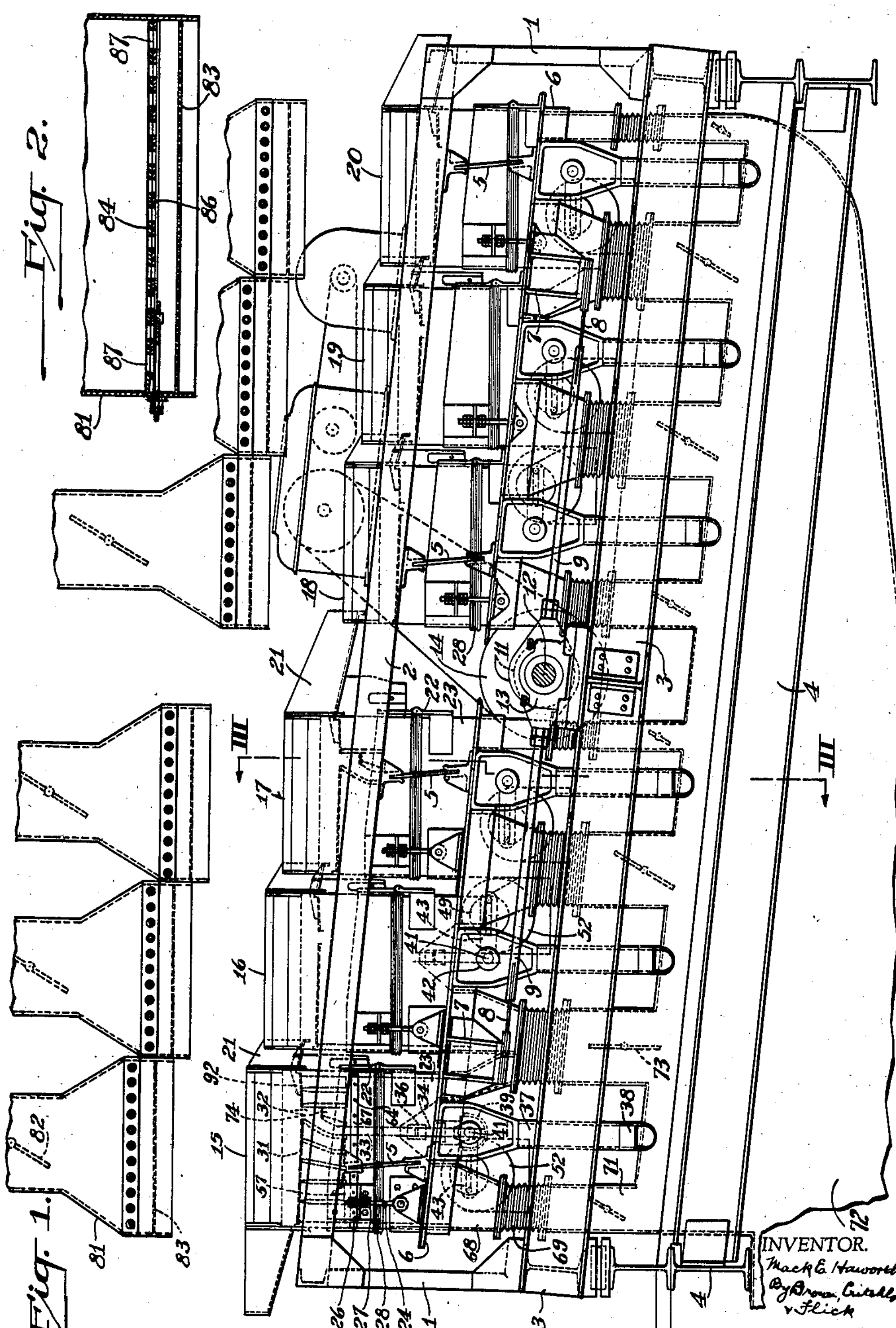
April 14, 1942. M. E. HAWORTH 2,279,590

APPARATUS FOR SEPARATING PARTICULATE MATERIALS

Filed Feb. 6, 1939 5 Sheets-Sheet 1



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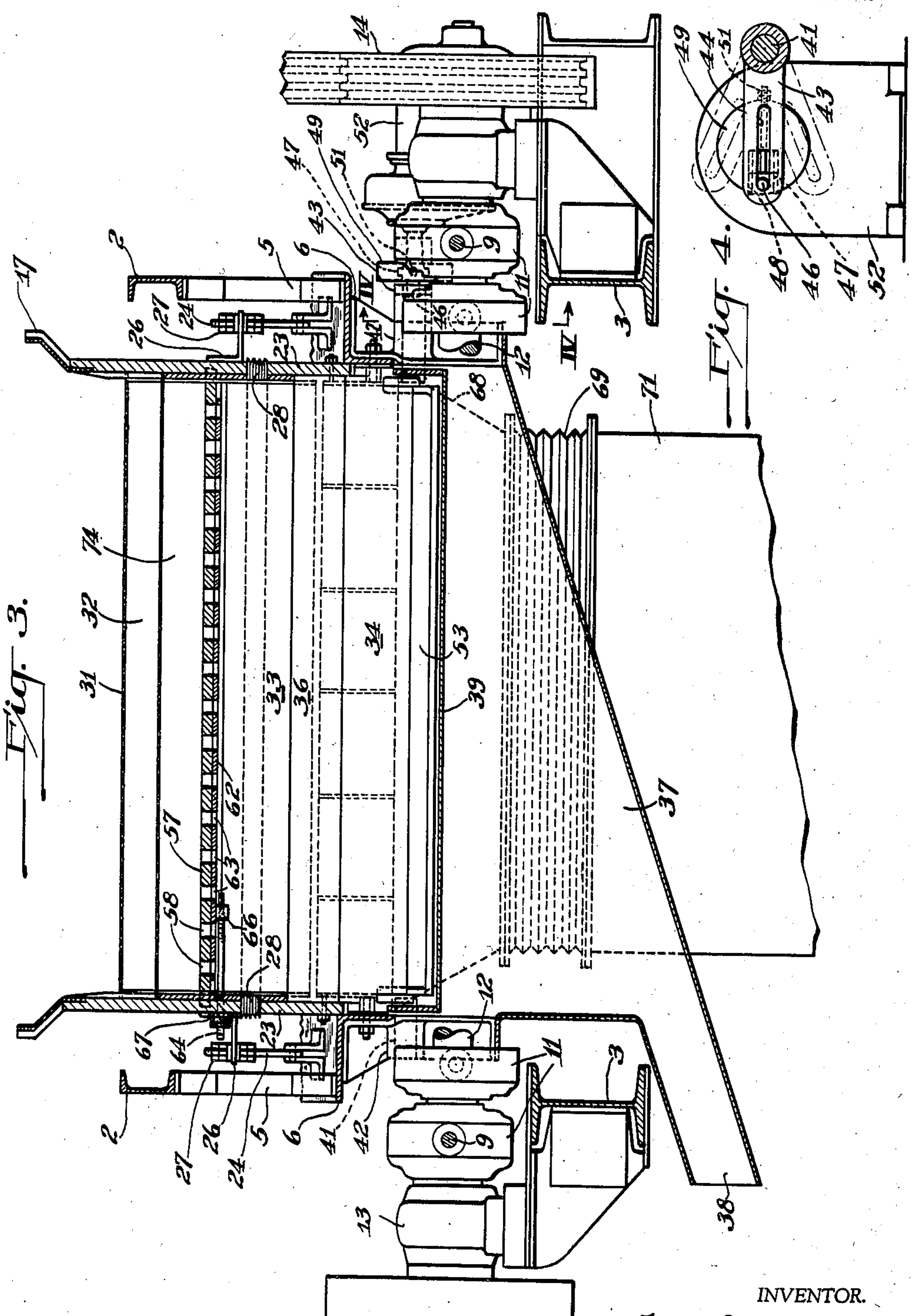

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APPARATUS FOR SEPARATING PARTICULATE MATERIALS

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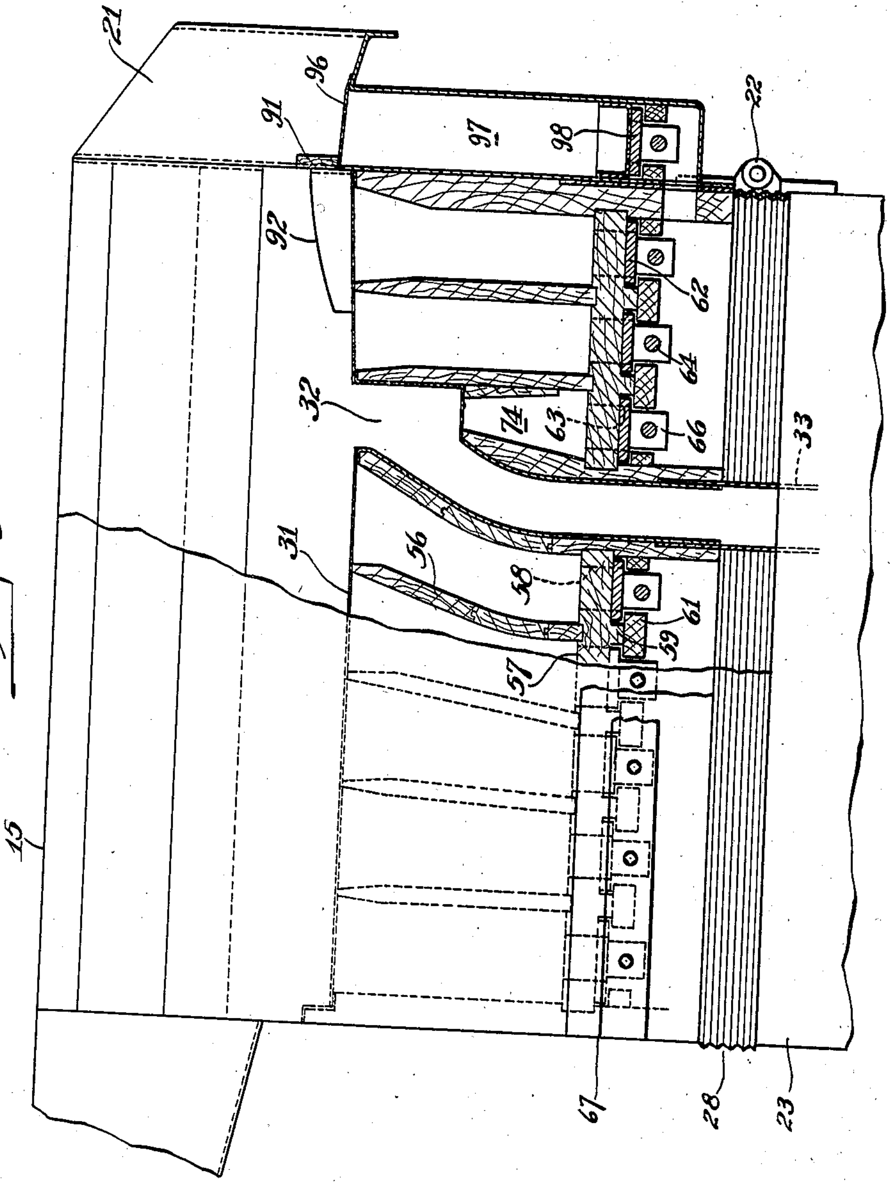

Fig. 5.

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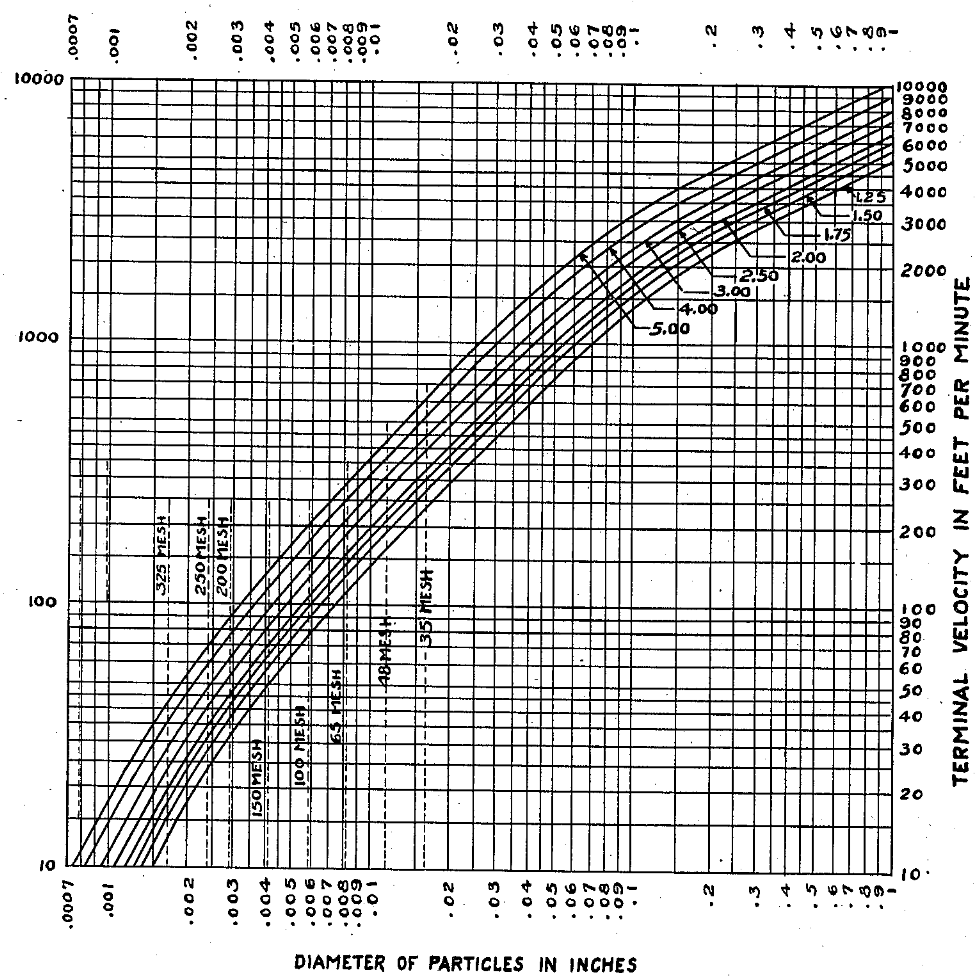
Fig. 6.



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APPARATUS FOR SEPARATING PARTICULATE MATERIALS

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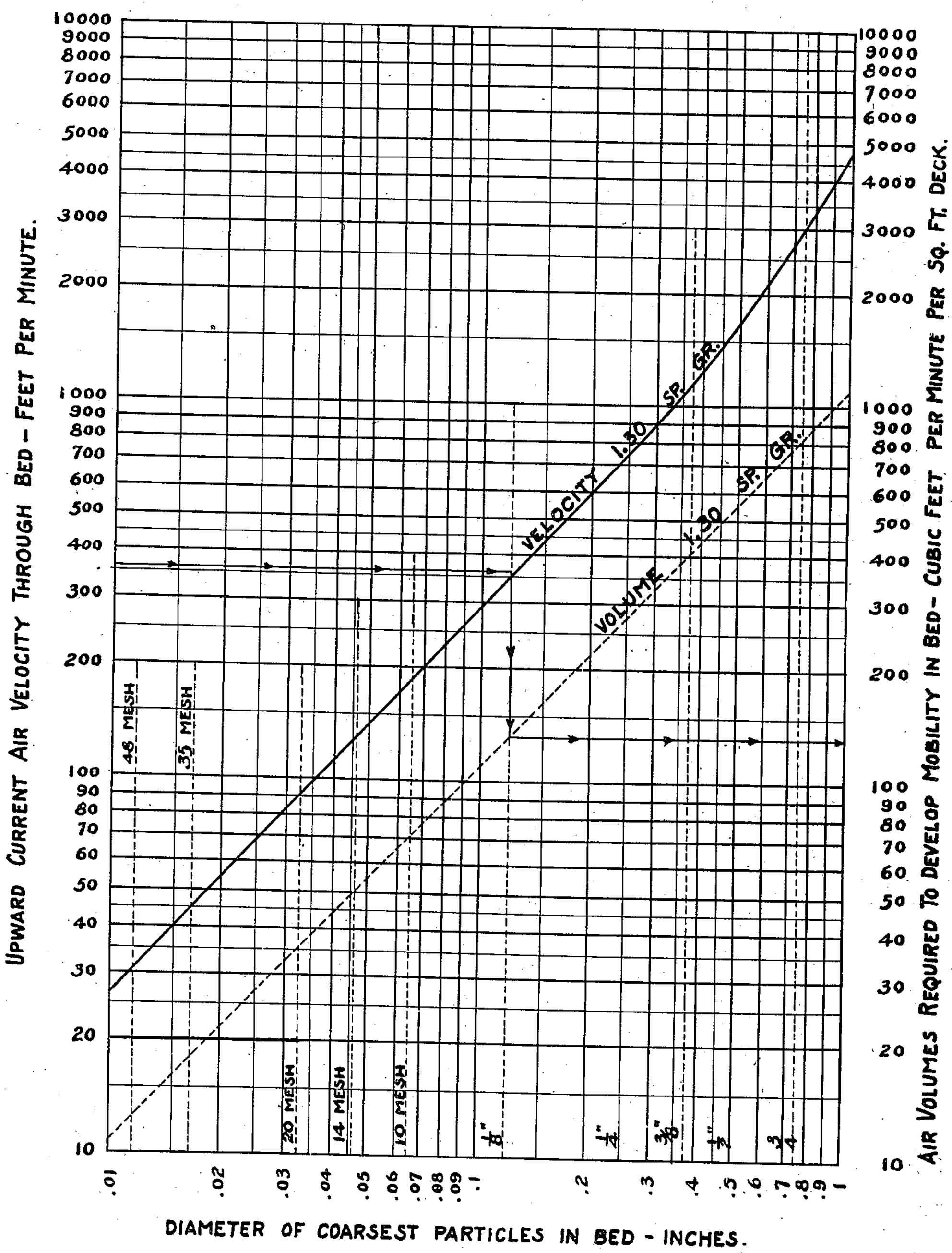
Fig. 7.



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Patented Apr. 14, 1942

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UNITED STATES PATENT OFFICE

2,279,590

APPARATUS FOR SEPARATING PARTICULATE MATERIALS

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Application February 6, 1939, Serial No. 254,750

10 Claims. (Cl. 209—466)

This invention relates to the separating or cleaning of particulate materials in which light, intermediate and heavy density particles are mixed together, the separations being effected principally by a process in which the laws governing hindered and crowded settling fundamentals prevail. For the purpose of illustration only, raw coal, by which is meant a mixture of pure coal and heavier density impurities or foreign matter encountered in mining, such as bone coal, shale and pyrites, will be used as an example of such particulate material. A dry cleaning process using air as the fluid medium will serve as a basis for illustrating the method employed.

Many types of apparatus have been designed for this general purpose, and some have met with a certain degree of success, but in so far as I know, all of them have failed to accomplish the desired degree of refinement in the separations or cleaning. That is, after cleaning, a certain percentage of heavier density particles remains mixed with the light density particles, i. e., clean or pure coal, and an unduly large amount of coal remains mixed with the removed intermediate and heavy density particles, known as the rejects or foreign matter. As long as this situation prevails either the coal is not properly cleaned, or coal is wasted with the rejects, or both.

In the dry cleaning of coal as generally practiced heretofore, the raw coal is fed in a continuous stream to one end of an inclined table or deck which may be reciprocated to agitate the raw coal and cause it to travel toward the opposite end of the deck. The deck is perforated or foraminous to permit fluid under pressure to be forced upwardly through the mixture of raw coal. If the bed is mechanically agitated, this fluid is usually continuously moving air delivered to the deck at a velocity sufficient to "loosen up" the mixture and thereby facilitate stratification. In case the deck is stationary, a pulsating air current is used for agitating the mixture.

Heavy density particles settle through the mixture and produce a bed of such particles on the pervious deck surface. This bed is made up of pyrites, shales, and coarser heavy bone coal, and its density is therefore high compared with the coal and lighter bone particles. The term "bone coal" designates the fractions containing a high percentage of combustible material, but containing too much ash or sulphur to be included with the clean coal; and includes the fractions from the heaviest coal particle permissible in the clean coal to about 1.90 specific gravity. It will be understood that laminated particles such as coal and shale; bone and shale; coal, pyrite, bone and shale, or various combinations thereof, having a specific gravity included within the specific gravity range specified, are included under this term. The term "shale" or "slate" designates the fractions from about 1.90 specific gravity to about 2.60 specific gravity and includes shale, varying in density from 2.30 to 2.60, together with laminated particles of coal, bone, pyrite and shale in various combinations in which the particles have specific gravities within the specific gravity limits specified for this term. The term "pyrites" designates the fractions from about 2.60 specific gravity to about 4.80 specific gravity and includes laminated particles of coal, bone, shale and pyrite in various combinations in which the particles have specific gravities within the specific gravity limits specified for this term.

It is characteristic of crowded settling stratification, which takes place in the heavy density bed, that small heavy density particles that reach the lower strata wedge their way under larger ones and form the bottom of the heavy density bed which acts in a manner similar to a heavy density fluid and crowds out or prevents lighter particles from penetrating it.

Above the heavy density bed are found the intermediate and light density bone particles, fine heavy density particles, and coal particles which extend to the top of the raw coal mixture. The light density particles, i. e., pure coal, preponderate in the upper bed. The term "pure coal" designates the lighter specific gravity fractions in the mixture of raw coal, and ordinarily includes the fractions from about 1.25 specific gravity to a range between 1.40 and 1.50 specific gravity or slightly wider, depending upon the specific gravity of the heaviest density coal particles permissible in the clean coal product.

In order to satisfactorily separate the light density coal particles contained in the upper bed from the heavy density particles in the lower or heavy density bed, the intermediate bed which comprises both coal and foreign particles and is known as middlings is withdrawn separately from the side or end of the body of raw coal. However, there is too much coal in this intermediate bed for efficient cleaning. Ordinarily these middlings are recirculated and the heavier density particles removed as rejects or subjected to retreatment for recovery of coal particles contained therein. If the middlings, or the middlings and rejects, are retreated by a similar process in similar apparatus, some recovery of the light density coal particles therein may be obtained, but that treatment is characterized by the same overlap of size-density range which characterizes the primary treatment. Therefore, efficient separations have not been obtained with the systems used heretofore, and dry cleaning has not proved successful at all with raw coal mixtures in which the particles are smaller than ⅛ inch in diameter.

It is among the objects of this invention to provide a method and apparatus for separating or cleaning particulate materials which is highly efficient, relatively inexpensive, suitable for material comprising very small sizes, and readily adaptable to materials of different character.

My invention is predicated in part upon my discovery that in order to produce proper stratification in separations by a dry cleaning process the settling or terminal velocities of the particles must bear a definite relation to the upward fluid current through a mixture of them. The terminal velocity of a particle is the velocity at which it falls freely through a fluid medium after the resistance of the fluid has stopped acceleration of the particle's velocity. That is, if a certain particle has a terminal velocity of 1000 feet per minute in still air, the particle will teeter in an upward air stream having approximately that velocity. Terminal velocities depend not only on the specific gravity or density of the particles, but also upon their size and to a lesser extent their shape. Consequently, certain small size heavy density particles settle at the same rate, or have the same terminal velocities, as larger lighter density particles so that certain particles tend to associate together in their falling.

Due to restriction of the upward air current by the raw coal, the velocity of the air as it passes through the voids between the particles in the mixture is greatly increased. I use air at a velocity that produces a fluid or mobile condition of the bed of coal in order to obtain hindered settling and rapid stratification. That is, the air current causes the coal bed actually to expand upwardly so that the coal particles appear almost to be floating in the bed. It is unnecessary and may even be undesirable, to develop mobility of the intermediate and heavy density beds in which crowded settling occurs. The largest heavy density particles, which are foreign particles comprising pyrites, shales, heavy bone, and the like, settle rapidly through the upward air current because their terminal velocities are materially greater than the velocity of the air that would normally be used. Any particles that have terminal velocities less than the velocity of the air passing through the mixture can not settle therein, although they will not be carried away with the air unless their terminal velocities are also less than the air velocity above the mixture where it again assumes substantially the same velocity it had below the deck.

It is therefore important that, before stratification is attempted, the particles of raw coal be sized by screening or other means in order to produce a mixture in which substantially all of the foreign particles that it is desired to remove have terminal velocities greater than the minimum air velocity upwardly through the mixture that it will be necessary to use to keep the lightest density bed (coal) therein expanded or mobile during final stratification. This presizing factor has never before been recognized, so far as I know. In the case of very small particles, such as those passing through a ⅛ inch square mesh screen, the presizing should be preceded by an effective drying and dedusting operation; otherwise, presizing is very difficult, if not impossible.

Furthermore, in accordance with this invention, cleaning is not attempted with only one deck, but the raw coal passes from one to another of a series of independent short decks from each of which some of the foreign particles are removed until the overflow from the last deck consists of substantially pure coal. To prevent as much as possible the mixing of coal with the rejects, the rejects are withdrawn from each deck through an opening in its bottom, and a bed of the heavier density particles remaining is maintained at all times above the draw so as to prevent to the greatest possible extent the lighter density coal particles from reaching it. The maintenance of such a lower bed of suitable thickness depends to a large extent upon the rate of travel of particles across the deck. With a uniform rate of deck reciprocation or oscillation, a uniform stroke, and given rates of feed and withdrawal of particles, I have found that the longitudinal inclination or pitch of each deck determines the rate of travel across the deck and, consequently, whether the lower bed will be developed; whether, if developed, it will move toward the draw too slowly, and thus limit the rate at which it may be withdrawn; or whether it will move too rapidly and thus be dissipated, any one of which conditions will prevent proper stratification or separation. The pitch of each deck is therefore made adjustable so that the lower bed will be maintained of substantially constant thickness. The pitch of each deck is independently adjustable and the supply of air to each is likewise separately controlled because the characteristics of the mixture of raw coal on each deck are different, due to the removal of certain foreign particles from the preceding deck.

As the density range of the particles in the raw coal becomes narrower because of the removal of the heavier density particles through the preceding decks, there will eventually be some mixing of coal particles with the intermediate density particles then drawn off. This mixing is due to the lower bed no longer being dense enough to prevent some of the coal particles from penetrating it and filling up the voids not filled by particles other than coal. In other words, the type of stratification existing in the lower bed is no longer the crowded settling type existing in the lower bed of the first deck, but more nearly approaches the hindered settling type existing in the upper bed. The average density of the particles in the lower bed approaches the average density of the coal particles. In order to recover the coal thus withdrawn with the intermediate density rejects, a process is employed in which the separation is effected by density only and in which size and shape have no influence. Such a process is one in which a fluid is employed at the gravity required to effect the desired separation and is commonly referred to as a "heavy density fluid" process. If desired, the particles recovered from the last draw may be recirculated over all of the decks in order to build up denser lower beds that will more successfully resist penetration by the light density coal particles, or they may be recirculated in similar apparatus. This does not remove the necessity for the heavy density fluid process treatment but reduces the quantity of coal escaping with the rejects, and may reduce the number of draws from which particles should be retreated by the heavy density fluid process.

The preferred embodiment of the invention is illustrated in the accompanying drawings in which Fig. 1 is a side view of my separating apparatus; Fig. 2 is a transverse vertical section through one of the exhauster hoods; Fig. 3 is an enlarged vertical section taken approximately on the line III—III of Fig. 1 but including the central eccentrics that oscillate the tables; Fig. 4 is an enlarged view of the gate-operating mechanism taken on the line IV—IV of Fig. 3; Fig. 5 is an enlarged side view, partly in section, of one of the separating tables; Fig. 6 is a graph showing terminal velocities of particles of certain sizes and densities in air; and Fig. 7 is a graph showing approximate air volumes required to develop mobility of beds of coal particles of different sizes.

Referring to Fig. 1 of the drawings, four upright corner posts 1 are rigidly connected at their tops and bottoms by inclined structural members 2 and 3, respectively. The rigid framework thus formed rests on a substructure 4 and supports the cleaning apparatus now to be described.

Suspended from top members 2 by means of multiple leaf springs 5 is a pair of inclined frames 6 having open central potrions. Rigidly secured to a bracket 7 depending from each side of each frame is one end of a leaf spring 8, the other end of which is attached to one end of a connecting rod 9. The other end of the connecting rod is connected to an eccentric 11 mounted on a shaft 12 journaled in bearings 13 fastened to bottom framework members 3 (Figs. 1 and 3). This shaft is driven through a fly-wheel pulley 14 by any suitable means, and through the eccentrics and connecting rods it causes the two frames to reciprocate or oscillate. Eccentrics 11 are mounted 180° apart so that they move the frames toward and away from each other at the same rates of acceleration, whereby vibration in the framework is held at a minimum.

Mounted on frames 6 are a plurality of tables 15, 16, 17, 18, 19 and 20, each of which is slightly below the preceding one so that particles can flow from the discharge end of each table through a spout 21 to the upper end of the next table. Each table is more or less box-like with an open top and with the upper half of a hinge 22 attached to its front wall. The lower half of the hinge is connected to the front wall of a box 23 mounted in the underlying frame and having an open top and bottom. The rear end of the table is supported by means of upright bolts 24 pivotally connected to the top of the supporting frame 6 and extending up through brackets 26 attached to the sides of the table. Nuts 27 determine the position of the brackets vertically of the bolts, while a bellows-type of coupling 28 seals the space between table and box regardless of the adjustments of the nuts.

About half-way down in each table there is a foraminous deck 31 the major portion of which is flat and unobstructed and inclined downwardly from the feed end of the table. Near the lower or discharge end of the table the deck is provided with a discharge opening or draw 32, as shown in Fig. 5, between which and the adjacent end of the table the deck is inclined upwardly a slight amount. The draw is connected by conduit sections 33 and 34 and flexible coupling 36 with a casing 37 rigidly suspended from the frame (Figs. 1 and 3). The bottom of this casing slopes laterally and terminates in a spout 38 which empties into any suitable conveyor (not shown) disposed at one side of the machine, or elsewhere as may be convenient.

As shown in Fig. 1, at the bottom of conduit 34 there is a trough-like gate 39 with vertical sides high enough to prevent discharge of particles therefrom due to the oscillating motion of the table, but permitting discharge when the gate is positively oscillated back and forth through an arc about stub shafts 41 (Fig. 3) fitted to the ends of the gate and mounted in bearings 42 attached to the frame 6 above. The gate is rotated back and forth by means of a lever 43 (Figs. 3 and 4) extending laterally from one of the stub shafts 41 and provided with a longitudinal slot 44. A pin 46 is loosely mounted in this slot and is carried by a slide 47 disposed in a radial slot 48 in a disc 49 where it is adjustable by a threaded rod 51. The disc is rotated by an electric motor 52 mounted on one of the lower framework members 3. As the disc rotates, the lever arm and curved gate are oscillated and the discharge of particles from the draw thereby effected. Discharge is facilitated by a bar 53 mounted in fixed position between the bottom of conduit 34 and the gate. The rate of discharge is determined by the rate and amplitude of oscillation of the gate. The rate of oscillation is determined by the speed of revolving disc 49, and the amplitude by the position of pin 46 relative to the center of the disc.

The hollow space in each table below its pervious deck is divided into a plurality of compartments by transverse partition members 56 disposed at spaced intervals longitudinally of the table, as shown in Fig. 5. At the bottom of these compartments there is a floor 57 provided beneath each compartment with a series of openings 58 (Fig. 3). Between the compartments the floor is provided with parallel depending ribs 59 carrying laterally projecting flange members 61 that support longitudinally slidable valve plates 62. Each of these plates is provided with a series of openings 63 adapted to register with openings 58 when the plate is in one position, and to overlap the solid portions of the floor when in any other position whereby the volume of air entering each compartment can be independently regulated. Adjustment of each valve plate is effected by means of a screw 64 threaded in a block 66 attached to the bottom of the valve plate, the outer end of the screw being journaled in fixed position in a plate 67 secured to the outside of the table.

Air is supplied to the tables through ducts 68 extending downwardly from boxes 23 and connected by flexible couplings 69 to stationary vertical ducts 71 communicating with a main horizontal duct 72. In each duct 71 there is preferably a main valve 73 for providing coarse regulation of the air supplied to the tables. It will be seen in Fig. 5 that draw 32 has an offset portion and that there is therefore a short compartment 74 below the deck opening. This is for the purpose of permitting air to be forced upwardly through the deck opening as well as through the remainder of the deck. To further prevent any material portion of the deck from being unexposed to the upward air currents, the upper edges of partition members 56 are tapered.

As the upward air streams will of course carry some dust particles up with them from the tables, an exhaust hood 81 is suspended in any suitable manner over each table. These hoods are all connected to a common duct in which there is an exhaust fan (not shown). Each hood is preferably provided with a main valve **82** for roughly adjusting the suction therethrough. As shown in Fig. 2, each hood is rectangular when viewed transversely of the table, and is provided near its lower end with a perforated plate **83** that offers resistance to the air current entering the hood. With this construction the upward velocity of the air entering the hood is maintained substantially uniform across its width, instead of being so decreased near its sides as to permit dust-laden air to escape therefrom. Each hood is also preferably provided with a plate **84** having several parallel rows of openings therethrough which are regulated in size by underlying independently adjustable valve plates **86**. This valve structure is substantially the same as that used in the tables, although the end openings **87** in the valves are larger than the others to aid in increasing the air velocity at the sides of the hood. The purpose of these valves is to permit the suction by each hood to be maintained substantially uniform lengthwise of the underlying table by decreasing it at the central portion of the hood.

In practicing my invention with the apparatus disclosed herein the raw coal, or other particulate material to be separated, is first presized by screening or the like in order to obtain a size range in which all of the foreign particles to be removed have terminal velocities greater than the upward fluid velocity through the lightest density or pure coal bed in the mixture required to develop mobility of that bed. Although it is the general practice to screen raw coal to divide it into different grades or size ranges for classification purposes, these ranges bear no particular relation to the fluid velocities required in cleaning the mixture. As an example of the application of my invention, assume that raw coal, that has thus been roughly sized so that the smallest particles in the mixture are .1 inch in diameter, is to be cleaned. In accordance with this invention the largest size or coarsest particles that can be included in the feed to the separating apparatus must be determined in order to find the size range of the raw coal particles that can be cleaned satisfactorily. By reference to the graph shown in Fig. 6 it will be seen that a foreign particle of .1 inch diameter and of 1.75 density, which is bone coal, has a terminal velocity in air of about 1700 feet per minute. Of course, the foreign particles of greater densities have greater terminal velocities. The solid diagonal line in the graph of Fig. 7 illustrates the approximate upward air velocity through a bed of pure coal of average shape (approximately 1.30 density) necessary to develop mobility of that bed in which the coarsest particles are of any given size. In order that the smallest and lightest foreign particles which it is desired to remove may settle through this upward air current, its velocity must be less than the terminal velocity of those particles; in this example 1700 feet per minute for the smallest bone coal particles. To cause quick stratification or rapid settling of the bone coal when the mixture reaches the last deck, the upward air velocity at that deck might be limited to 1500 or 1600 feet per minute. The Fig. 7 graph shows that with such air velocity the coarsest particles of pure coal that can be in the feed and still permit a mobile coal bed to be produced should be limited to about .475 inch in diameter. Thus, the size range is restricted to raw coal particles having a minimum diameter of substantially .1 inch and a maximum diameter of substantially .475 inch. The raw coal should therefore be presized by screening to obtain this size range. By taking a .475 inch particle on the dotted diagonal line in Fig. 7, the approximate number of cubic feet of air required per minute for each square foot of deck space can be found at the right side of the graph.

As previously pointed out, it is very difficult to separate particles varying only slightly in density, although it can be done with more or less success if the size range is small, the ideal condition being one in which all particles are of substantially the same size. Therefore, if it is desired to have coal exceptionally free from lighter density bone coal (the lightest density foreign matter) it is advisable to use a size range smaller than the maximum one in which all of the foreign particles have terminal velocities greater than the upward air velocity required to develop mobility of the coal bed.

If it is not desired to remove bone coal, but only foreign particles of a density of about 2.00 and greater, the Fig. 6 graph shows that the terminal velocity of particles of 2.00 density and .1 inch diameter is about 1850 feet per minute. Taking an upward air velocity of 1700 feet to allow for rapid stratification, Fig. 7 shows that in order to develop mobility of the coal bed the coarsest particles in the feed should not be over about .5 inch in diameter, and that approximately 550 cubic feet of air per minute per square foot of deck space should be supplied to the last deck.

Conversely, if raw coal has been previously rough-sized so that its largest particles are .6 inch in diameter, it is found in Fig. 7 that it will take an upward air velocity through the mixture of about 2100 feet per minute to develop mobility of the coal bed. According to this invention, all of the foreign particles that it is desired to remove from the mixture must therefore have terminal velocities in excess of 2100 feet per minute. By reference to Fig. 6 it will be seen that bone coal particles (density of the order of 1.75) of .15 inch diameter or slightly smaller will settle, as will all of the heavier density particles of that size. The proper maximum size range is thus substantially .15 inch by .6 inch.

Although the graphs of Figs. 6 and 7 chart particle sizes up to 1 inch in diameter, due to the cost of the great volume of air required to develop mobility of a coal bed comprising particles of such large size, this method of cleaning coal is not recommended for particles over ¾ of an inch in diameter.

The pitch of the first deck is so adjusted by nuts **27** in connection with the rate of feed and the oscillations of gate **39** that the heavy density particles travel towards the draw at about the same rate they are withdrawn therefrom, whereby the depth of the heavy density bed is maintained substantially constant. This bed is so dense that it prevents the intermediate and light density particles from penetrating it. As it is only necessary to remove the coarser heavier density foreign particles from the first deck, the upward air velocity through the mixture thereon may be increased so that the fine particles can not settle through it.

The maximum depth of the heavy density bed is determined by a barrier plate **91** (Fig. 5) extending transversely of the deck at its discharge end. To assist in regulating the total depth of the mixture on the deck, the velocity of flow of particles through spout 21 is regulated. This is done by providing the spout floor with a perforated section 96 up through which air is blown from a compartment 97 below the spout provided with a regulating valve plate 98. The feed, deck pitch and withdrawal are so regulated that the heavy density bed does not flow over barrier 91 onto the second deck. It has been found that if a barrier alone is provided close to the draw the particles between it and the draw tend to circulate in vertical planes, whereby lighter density particles are drawn into the lower strata. Consequently, the heavier density particles cannot be removed through the draw without including some of the lighter density particles. To aid in reducing this circulation a plurality of vertical baffle plates 92 extending longitudinally of the deck are preferably mounted on edge directly in front of the barrier at transversely spaced intervals across the deck. The friction developed between the heavy density particles and the sides of these baffles materially decreases their circulation, and the portion of the bed between the draw and barrier 91 forms a body in the nature of a shock-absorber which does not permit circulation still existing at barrier 91 to extend across the intervening space to the draw and take place at the point where the freely moving particles are removed through the draw. The two air compartments between the barrier and draw are provided for the two-fold purpose of developing the fluidity required in the heavier density bed at the draw to permit flow into the draw without vertical circulation, and, in combination with riffles 92 and barrier 91, of gradually reducing the fluidity over the two compartments to a degree of comparative compactness at barrier 91.

As there is always a reservoir of heavy density particles over the draw, and as the particles that are withdrawn from this bed are taken from the bottom of this reservoir, it can safely be said that nothing but heavy density particles or rejects are withdrawn through the first draw. The light density particles or coal, and the intermediate density particles, except possibly the coarsest, together with some of the very smallest particles of heavier density, flow from the first deck over barrier 91 and through spout 21 to the second deck in table 16.

The physical characteristics of the raw coal mixture on the second deck are different from those of the raw coal on the first deck because most of the heaviest density and coarse intermediate density foreign particles have been removed. Because of this the terminal velocities of the heavy density particles remaining in the second bed are lower, so the upward fluid velocity through the mixture on the second deck should be reduced, but sufficient velocity must still be maintained to keep the bed of pure coal mobile in order to develop the condition of fluidity required for satisfactory stratification. The finer heavy density particles are stratified in the lower stratum of the heavy density bed accumulating on this second deck, together with such intermediate and lighter density particles as may associate together in the same bed. The coefficient of friction between the deck surface and the particles accumulating thereon is different from that found on the first deck, due to the different physical characteristics of the particles or the different air stream velocities, or both. Therefore, to effect an accumulation of a heavy density bed on the second deck, it is necessary to adjust the pitch of the deck surface to that required. Since the heavy density bed on the second deck necessarily includes particles whose average density is less than the average density of those accumulated on the first deck, and as it is likewise more mobile under the combined influence of mechanical agitation and the upward fluid stream, its resistance to penetration by intermediate density and some lighter density particles is less pronounced.

Each successive deck is adjusted in pitch and air stream to produce the necessary stratification and accumulation of the heavier of the remaining particles in a heavy density bed thereon. As the heavy density bed is lighter in average density on each succeeding deck, a point is reached in the passage of raw coal from deck to deck where a small amount of the lighter intermediate density particles and certain of the light density particles may penetrate the heavy density bed and be withdrawn with the rejects. However, on each succeeding deck the entire mixture contains fewer intermediate density particles and fewer, if any, of the extremely fine heavy density particles.

On the last deck the terminal velocities of the heavier and intermediate density particles are still greater than the minimum air velocity required to keep the pure coal bed mobile. Nevertheless, as these particles are so much smaller, their average density is so close to the average density of the coal particles that they tend to associate in settling with some of the coal particles which have approximately the same terminal velocities. It is therefore probably inevitable that some coal will be withdrawn with the rejects from the last deck or the last several decks, depending upon the density of the lightest particles required to be removed. The rejects from the last deck may be recirculated through the entire apparatus in order to produce lower strata of greater density on the various decks, and this will to some extent increase resistance to penetration by coal particles. Or, any desired amount of the rejects may be retreated alone by a hindered-crowded settling process in similar apparatus.

To effect complete separation of coal from the finest of the lightest density rejects it is highly desirable to subject the rejects from one or more draws preceding the last draw to a heavy density fluid process in which size and shape have no influence. Such a process is one in which a heavy density fluid, such as calcium chloride or other chemical, or the equivalent in a mixture of sand and water, is employed at the gravity required to effect the desired separation of the light density particles from the heavier density particles. In some cases it may be found desirable to screen the rejects before retreatment in order to remove the finest sizes without submitting them to such retreatment.

Heretofore the separation of particle sizes below ⅛ inch square mesh has been extremely difficult and usually impracticable. Such separations can be produced satisfactorily with my method and apparatus if the particles fed to the presizing apparatus are extremely dry. But with the average conditions usually encountered in practice excessive moisture is present on the surface of the fines below ¼ inch to ⅛ inch. This moisture holds fine dust particles below 35 or 48 mesh against the coarser particles, whereby the mixture is not susceptible to the development of the fluid conditions required for effective stratification. I have found that in order to separate particles below ⅛ inch ordinarily, and in many cases below ¼ inch, it is advisable to reduce this extraneous moisture to a maximum of about 2 per cent to 3 per cent by weight and to remove extremely fine dust particles below 35 to 48 mesh. After the moisture and dust particles have been removed, the remaining particles can then be sized in accordance with the present invention and fed to the separating apparatus described herein.

According to the provisions of the patent statutes, I have explained the principle and mode of practicing my invention and have illustrated and described what I now consider to represent its best embodiments. However, I desire to have it understood that, within the scope of the appended claims, the invention may be practiced otherwise than as specifically illustrated and described.

I claim:

1. Apparatus for cleaning particulate material, comprising a series of longitudinally inclined flat foraminous decks, each provided with a bottom draw adjacent to but spaced from its lower end, the short deck portion between said draw and lower end lying in a plane intersecting the plane of the main portion of the deck at an obtuse angle, means mounted on said short deck portion for retarding movement of the lower bed of particulate matter thereon, a barrier member extending transversely of the delivery end of said short deck portion, a rigidly mounted elevated frame, a rigid frame disposed below said elevated frame and movably suspended therefrom, means on said suspended frame connected with said decks for independently adjusting the pitch of each deck, means for actuating said suspended frame to reciprocate the decks longitudinally, and means for directing fluid under pressure upwardly through the decks and draws.

2. Apparatus for cleaning particulate material, comprising a series of longitudinally inclined flat foraminous decks, each provided with a bottom draw adjacent to but spaced from its lower end, there being a flat short deck portion between said draw and lower end lying in a plane intersecting the plane of the main portion of the deck at an obtuse angle, a rigidly mounted elevated frame, a rigid frame disposed below said elevated frame and movably suspended therefrom, means on said suspended frame connected with said decks for independently adjusting the pitch of each deck, means for actuating said suspended frame to reciprocate the decks longitudinally, a plurality of upright partitions forming open-top compartments directly below each deck and draw and extending transversely thereof, the top of each partition being tapered upwardly to reduce its thickness, means for directing fluid under pressure to said compartments, and means for independently controlling the supply of fluid to each compartment.

3. Apparatus for cleaning particulate material, comprising a series of longitudinally inclined foraminous decks, each provided with a bottom draw adjacent to but spaced from its lower end, means for independently adjusting the pitch of each deck, means for reciprocating the decks longitudinally, means for directing fluid under pressure upwardly through the decks, an exhaust hood mounted above and spaced from each deck for receiving said fluid, each hood being substantially rectangular in vertical section transversely of the deck, a plate provided with rows of openings disposed in said hood and extending therein across the lower intake portion thereof, the openings near the periphery of said plate being larger than the openings in the central portion thereof to increase the air velocity at the sides of said hood, and a substantially rectangular exhaust duct connected to the top of said hood and being substantially as wide as the hood, whereby uniform air velocities are obtained in said hood.

4. Apparatus for cleaning particulate material, comprising a series of longitudinally inclined foraminous decks, each provided with a bottom draw adjacent to but spaced from its lower end, means for independently adjusting the pitch of each deck, means for reciprocating the decks longitudinally, means for directing fluid under pressure upwardly through the decks, a substantially rectangular exhaust hood mounted above each deck for receiving said fluid, a substantially rectangular exhaust deck connected to the top of said hood and being substantially as wide as the hood, and a plurality of substantially parallel valve members mounted in each hood and extending transversely thereof, each member being provided with a series of adjustable valve openings.

5. Apparatus for cleaning particulate material, comprising a series of longitudinally inclined flat foraminous decks, a spout connected to the lower end of each deck and emptying onto the next succeeding deck, each deck being provided with a bottom draw adjacent to but spaced from its lower end, a rigid elevated mounting frame, a rigid frame disposed below said elevated frame and movably suspended therefrom, means on said suspended frame connected with said decks for independently adjusting the pitch of each deck, means for actuating said suspended frame to reciprocate the decks longitudinally, means for directing fluid under pressure upwardly through the decks, and means for directing fluid under pressure upwardly through the bottom of said spout for regulating the depth of the upper bed of particles on the adjoining deck.

6. Apparatus for cleaning particulate material, comprising a rigid elevated structural frame, a mounting frame disposed below said elevated frame and extending substantially in parallel therewith, spring means for suspending said mounting frame from said structural frame, means for reciprocating said mounting frame longitudinally, a plurality of boxes rigidly mounted in said mounting frame and having open tops and bottoms, conduits flexibly connected to the bottoms of the boxes for delivering fluid thereto, a box-like table disposed above each of said boxes, a hinge connecting one end of each table to its underlying box, means hingedly attached to said mounting frame and adjustably connected with the opposite end of each table for raising and lowering said opposite end of each table independently of the other tables, flexible couplings connecting each table and its supporting box, a longitudinally inclined flat foraminous deck in the upper portion of each table, each deck being provided with a bottom draw adjacent to but spaced from its lower end, a discharge conduit leading downwardly from said draw, a plurality of upright partition members extending transversely of each deck to divide the table below the deck into a plurality of longitudinally spaced fluid compartments, and a

separate valve at the lower end of each compartment.

7. Apparatus for cleaning particulate material, comprising a series of longitudinally inclined foraminous decks, each provided with a bottom draw adjacent to but spaced from its lower end, means for independently adjusting the pitch of each deck, means for reciprocating the decks longitudinally, means for directing fluid under pressure upwardly through the decks, a substantially rectangular exhaust hood mounted above each deck for receiving said fluid, a substantially rectangular exhaust duct connected to the top of said hood and being substantially as wide as the hood, a plurality of substantially parallel valve members mounted in each hood and extending transversely thereof, each member being provided with a series of adjustable valve openings, and a foraminous member disposed below said valve members and extending across the entire width and length of the hood.

8. Apparatus for separating particulate material in accordance with the specific gravities of the particles thereof comprising, in combination, means forming a rigid longitudinally inclined centrally open top frame, yieldable means depending from the sides of said top frame, a plurality of structural members secured to the lower ends of said yieldable means on either side of said top frame and forming below the top frame a plurality of centrally open mounting frames which are yieldably suspended from said top frame by said yieldable means and extend therebelow substantially in parallel therewith but lengthwise spaced from each other, a plurality of structures each individually adjustably mounted on each of said mounting frames forming between the sides of said inclined top frame a descending series of individual separating tables, each table comprising sides forming a a box-like frame open at the top, a perforate longitudinally inclined deck disposed in said box-like frame below the upper edges of the sides thereof for receiving material to be separated, each deck provided with a bottom draw adjacent to but spaced from its lower end, a discharge spout for each deck disposed at the lower end thereof above the adjacent upper end of the next lower table for delivering separated material to the deck of said next lower table, means forming air compartments extending transversely underneath and across the entire deck and underneath and across said discharge spout, means for directing air under pressure to said compartments for agitating the material thereon, and actuating means for periodically moving said suspended mounting frames simultaneously longitudinally toward and away from each other at substantially the same rates of acceleration to reciprocate said tables, whereby the vibration of the entire apparatus structure is held at a minimum.

9. The structure and combination defined in claim 8, together with an exhaust hood for each deck disposed thereabove but spaced therefrom for receiving the air directed to said compartments and through the material on the deck, and means in said exhaust hood for maintaining uniform air velocities therein across the lower end thereof which is disposed above said deck.

10. The structure and combination defined in claim 8, together with an exhaust hood for each deck disposed thereabove but spaced therefrom for withdrawing air directed to said compartments and through the material on the deck, a plate provided with openings disposed in said hood and extending therein across the lower intake portion thereof, the openings near the periphery of said plate being larger than the openings in the central portion thereof to increase the air velocity at the sides of said hood, valve means for controlling the flow of air through said openings, and a perforate plate in said hood spaced from said valve means, whereby uniform air velocities are obtained in said hood.

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