22 and being driven by a belt 23 from a motor 24 mounted on the chassis 14. By adjusting the relative position of the weights 22, the intensity of the vibrations can be varied as desired.

Mounted within the receptacle 5 spaced from the bottom wall 10 thereof is a pervious deck plate 25, preferably formed of sheet metal provided with perforations 26 and crimped or corrugated into a stepped formation providing a plurality of steep shoulders 27 facing the end wall 8 and sloping portions 28 extending from the top of one shoulder to the bottom of the next in the direction of the wall 9. The stepped corrugations extend transversely of the deck plate between the side walls 6 and 7.

Immediately beneath the deck plate 25 is a permeable but air resistant layer of material 29 supported on a wire screen 30. The layer 29 may be formed of closely woven canvas, felt, rock wool, asbestos wool, layers of woolen cloth or the like. The deck 25 is mounted on an inclination of 1° to 3° from the wall 8 to the wall 9.

The space between the screen 30 of the deck structure and the bottom wall 10 is divided into

a plurality of separate air boxes or compartments 31 by transverse partition plates 32. Each of the air boxes 31 is supplied with air under pressure from a pressure pipe 33 through branch pipes 34, each of which is provided with a regulating valve 35 so that the air pressure in each of the respective air devices 31 may be varied independently of the others.

The receptacle 5 is provided with a hood 34 having an exhaust outlet 35 leading to an exhaust fan (not shown) for withdrawing fine dust given off during operation of the apparatus. A U-shaped rim 36 formed on the hood 34 embraces a flange 37 carried by the walls of the receptacle and forms a seal to prevent escape of dust to the surrounding atmosphere.

The mixture of raw materials to be separated is fed into the apparatus through an inlet pipe 38 which extends through the hood 34 at an angle of about 60° to the horizontal. The lower end of the pipe 38 terminates above the normal level of the bed of fluidic flotative medium 39 at about one-third the length of the receptacle 5 from the wall 8 thereof. Due to the angularity of the inlet pipe, the mixed materials plunge deeply into the bed 39 of medium in the receptacle as they are introduced through said pipe.

An inlet pipe 40 extends through the hood 34 adjacent the wall 8 for the introduction of reconstituted medium to make up for loss of medium from the bed resulting from the discharge of medium with the separated products through the various outlets from the receptacle 5.

An endless raking conveyor 41 supported loosely by sprockets 42 above the bed 39 removes the light products floated on the bed over an adjustable weir 43 carried by the wall 9. The rakes 44 are formed with teeth set about one-half inch apart so as to create a minimum disturbance of the bed 39, into which they dip slightly, and to reduce to a minimum the amount of medium removed over the weir plate 43 with the light material. The loose mounting of the chains of the conveyor prevents breakage of the raking elements in the event large pieces of material are caught between the rakes and the weir 12.

The light material—clean coal in the example chosen for illustration—and medium removed therewith over the weir 43 pass into a discharge chute or conveyor 45 and are delivered onto a vibrating screen 46, as will be hereinafter described.

The heavy material separated from the mixture under treatment sinks through the medium and is discharged through an outlet duct 47 in the wall 8 at the high end of the deck 25 to an adjustable valve or baffle plate 48 from which it and the medium removed therewith are delivered onto a vibrating screen 49.

It will be noted that the heavy products sinking through the bed of medium onto the deck 25 are removed in counterflow with respect to the movement of the main body of materials and are finally discharged at the high end of the deck, the latter being disposed at an inclination of from 1° to 3°, as previously stated. This counterflow movement which is imparted to the heavy materials is due to the formation of the deck and the manner of mounting and vibrating the receptacle 5 on the arms 11. With the apparatus in operation and vibrating at the rate of 400 to 500 pulsations per minute, the heavy material sinks through the bed 39 and comes in contact with the stepped deck 25. The inclination of the arms and disposition of pivots 12 and 16 are such that during a pulsation the deck moves downwards and forward, that is in the direction of the light materials discharge, then rises and moves backwards, that is toward the heavy materials discharge. The action of a piece of heavy material resting on the deck 25 at a given time is as follows: While the deck moves downwards and forward during the first half of a pulsation, the heavy piece will tend to remain stationary due to its inertia, and will be able to do so due to the low angle of the steps of deck 25 in that direction. In other words, during the first half of the pulsation, the piece of heavy material will have remained more or less in the same absolute position, while the point of the deck which was in contact with it will have moved forwardly and downwardly away from it.

During the second half of the pulsation, the piece of heavy material meets the deck as it moves upwards and backwards, and the heavy piece will come to rest on the deck at a point situated farther back than the original point at which it rested. It will remain there during the rising half of the pulsation due to the concording influence of frictional contact and of the steep shoulders 27 of the steps facing in the backward direction. Hence, the piece will move backwards and upwards with the deck on each upward stroke thereof.

At the end of a pulsation, a piece of heavy material will thus have moved for a small distance backwards on the deck 25 against the slight slope of the deck (which pitches from 1° to 3° towards the wall 9). Thus a continuous progress of the heavy material along the deck 25 towards the rear of the machine to the outlet 47 is effected. When the heavy material reaches the spout 47, it is caught in a slight flow of medium out through the same which flow is controlled by the motion of the end of the spout in relation to the stationary and adjustable valve or baffle.

If it is necessary or desirable to extract a third product of intermediate specific gravity (such as "middlings" in the case of coal), this is discharged through an outlet spout having a stationary and adjustable plate 51 associated therewith and discharging through the wall 9 at the forward end of the machine.

The "middlings," being by definition of a specific gravity only a little greater than that of the medium, sink very slowly through the medium. When they come in contact with the deck 25, only a very small frictional force of contact will be created by the deck against them. To overcome that small frictional force, it will be sufficient to create a slight horizontal flow of medium through spout 50 in order to carry the "middlings" into spout 50 and thence outside the machine. Such flow is facilitated by the slight pitch of the deck.

The middlings and medium discharged through spout 50 are delivered to a vibrating screen 52 by a suitable conveyor.

The vibrating screens 46, 49 and 52 to which the light material, heavy material and middlings, respectively, are delivered with the medium discharged therewith from the receptacle 5, by suitable conveyors 53, 53*a* and 53*b*, respectively, are preferably equipped with ¼" mesh wire and mounted in a bank, as shown, within a hooded housing 54 provided with an exhaust fan (not shown) for removing fine dust in suspension. Discharge outlets 55, 56 and 57 are provided leading from the respective screens for the discharge of the separated materials to storage or waste.

The medium and other materials passing through the screens 46, 49 and 52 is collected in a bin 58 beneath the screens and from the bin is fed to a magnetic separator 59 which removes the magnetic material component of the medium from the mixture. The separated clean magnetic material is delivered by the separator 59 through chute 59a and demagnetizing coil 59b to a storage bin 60. Fresh magnetic material of proper particle size is supplied to the storage bin 60 to make up for loss of the magnetic component due to dusting etc.

The non-magnetic materials pass from the separator 59 to a hummer type vibrating screen 61 where dust and particles finer than desired in the medium are eliminated. From the screen 61, the calibrated non-magnetic materials pass to a storage bin 62.

For the purpose of preventing over-contamination of the non-magnetic component of the medium by particles of rock, etc., that pass through the vibrating screens, means, indicated at 63, in the form of an adjustable diverting baffle, is provided to bleed off constantly a desired quantity of the non-magnetic material from the system and discharge the same to waste. Clean calibrated non-magnetic material is added to make up for the loss through bleeding off and thus the building up of the concentration of contaminating materials is prevented.

The storage bins 60 and 62 discharge onto rotating tables 64 and 65, respectively, and adjustable scraper blades or knives 66 and 67 are provided for removing regulated amounts of magnetic material 68 from the table 64 and of non-magnetic material 69 from the table 65 necessary to form the composite flotation medium. The materials fed off of the tables by the knives 66 and 67 are carried by a conveyor, indicated at 70, to the feed pipe 40 through which the regenerated and reconstituted medium is returned to the receptacle 5.

It will be understood that any suitable type of conveyors may be employed for moving the materials through the treatment cycle involving the various parts of the apparatus; therefore, in the interest of simplicity, no particular conveyor structure has been illustrated. Where space requirements permit, gravity flow between the successive stages will be most economical. Otherwise belt conveyors may be used.

It will be appreciated, from the foregoing, that in the carrying out of the process in the apparatus just described there is a continuous movement of the composite medium through the separator, freshly re-formed medium being continuously deposited upon the bed of medium at the rear end of the latter, medium plus lighter ingredient of the mixture undergoing the separatory treatment being continuously removed at the top of the forward end of the bed, medium plus heavier ingredient of the mixture being continuously removed at the bottom of the bed at the rear end of the latter, and medium plus middlings being continuously removed at the bottom of the forward end of the bed: the so-removed portions of medium are separately freed from lighter ingredient, heavier ingredient, and middlings, respectively, are admixed with each other, the mixture of removed medium is divided into magnetic and non-magnetic portions, a part of the non-magnetic portion, containing some contaminating fines of heavier component, is discarded (being substituted by a corresponding amount of the pure non-magnetic material), and the magnetic and non-magnetic portions are re-combined, in predetermined proportion, (with or without a calibrating step) to reconstitute the original homogeneous medium of desired specific gravity, for addition to the separatory bed.

I claim:

1. In the sink-and-float process of separating a dry mixture of materials of different specific gravities involving the selective flotation of a lighter constituent of such mixture on a dry fluidic medium to which latter is imparted a fluidizing aerating movement and a translating movement, the improvement which consists in forming the medium from a plurality of different ingredients of different specific gravities, each of said ingredients being so subdivided as to be equivalent to each of the other ingredients of the medium in terminal velocity whereby homogeneity of the composite medium is assured, and so adjusting the proportions of said ingredients with respect to each other and to the mixture to be separated as to provide a composite medium having a resultant specific gravity intermediate the specific gravities of the lighter and heavier constituents of the mixture to be separated and closely approaching that of the lighter constituent, whereby the composite medium is fluidizable with a minimum of aeration.

2. In the sink-and-float process of separating a dry mixture of materials of different specific gravities involving the selective flotation of a lighter constituent of such mixture on a dry fluidic medium to which latter is imparted a fluidizing aerating movement and a translating movement, the improvement which consists in forming the medium from a plurality of different ingredients of different specific gravities, one ingredient being magnetic and another ingredient being non-magnetic and lighter than the magnetic ingredient, each of said ingredients being so subdivided as to be equivalent to each of the other ingredients of the medium in terminal velocity whereby homogeneity of the composite medium is assured, and so adjusting the proportions of said ingredients with respect to each other and to the mixture to be separated as to provide a composite medium having a resultant specific gravity intermediate the specific gravities of the lighter and heavier constituents of the mixture to be separated and closely approaching that of the lighter constituent, whereby the composite medium is fluidizable with a minimum of aeration.

3. The improved sink-and-float dry separatory process defined in claim 2, according to which the medium consists essentially of a heavier ingredient which is magnetic and a lighter ingredient which is formed from a lighter, non-magnetic, component of the mixture to be separated, the heavier, magnetic, ingredient of the medium being of sufficiently smaller particle size than the lighter ingredient to make the two ingredients equivalent.

4. Cyclical process of separating a dry mixture of materials of different specific gravities by selective flotation on and in a bed of dry fluidic medium, which comprises forming a bed of homogeneous medium consisting essentially of particles of a magnetic ingredient and larger particles of a non-magnetic ingredient having a lesser specific gravity than the magnetic ingredient in such proportion as to yield a composite of predetermined specific gravity, depositing onto such bed the mixture to be separated and im-

parting to the bed and deposited mixture fluidizing and translating movements, removing medium from said bed, dividing the removed medium into magnetic and non-magnetic portions, reforming from such portions fresh medium of original composite specific gravity, and adding such reformed medium to said bed.

5. Cyclical process of separating a dry mixture of materials of different specific gravities by selective flotation on and in a bed of dry fluidic medium, which comprises forming a bed of homogeneous medium consisting essentially of particles of a magnetic ingredient and larger particles of a non-magnetic ingredient having a lesser specific gravity than the magnetic ingredient, in such proportion as to yield a composite of predetermined specific gravity, depositing onto such bed the mixture to be separated and imparting to the bed and deposited mixture fluidizing and translating movements, separately removing medium from top and from bottom of said bed, separately abstracting over-sized solids from the removed medium, dividing the removed medium freed from over-sized solids into magnetic and non-magnetic portions, reforming from such portions fresh medium of original composite specific gravity, and adding such reformed medium to said bed.

6. Cyclical process of separating a dry mixture of materials of different specific gravities by selective flotation on and in a bed of dry fluidic medium, which comprises forming a bed of homogeneous medium consisting essentially of particles of a magnetic ingredient and larger particles of a non-magnetic ingredient having a lesser specific gravity than the magnetic ingredient, in such proportion as to yield a composite of predetermined specific gravity, depositing onto such bed the mixture to be separated and imparting to the bed and deposited mixture fluidizing and translating movements, separately removing medium from top and from bottom of said bed, separately abstracting over-sized solids from the removed medium, dividing the removed medium freed from over-sized solids into magnetic and non-magnetic portions, separately removing under-sized particles from said portions, reforming from the so-calibrated portions fresh medium of original composite specific gravity, and adding such reformed medium to said bed.

7. In the cyclical separatory process defined in claim 4, the steps which consist in imparting movement in one direction to material selectively floated on said bed while simultaneously imparting movement in a different direction to material which has sunk through said bed.

8. In apparatus for separating mixed materials according to specific gravity, a receptacle adapted to contain a bed of dry fluidic medium comprising a mixture of magnetic and non-magnetic materials in proportions to produce a bed of a desired apparent specific gravity, means for fluidizing said bed comprising means for forcing air under pressure upwardly therethrough, means for withdrawing medium from said bed, means for separating oversize particles and undersize particles from the medium withdrawn from the bed, a magnetic separator for separating the magnetic component from the non-magnetic component of the medium, means for remixing the separated components in proportions to form a mixture of desired apparent specific gravity, and means for charging the reconstituted medium into the receptacle.

9. In apparatus for separating mixed materials according to specific gravity, a receptacle adapted to contain a bed of dry fluidic medium comprising a mixture of magnetic and non-magnetic materials in proportions to produce a bed of a desired apparent specific gravity, means for fluidizing said bed comprising means for forcing air under pressure upwardly therethrough, means for withdrawing separated light material and medium from adjacent the top of the bed, means for withdrawing separated heavy material and medium from adjacent the bottom of the bed, means for separating the light and heavy materials from the medium withdrawn therewith, a magnetic separator for separating the magnetic component of the so separated medium from the magnetic component thereof, means for bleeding off a portion of the non-magnetic component, means for remixing the separated components in proportions to form a mixture of desired apparent specific gravity, and means for charging the reconstituted medium into the receptacle to replace the medium withdrawn therefrom with the separated materials of the mixture.

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