

Oct. 17, 1939.

F. E. SMITH

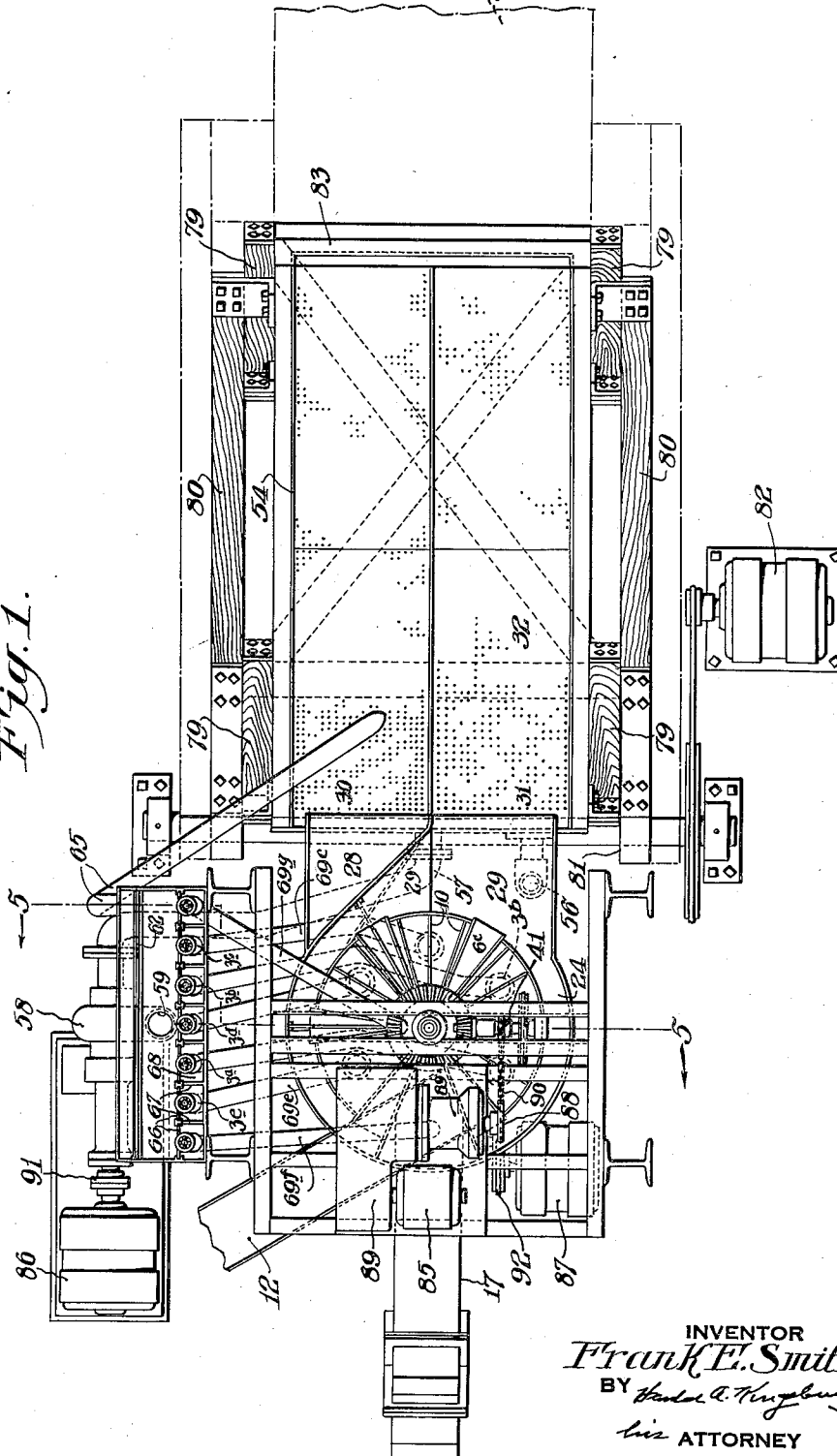
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SEPARATION OF MATERIALS

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Fig. 1.



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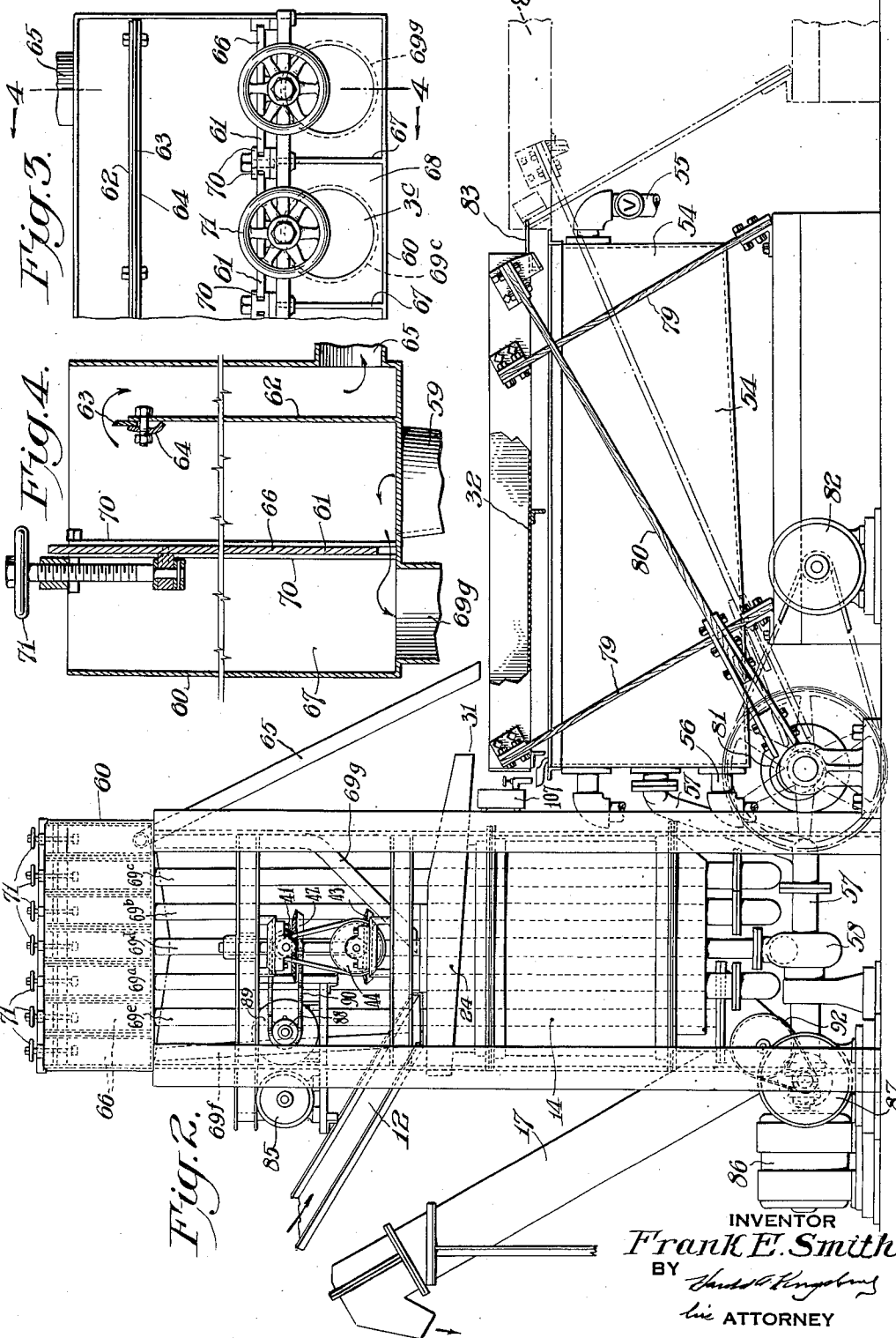
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SEPARATION OF MATERIALS

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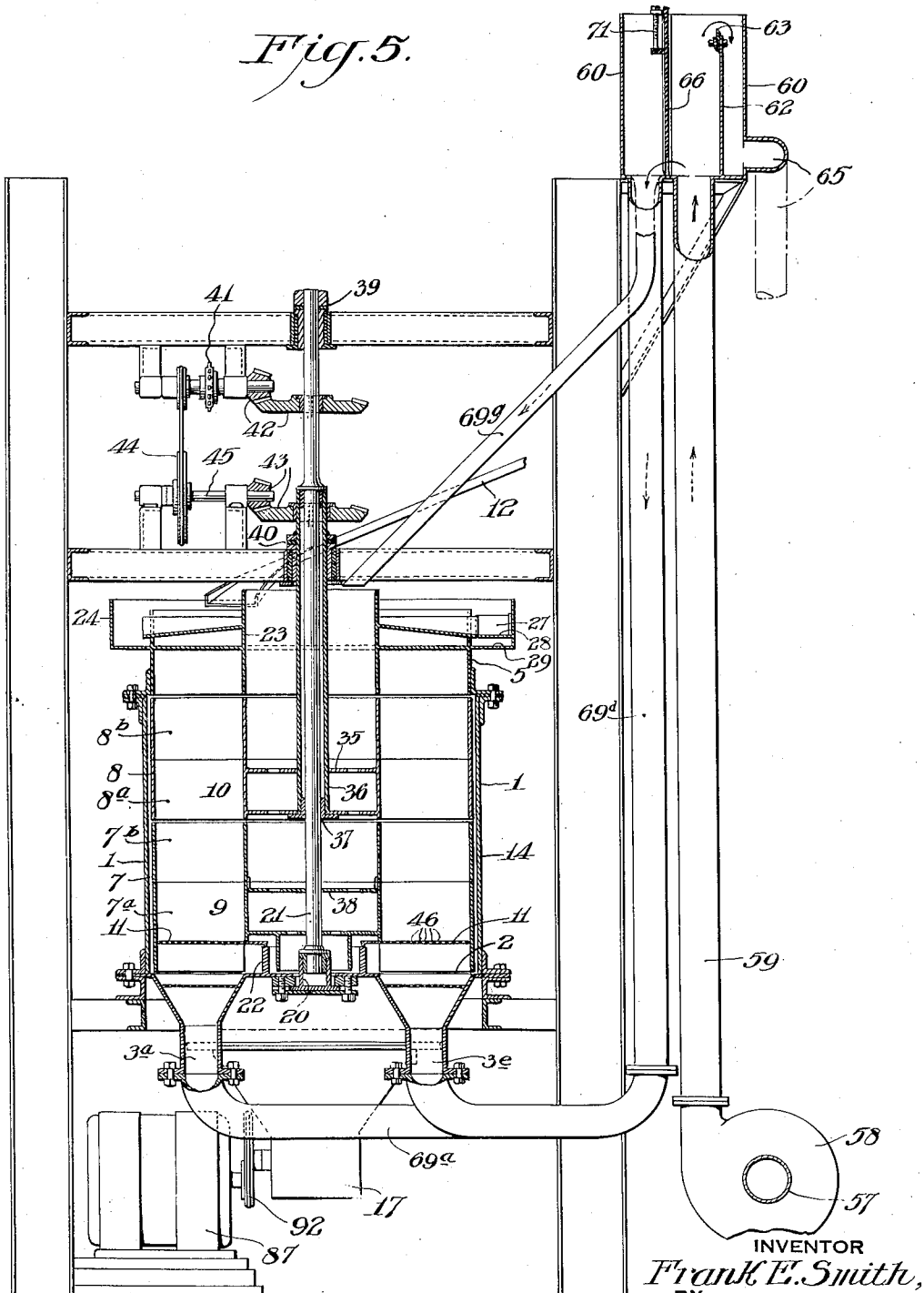
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SEPARATION OF MATERIALS

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*Fig. 5.*



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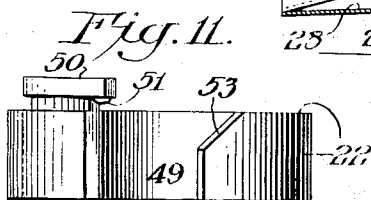
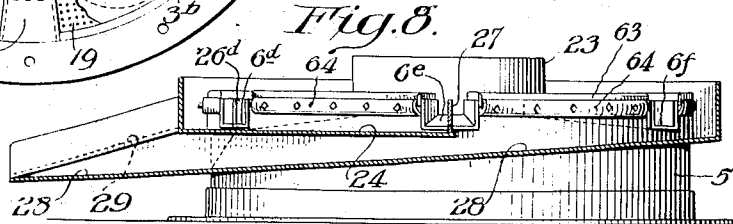
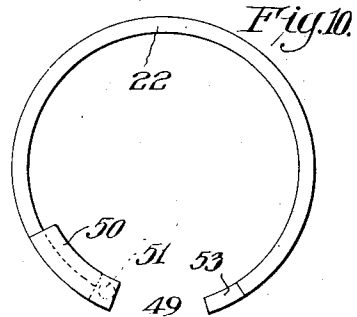
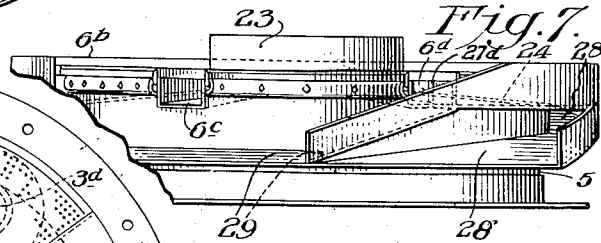
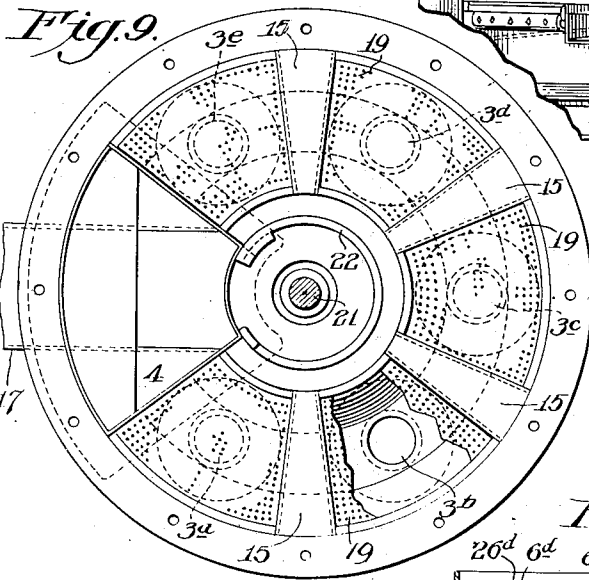
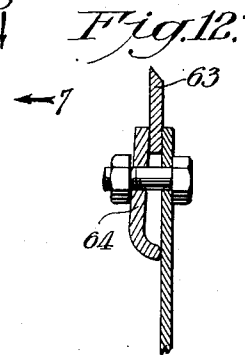
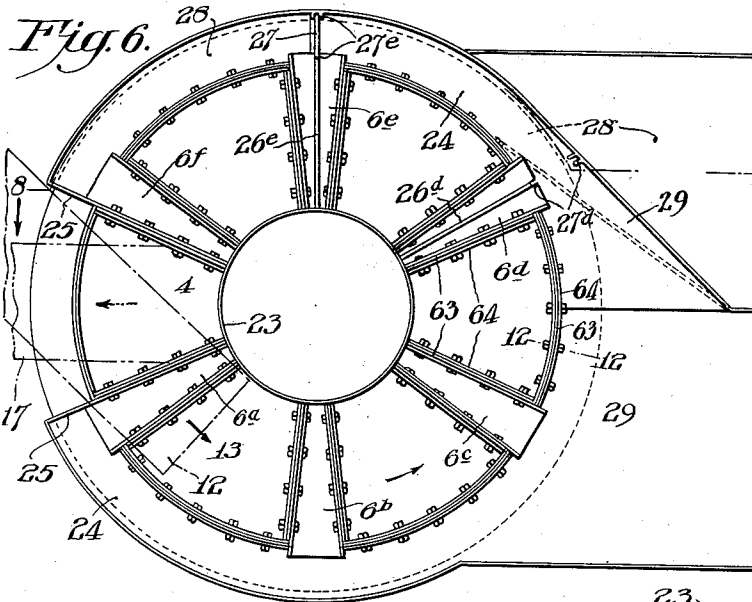
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SEPARATION OF MATERIALS

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8 Sheets-Sheet 4



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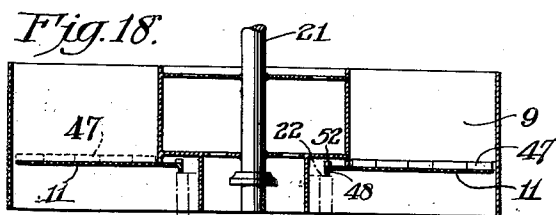
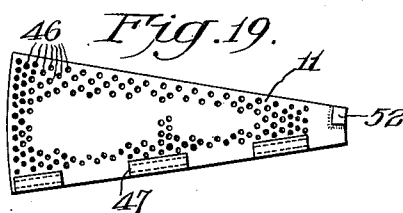
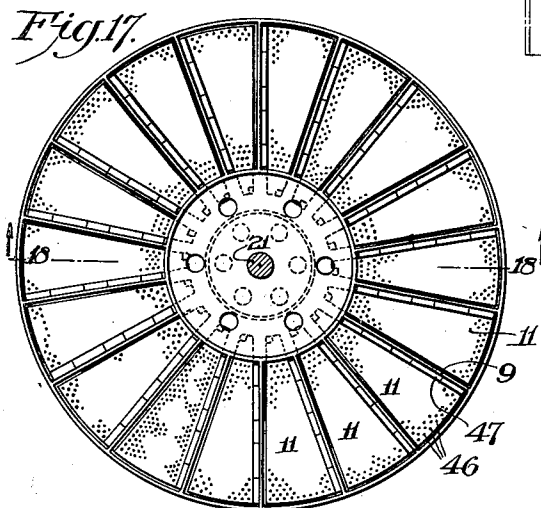
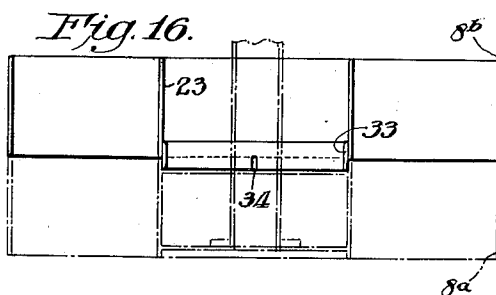
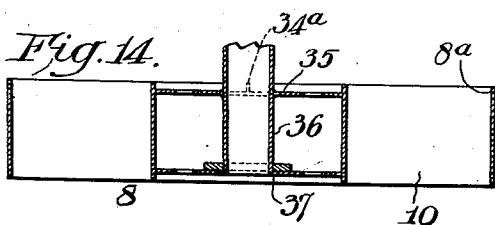
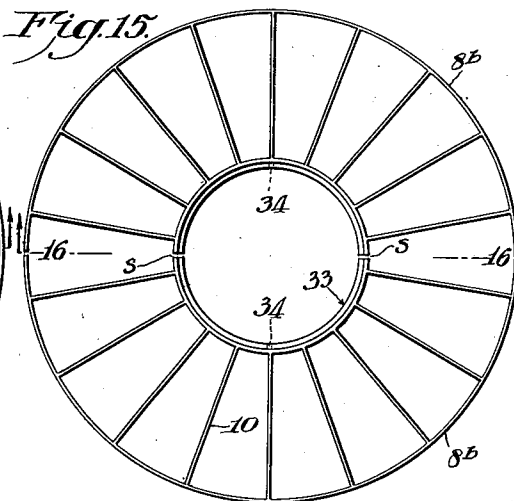
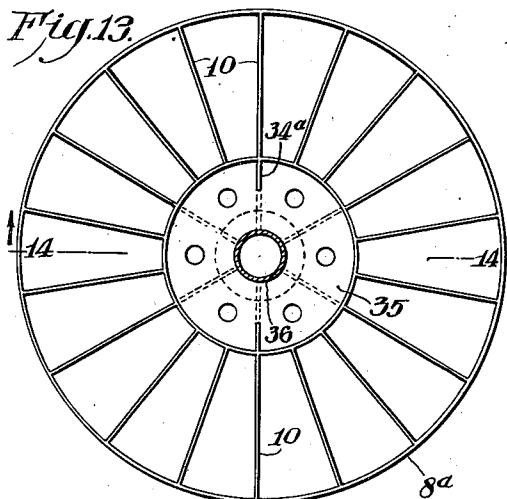
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SEPARATION OF MATERIALS

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8 Sheets-Sheet 5



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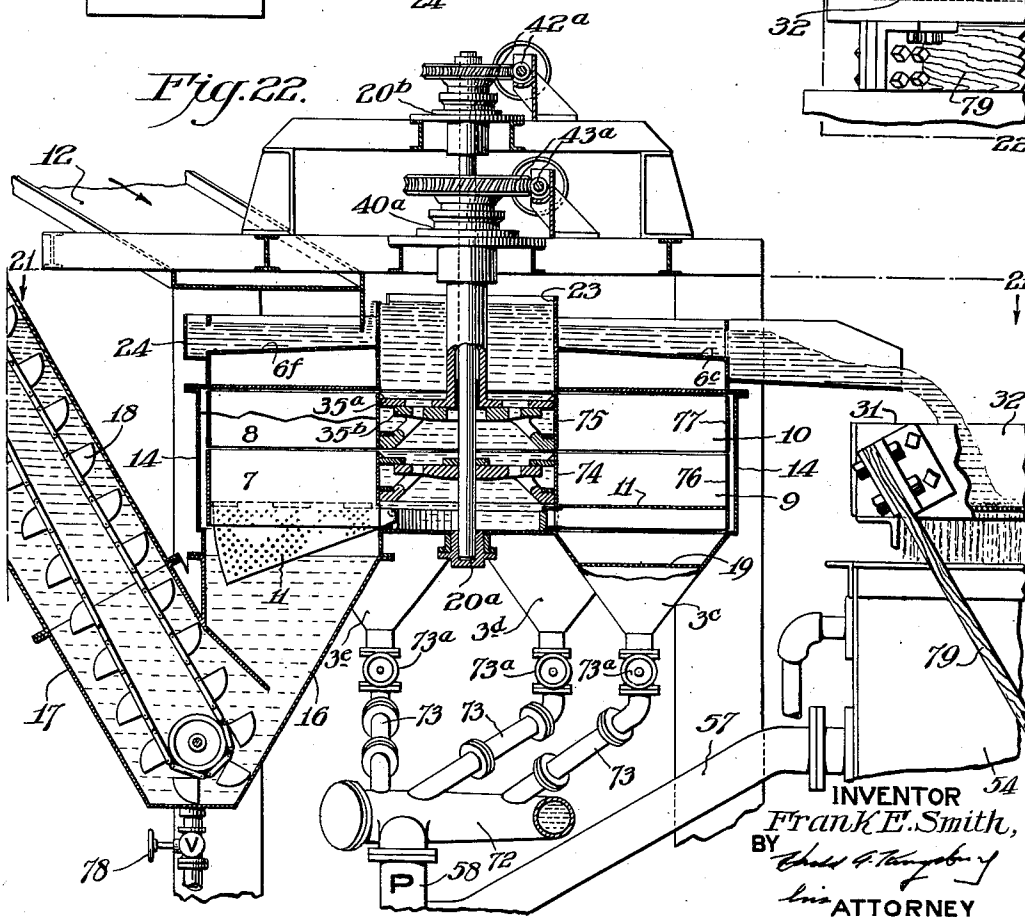
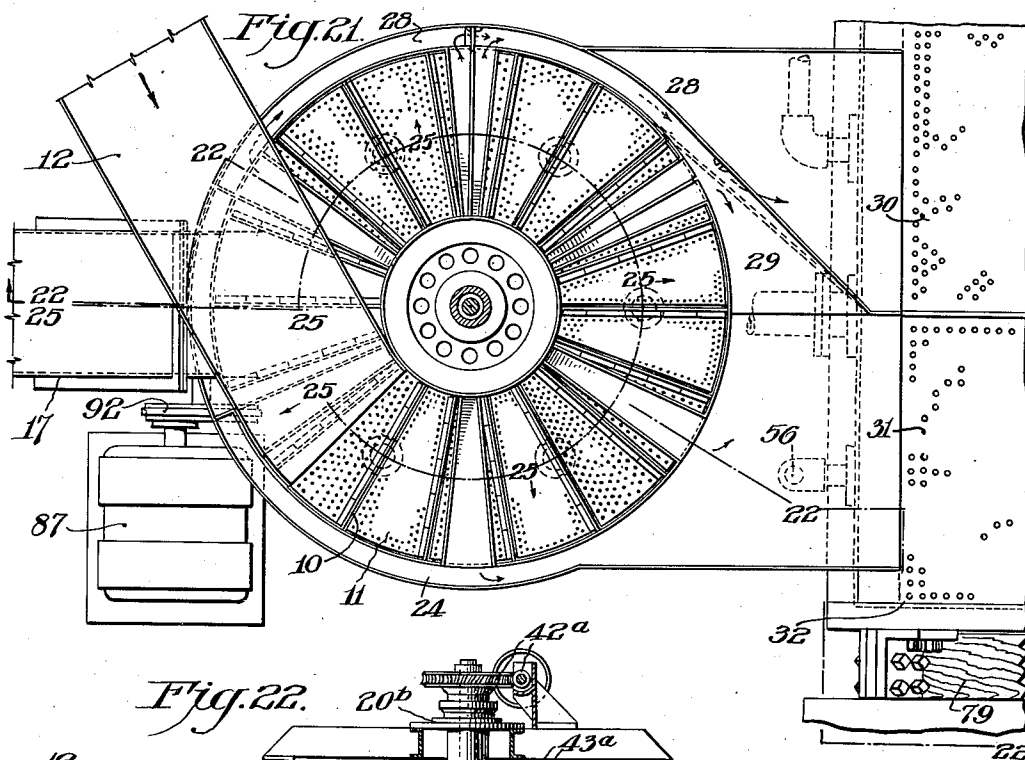
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SEPARATION OF MATERIALS

Filed May 25, 1937

8 Sheets-Sheet 6



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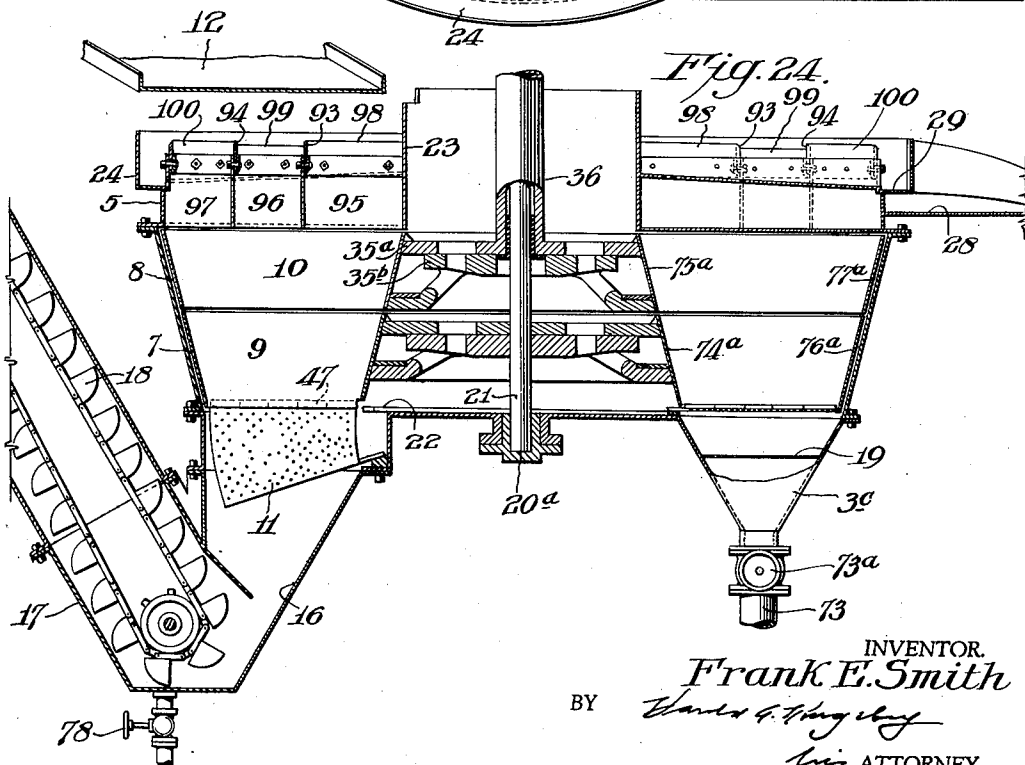
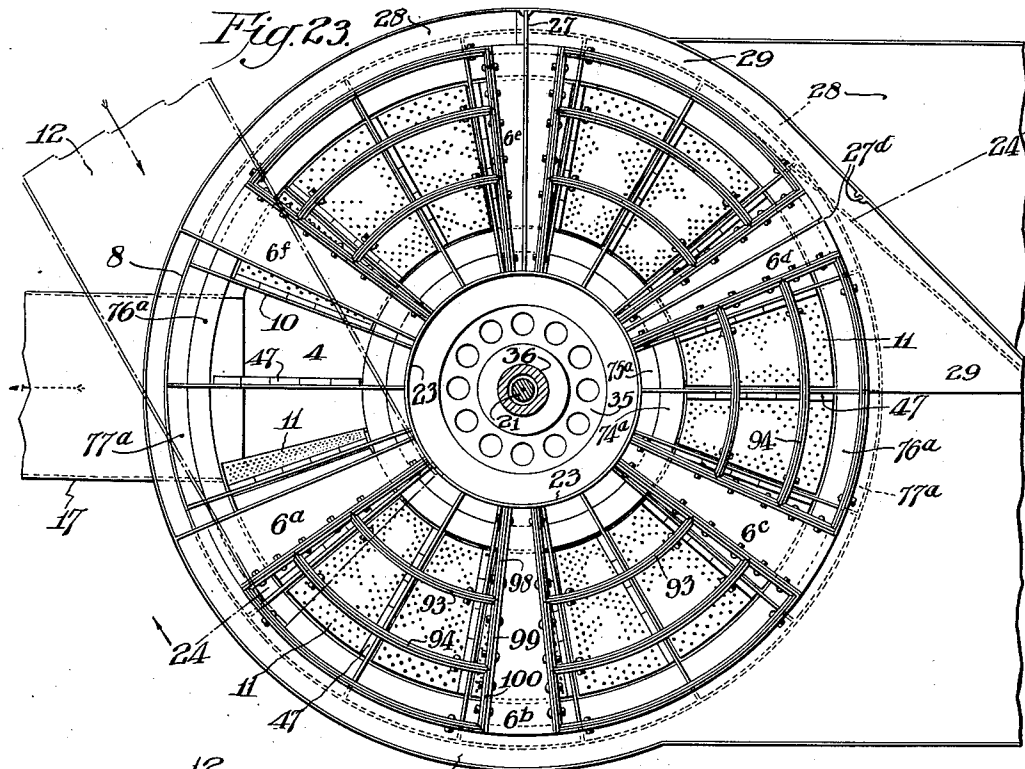
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SEPARATION OF MATERIALS

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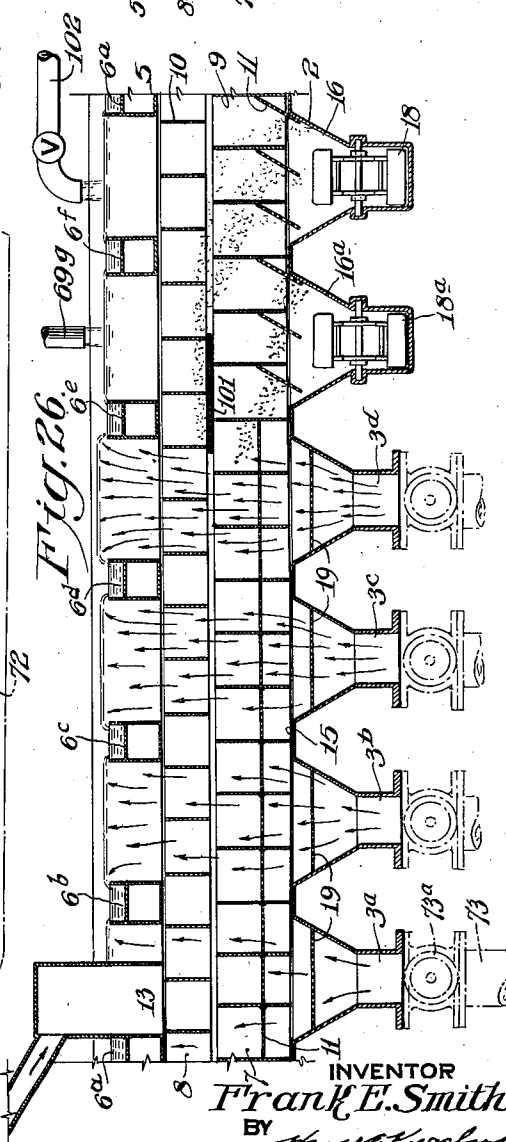
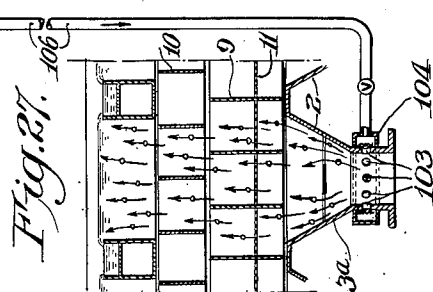
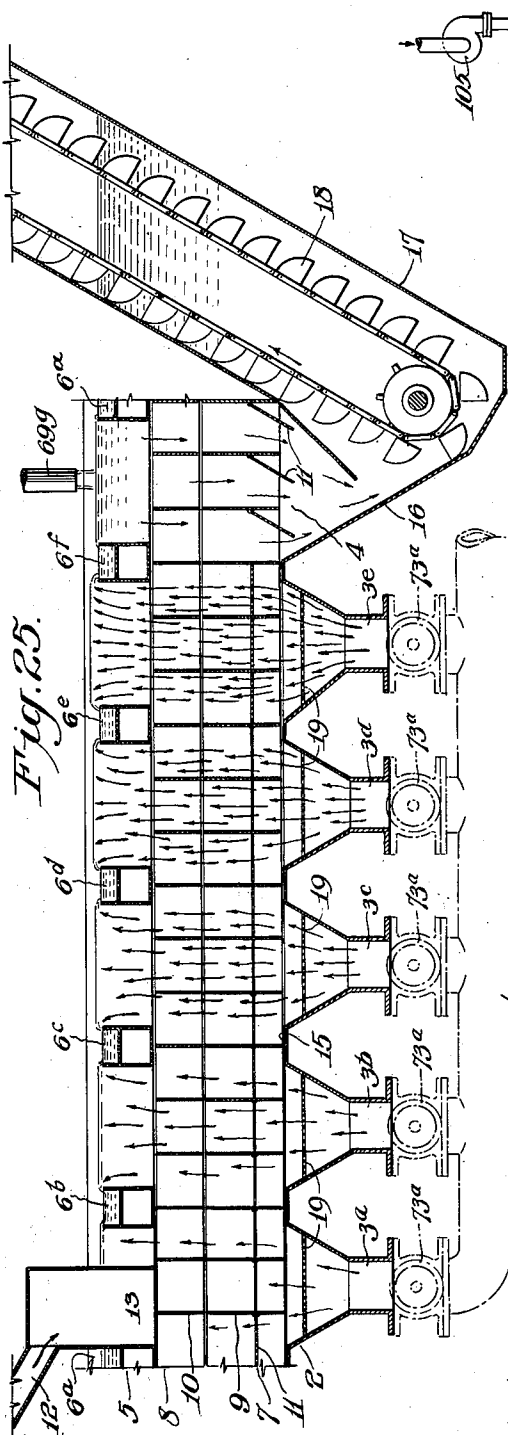
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SEPARATION OF MATERIALS

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8 Sheets-Sheet 8



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## UNITED STATES PATENT OFFICE

2,176,107

## SEPARATION OF MATERIALS

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Application May 25, 1937, Serial No. 144,624

20 Claims. (Cl. 209—209)

This invention relates to the separation of materials, and more particularly to a method and an apparatus for the practice thereof, for the hydraulic separation of relatively small bodies that because of differences in size, specific gravity and/or shape are amenable to such a separation. For definiteness, and not by way of restriction, the invention is described with more particular reference to its application to the washing and classification of coal, the coal in such application being washed to separate it from slate, and the washed coal being classified, the two operations being carried on simultaneously.

In separation of the general character of that to which the present invention relates, a difficulty has been that the layer of coal difficult to classify, which forms in an upward-current hydraulic classifier, greatly interfered with the operations, reducing speed and efficiency. Various efforts to overcome this difficulty have been made, but without such success as is desirable, due to various causes; for example, an effort to treat different portions of the column with different water supplies of different velocities introduced at different heights into the sides of the column, interfered with the separation. A further difficulty has been that it has not been feasible to treat each "layer" in the column with just that water flow best adapted to bring about the separation desired in it, because of the presence of other "layers" of different character in the same column.

One object of the present invention is to provide a method by which the above and other difficulties are overcome. Another object is to provide a method wherein, upon the column undergoing a separation into (somewhat approximate) layers, zones, or divisions to the extent desirable under the hydraulic conditions obtaining, the layers, still containing particles capable of separation, but more readily separable under different hydraulic conditions, are bodily displaced with respect to each other and such "different hydraulic conditions" are then individually imposed; this procedure being carried on with avoidance of all complications and any unsatisfactory operation that might result from attempting to impose on the hydraulic water the double duty of bodily displacing the layers and at the same time performing the hydraulic separation. A further object is to provide an apparatus for the performance of such methods. Other objects will become apparent as this description proceeds.

The above objects may be accomplished with

the apparatus illustrated in the accompanying drawings and, without restricting the invention to such apparatus, it is described with more particular reference to it. In these drawings:

Figure 1 is a plan view of the present apparatus. Figure 2 is a side elevation thereof. Figure 3 is a fragmentary plan view of one end of the weir box included in the apparatus. Figure 4 is a transverse section of the box taken substantially on the line 4—4 of Figure 3. Figure 5 is a vertical section of the separator taken, on a somewhat enlarged scale, substantially on the line 5—5 of Figure 1.

Figure 6 is a plan view of the upper portion of the separating compartments, the discharge troughs and the feed chute being also indicated, the latter in phantom lines. Figure 7 is a side elevation of the portion of the structure shown in Figure 6 looking in the direction of the arrows 7—7 in Figure 6. Figure 8 is a section substantially on the line 8—8 of Figure 6. Figure 9 is a plan view of the tank, or fluid container, of the apparatus, which receives the rotor; the perforated plates for equalizing the flow of the hydraulic medium, the discharge port communicating with the conveyor boot and the fixed cam for operating the dumping sectors being also shown.

Figures 10 and 11 are a plan and an elevation respectively, of the fixed cam for operating the dumping sectors. Figure 12 is a fragmentary detailed vertical section, taken substantially on the line 12—12 of Figure 6, illustrating a leveling weir. (In certain of the other figures, showings of these weirs, preferably used throughout the machine wherever an overflow is to be taken care of, are omitted for the sake of clearness.) Figure 13 is a plan view of the upper, or "zoner" element of the rotor of the apparatus. Figure 14 is a section of the zoner element taken substantially on the line 14—14 of Figure 13.

Figures 15 and 16 are respectively a plan view and a section taken substantially on the line 16—16 of Figure 15, illustrating the construction of the said zoner element in two annular portions, the portion illustrated in Figure 13 being the lower annulus of the showing in Figure 16. Figure 17 is a plan view of the bottom or "basket" element of the rotor, with its perforated dumping sectors. Figure 18 is a section taken substantially on the line 18—18 of Figure 17. Figure 19 is a detailed plan view of one of the dumping sectors and Figure 20 is a longitudinal edge view of such sector in elevation.

Figure 21 is a plan view of another form of the apparatus of the invention, wherein the several

liquid flows are controlled by valves and are delivered from a common source. Figure 22 is a sectional elevation taken substantially on the line 22—22—22—22, of Figure 21. Figure 23 is a plan view similar to Figure 21 illustrating a further modification of my invention. Figure 24 is a sectional elevation on line 24—24 of Figure 23. Figure 25 is a developed section taken substantially on the line 25—25—25—25—25—25 of Figure 21.

Figure 26 is a view similar to Figure 25 of an apparatus wherein two conveyors are used, and a fixed plate is interposed between the upper and lower rotor elements, to provide for the separation of the discharges from the two elements and the reception of each in the particular conveyor therefor. Figure 27 is a fragmentary sectional elevation showing an air supply for assisting in separation of the mineral particles.

Briefly describing the illustrated apparatus, and referring more particularly to Figures 1, 2, 5, 6, 9, 17 and 25 of the drawings, in general the apparatus comprises a cylindrical container or tank 1, the bottom 2 of which is provided with a series or rank of equally spaced-apart water inlets as 3<sup>a</sup>—3<sup>e</sup>, and a bottom discharge opening 4. The top 5 presents a radiating series of discharge troughs 6<sup>a</sup>—6<sup>f</sup> in alignment with the spaces between one water inlet and the next, or between a water inlet and the discharge opening 4, as the case may be. Axially and rotatably received in tank 1 is a rotor 7—8 comprising, what I term for convenience, a "basket" element or "collector" 7 and "zoner" element or "zoner" 8, these being independently rotatable. The zoner is open at top and bottom; while the basket is open at the top but provided with a bottom. Each is provided with a radiating series of partitions 9 or 10. The bottom of the basket is made up of a series of perforated sector plates 11 hinged to the bottoms of the partitions 9 to be normally held in closed position but dumpable on occasion over the bottom discharge 4. A feed chute for the material to be separated is provided at 12.

It will be seen that the above described structure presents, in effect, a series or rank (in this case parti-annular) of hydraulic columns, each column being structurally defined by a water inlet, the vertically aligned space, as 13 (Figure 6), between a pair of the discharge troughs, and whatever sectoral spaces (between partitions 9 of the basket and partitions 10 of the zoner) are in communicating vertical relation with each other and with the space 13 and the water inlet. It will be further seen that, depending upon differences among the strengths of the water flows in the different columns, the hydraulic conditions in different columns will differ from each other.

In usual operation the water flows are so set that they increase, and hydraulic conditions are more vigorous, from column to column in the direction of travel of the two rotor elements from material inlet 12 to discharge 4. The rotor elements travel continuously in the same direction, e. g. anticlockwise in Figure 1 and left to right in Figure 25. In a case wherein the proportion of "heavy" material, i. e. material that is to be discharged at the bottom of the apparatus, is small, as in the case of slate in coal, the basket is rotated faster than the zoner, the difference in speed depending on circumstances. While in the present case five columns are provided for, it will be understood that the number of columns need be but such as is desirable for the degree of

separation called for. Furthermore, while the column that directly receives the feed of material is here shown as provided with a water inlet for upward current separation, it may be desirable in some cases to so far reduce the flow that this column is of practically quiescent water and mere (but brief) unhindered settling takes place therein, it yet being a "column" from the point of view of the present invention.

In the operation of the apparatus, as the travelling rotor elements 7 and 8 pass under the space 13 the raw feed is delivered to them and initiatory separation into hydraulically separable components begins, the best-differentiated "lights" rising, assuming sufficient upward current (or at least "hanging behind" when no upward current is used), the best-differentiated "heavies" sinking fastest, and the less well differentiated components collecting part way up the column in the space to which the zoner is designed, for practical purposes, to at least approximately correspond. Similarly, the basket, and the divisions above the zoner formed by the depending radial trough structures, correspond in location and in height to the locations and thicknesses of the layers of heavies and lights. While but one zoner is generally sufficient, more (each, if desired, independently driven at a different speed from the others) can be used if found desirable. Obviously, the heights of the basket, zoner or zones, and the top divisions will be such as called for in any particular circumstances, to give the closeness of zoning desired. (It will be understood that terms such as "lights", "intermediates" and "heavies" are used herein to indicate relative separative characteristics whether due to differences in specific gravity, weight, size, shape, or whatnot, rather than to necessarily indicate differences in specific gravity.) As the process continues in this column, assuming a continuous feed, the collection, "zone" or "layer" of intermediates tends to build up, and interfere with and adversely affect operation. The operation of a hydraulic column is of course well understood in the art; and, indeed, the creation and building up of the intermediate layer is a recognized major difficulty in the art.

But of particular present significance is the fact that, in the present apparatus, the layer of intermediates and the layer of heavies are collected each in a zone that may be bodily shifted with respect to the other, and with respect to the upper layer of lights. An advantage of this is that as soon as either one of the movable layers has reached such a condition of separation, density, or whatnot, that one could be better treated under different hydraulic conditions (e. g. with increased current) than those existing in the column in question and/or the other layer could be better treated in the column in question if the said one layer were removed from the column, the desired change can be made forthwith by shifting one or both of the rotor elements. As a matter of fact, the two conditions—one layer being ready for different hydraulic conditions, and the other in a condition for better treatment if the one layer were removed from the column in question—occur sufficiently close together so that both conditions may, as a practical matter, be satisfied simultaneously. In other words, a forward shift of one layer, e. g. the bottom one, to bring it under the influence of the different hydraulic flow, will, with proper timing, also remove the other layer, e. g. the intermediate one, from immediate relation with the one layer, at the

proper time; and furthermore shifting of the bottom layer and of the intermediate layer will also remove the top layer from immediate relation with the other two layers at the proper time. Also, of course, although both the intermediate layer and the bottom layer are advancing, the speed difference can be such as to establish and maintain the desired relation or separation between them. Continuous operation is thus entirely feasible.

As the layers advance they are evidently cleared as required, the action in the second column being a carrying forward of the initiatory separation in the first column. The linear distance that a layer should travel, and the time of travel, or in other words the extent of the hydraulic treatment before discharge, will of course be dictated by circumstances such as the character of the feed, the degree of washing and/or classification desired, and so forth. Similar comment applies to the number of water flows or "columns" desirable. In general, conditions should be such that the material is so cleared that, ultimately, the intermediate layer, now substantially freed of lights and heavies to the extent feasible in practical operation may be discharged separately for such further treatment as desired.

Since, on the one hand, such light or intermediate material as is carried (e. g. mechanically) to the bottom layer when the charge is introduced is, to a large extent, such that it can be readily and quickly removed from the bottom layer, and furthermore with coal the proportions of slate is relatively small, whereas, on the other hand, in the middle layer proper separation is less readily and quickly established, it is evident that the bottom layer may preferably be advanced from initial conditions to more vigorous conditions, i. e. increased water flow, earlier than should the intermediate zone. With other materials, and/or a greater proportion of heavies, this situation might reverse itself, indicating a greater speed for the intermediate layer than for the bottom layer.

In the continuous operation of the machine, as the sectors of the basket, the contents of which have been sufficiently treated in the first column, are rotated or shifted forwardly out of the column, such sectors are replaced by empty sectors advancing from the discharging position, and these are in turn charged, the contents given initiatory treatment, and the sectors advanced; and similarly with the sectors of the zoner. Among others, this has the advantage that the materials-content of the column is, because of the continuous replacement of treated layers by fresh material, always of the character, and in the separative state, to which the established hydraulic conditions are best suited. Similar comment applies to the column into which the sectors move, the fact that such column is, in a sense, charged from the side not introducing any fundamental departure from the method of operation and the significance thereof.

It is also to be noted that with the present apparatus, the function of the hydraulic water as a columnwise separator is not interfered with, or complicated by, an effort to impose on the water the function of a transfer means for shifting the layers sidewise from column to column. That function is performed by the basket and the zoner. This gives the advantage that the hydraulic water, and the rotor, can each be ad-

justed to perform its own function to the best advantage.

(At this point it may be remarked that, whereas it might at first appear that because of the container being, in the first instance, but an undivided tank, difficulty would be encountered in effecting established hydraulic columns of different current characteristics; but such is not the fact. While the rotor is not watertight between its zoner and basket, nor is it fitted watertight in the tank, so that the whole tank, to the extent it is not occupied by coal, is filled with water supplied by the water inlets, it is yet the fact that the different water supplies, the vertical radial partitions of the rotor, and the radiating discharge divisions establish, for all practical purposes, individually functioning hydraulic columns of different characteristics).

Referring further to the use of an upward current in the division or bay into which the material is charged (that is, the first division in the illustrated apparatus) this is advantageous in that separation by raising of the particles will be initiated earlier in the cycle, and in that a better separation is made in the basket, with the heaviest particles at the bottom and the lighter particles on top, at the time when the basket is being loaded. On the other hand; due consideration must be given to the fact that for efficiency the basket should be loaded or filled substantially to capacity during the time when it is passing under the charge. The question is, therefore, one of the free falling velocity of the material in the liquid.

Thus if the free falling velocity is only great enough to provide that the basket, at the speed at which it is being driven, will be adequately loaded in the time it is passing under the charge, an upward current is preferably not used; but if such falling velocity is greater, then an upward current may be used provided it is of a velocity that will still permit the basket to adequately load. For example, if with a given speed for the basket, it is necessary that the charge fall at 12 feet per minute to adequately fill a given portion of the basket during its passage under the charge, and the free falling velocity of the material (say a barley coal) is but 12 feet per minute an upward current is generally not desirable in the charging bay. On the other hand, if the material has a free falling velocity exceeding 12 feet per minute (say a rice coal with a falling velocity of 22 feet per minute) an upward current approximately equalling the difference, e. g. an upward current of 8 to 10 feet per minute velocity, may be used with the same basket speed as before. Obviously, a reduction in the speed of the basket will permit an increase in the velocity of the current, and conversely.

#### EXAMPLES

The following are illustrative but not restrictive of the present procedure:

#### I

Crude coal: barley size of  $\frac{3}{4}$  to  $\frac{1}{8}$ ; on 100 pounds basis, coal 75 pounds, boney material 10 pounds, slate 15 pounds; free falling velocity about 15 feet per minute in water. Coal supply to apparatus (and discharge therefrom)  $1\frac{1}{2}$  tons per minute.

Apparatus: rotor 9 feet in diameter; 6 divisions for the base of the tank (four with an upward current supply, and an initial or charged one and a final discharging one each without an upward

hydraulic current) providing 4 upward water current supplies spaced about 3 feet 4 inches apart from center to center, and each with a diameter of about 2 feet 3 inches for the orifice in the bottom of the tank. Basket and zoner each with 18 partitions; 6 divisions for top of tank; height of water, bottom of tank to overflow, 3 feet; height of basket, 1 foot; height of zoner, 1 foot 2 inches; height of top 10 inches. Speeds, basket, 1 R. P. M.; zoner  $\frac{1}{4}$  R. P. M. Water velocities (proceeding in direction of rotation), 3, 10,  $10\frac{1}{2}$  and 12 feet per minute as the water issues through bottom orifices. Collection: products raised by first three columns collected together, and material (coarse coal, boney material and raised slate) separately collected from fourth current.

Indicated separation on basis of 100 pounds of crude coal treated: pure fine coal 50 pounds; pure coarse coal 15 pounds; remaining raised material, i. e. coarse coal 9 pounds, boney material 4 pounds, and slate 1 pound, all amounting to 14 pounds. Refuse dumped, coal 1 pound, boney material 6 pounds, and slate 14 pounds. Since in this case the products raised by the first three currents are not individually collected, the mingled products, i. e. fine coal from the first current, fine coal with some coarse from the second current, and coarse coal from the third current are screened to separate the sizes. Also, the mass of coarse coal, raised boney material, and raised slate, raised together at the fourth column, is screened to free the high ash coal (i. e. coarse coal and boney material together) from slate.

## II

Crude coal: rice size  $\frac{1}{8}$  to  $\frac{3}{8}$ ; on 100 pound basis, coal 75 pounds, boney material 10 pounds, slate 15 pounds; free falling velocity about 22 feet per minute in water. Coal supply to apparatus (and discharge therefrom) 2 tons per minute.

Apparatus as above but with upward current supply in charged bay, providing 5 upward water currents spaced apart, and through orifices, as above. Speeds as above. Water velocities (proceeding in direction of rotation) 8, 13, 15, 16, 17, 19 feet per minute as the water issues through bottom orifices. Collections: products raised by first three columns collected together, and materials (coarse coal, boney material) from the fourth and fifth columns collected together but separately from the products raised by the first three columns.

Indicated separation on basis of 100 pounds of crude coal treated: pure fine coal 50 pounds; pure coarse coal 15 pounds; remaining raised material, i. e. coarse coal, 10 pounds, boney material 3 pounds, slate 0 pounds, all amounting to 13 pounds. Refuse dumped, boney material 7 pounds, slate 15 pounds. The mingled products, and the mass raised at the fourth and fifth columns, screened as above.

## DETAILED DESCRIPTION OF APPARATUS

Proceeding now to a detailed description of the apparatus, and first as to the tank 1: this comprises the circular bottom 2, side 14 and top 5. The bottom (Figures 5, 9 and 25) is provided with the conical water inlets 3<sup>a</sup> to 3<sup>e</sup>, equally spaced apart by the lands 15 and arranged in a parti-annular series. Between the first and last inlet, is provided a materials-discharge outlet 16. This latter communicates with the housing 17

of a conveyor 18 for the removal of the discharged material. Each of the inlets 3<sup>a</sup> to 3<sup>e</sup> is preferably provided with a flow distributing or equalizing screen 19. The bottom is provided with a bearing 20 for the shaft 21 of the basket 7, and with a cam track 22 for control of the sector plates 11 of the bottom of the basket 7 and later to be more fully referred to.

The circular top 5 (Figures 1, 5, 6 to 9, 12 and 25) carried by the cylindrical side wall 14 presents not only the radiating spaced discharge troughs 6<sup>a</sup> to 6<sup>f</sup>, closed at their inner ends by the depending annular wall 23, but also the surrounding collector trough 24. The ends of the trough are closed by the ends walls 25, 25.

The troughs 6<sup>d</sup> and 6<sup>e</sup> are each provided with a dividing partition 26<sup>d</sup> or 26<sup>e</sup>. There is also provided a shiftable gate or partition 27, that may be placed to serve as an extension of either the partition 26<sup>d</sup> or 26<sup>e</sup>, the partition 27 being optionally insertable in grooves 27<sup>d</sup>, 27<sup>e</sup> provided for that purpose. The partition 27 cooperates with the partition 26<sup>d</sup> or 26<sup>e</sup> to close the trough 24 crosswise.

The trough 24 is provided with a dual discharge comprised of a chute 28 communicating with the trough 24 to the left (in Figure 6) of the partition 26<sup>e</sup> and grooves 27<sup>e</sup> and a discharge chute 29 communicating with the trough 24 to the right (in Figure 6) of the partition 26<sup>d</sup> and grooves 27<sup>d</sup>. These chutes 29 and 28 are arranged one above the other to communicate each with its own side 30 (for chute 28) or 31 (for chute 29) of a dewatering and sizing screen 32, that may have screens of the same or different mesh on its two sides, the chute arrangement being shown particularly in Figures 7 and 8.

With this arrangement, the products hydraulically raised out of the spaces between the troughs 6<sup>a</sup>, 6<sup>b</sup>, 6<sup>c</sup> and 6<sup>d</sup> are discharged through the chute 29 to screen side 31 and the products raised through the space between the troughs 6<sup>e</sup> and 6<sup>f</sup> are discharged through the chute 28 to screen side 30. The products rising through the space between the troughs 6<sup>d</sup> and 6<sup>e</sup> may be directed either to the chute 28 by placing the partition 27 at 27<sup>d</sup> or to the chute 29 by placing the partition 27 at 27<sup>e</sup>. To provide for adjustment of the discharge level, the sides of the troughs 6<sup>a</sup> to 6<sup>f</sup> and the inner side of the trough 24, desirably include vertically adjustable portion 63 clamped to the wall proper by the clamping plate-and-binder-bolt arrangement 64 (Figure 12).

With the above trough arrangement, the raised products from the first three hydraulic columns are not separated from each other, but are collected together, while the product from the fifth column is separately collected; and that from the fourth column is collected with those of the first three, or with that of the fifth as desired. In explanation, it has been found that with suitable control of the apparatus, the discharges from the first three columns, and sometimes the fourth, are closely uniform (e. g. all fines), and it is not until the fifth, or sometimes the fourth column is reached that another size (e. g. coarse) is lifted out of the apparatus. However, it is evident that the separation of the different discharges may be such as desired in any particular circumstances, and a suitable number of dividing partitions, movable partitions, and chutes, here exemplified by the elements 26<sup>d</sup>, 26<sup>e</sup>, 27, 28 and 29, or any other arrangement suitable for the attainment of the desired ends, may be incorporated. For example, the raised products, or

floats, from the individual columns may be taken to individual screens for dewatering and treatment by screening, and the products from the different screens handled independently as separate products.

Not only is the screen important for dewatering, so as to leave the material in the desired condition after passing over the screen, but also as more particularly referred to hereafter under some conditions the screening may be considered as a part of the process as is evident from the following. While, if the feed to the machine were sized to vary narrow ranges with all the bodies of approximately the same characteristics with regard to size and shape, the machine would then make a close separation, in accordance with specific gravity, yet what may occur in practice is that the feed will cover a wide range of sizes and be composed of particles of different shapes such as flats with a low weight and a large surface, and of square fracture pieces with a heavy weight and smaller surface. In this latter case, the difficulty may arise that the very small high gravity pieces will rise out of the same column as the very large low gravity pieces. This can be corrected by feeding this raised material over a screen whereby the small particles are screened out, thereby taking from the floats the high gravity particles and leaving practically all low gravity particles. As more particularly referred to hereafter the water passing through the screen is collected in a tank and is available for reuse in the machine.

As to the rotor (Figures 5, 11, 13 to 20, and 25): as mentioned above this comprises the basket 7 and the zoner 8 axially mounted with respect to the tank 1 for independent rotation. For convenience in changing the capacity of each, by changing the depth thereof, each comprises a primary section 7<sup>a</sup> or 8<sup>a</sup> and a detachable section 7<sup>b</sup> or 8<sup>b</sup>, each of which latter is connected with its mated primary section by a telescoping portion 33 and slot-and-key arrangement 34-34<sup>a</sup> (Figures 13 and 16). For convenience in assembly and replacement the detachable section is split as indicated at s, s in Figure 15. As will be understood, when the changes are made by the addition or removal of parts 7<sup>b</sup> or 8<sup>b</sup> a side 14 of corresponding height will be used, thus placing the top 5 at proper height. As will be further understood, the indicated arrangement may include as many detachable sections as 7<sup>b</sup> or 8<sup>b</sup> as desired, connected for rotation together as indicated for parts 7<sup>a</sup> and 7<sup>b</sup>, and for parts 8<sup>a</sup> and 8<sup>b</sup>, or in any other suitable manner.

Each rotor element, in both its sections, is provided with a suitable number (illustrated as eighteen) of equally spaced radial partitions 9 or 10 extending the full height of the walls of the section that they divide. Desirably, and as illustrated in Figure 25, the partitions are arranged sufficiently close to provide about three sectoral divisions for the distance between a discharge trough as 6<sup>a</sup> and the next as 6<sup>b</sup>. The exact number of radial partitions 9 or 10 for a rotor element will depend upon the transporting ability desirable for the element in view of the results sought and the liquiform masses to be transported, and upon the extent it is advisable to prevent cross currents between the various columns. In reference to the first-mentioned conditions, partitions sufficient to give at least twice as many sectoral divisions as there are top divisions or bays are generally desirable; and in reference to the second-mentioned condition,

for full elimination of cross currents the partitions should be of such number that some partition of the zoner (and of the basket) is always in vertical alignment with the land between two immediately adjacent inlets as 3<sup>a</sup> and 3<sup>b</sup>, 3<sup>b</sup> and 3<sup>c</sup>, and so on, and the trough structures as those for 6<sup>a</sup> and for 6<sup>b</sup> and so on, thus to present a full wall between one current and the next.

However, full satisfying of this second condition is sometimes not necessary, as in cases where some cross currents are not objectionable. In the present instance, the eighteen partitions used fully satisfy the second condition; and, being more than the twelve that is required to create twice as many sectoral divisions as the six bays illustrated, obviously more than satisfy the first condition.

In the case of the basket, the partitions thereof may in some circumstances be practically eliminated as in cases wherein full separation, so far as the contents of the basket are concerned, is accomplished in the first column, since the basket load to be then transported is so far non-liquiform that it will be transported by the basket in any event. In such a case, the partitioning may be but an elementary webwork to connect the inner and outer walls of the basket and the sectors 11 may be hinged in such walls by pintles at the ends of the sectors and mounted in such walls.

On the other hand, with the use of partitions the basket may in some cases be fully open at the bottom similar to the zoner; and in such a case the liquid inlets as 3<sup>a</sup> to 3<sup>c</sup> will be provided with screens to prevent the fall of the material into the inlets as the basket transports the material thereover.

The zoner 8 is attached by its apertured web plate 35 fast to the hollow shaft 36, at 37 in any suitable manner, for rotation and support thereby, and the basket is similarly attached at 38 fast to shaft 21 for rotation and support thereby. The thrust loads, or weights, of the basket and the zoner are carried at the bearings 20 and 39, and 40 respectively. The drive for the shafts is from a sprocket 41 to gear sets 42 and 43, the speed ratio between shaft 36 for the zoner and shaft 39 for the basket being, of course, adjustable by suitable change of the gear sets or in the drive 44 for the shaft 45. In the event that in some case the zoner may be driven at the same speed as the basket the zoner becomes in such case, for practical purposes, a part of the basket, wherefor for such a case the zoner and basket may be constructed as a single rotary element or basket of a height to reach to immediately below the top 5.

As previously stated, the bottom of the basket 7 is made up of sector plates 11. These have perforations 46 for passage of the water currents, these perforations being sufficiently small to ensure that no materials, that the apparatus is intended to treat, will pass therethrough. To provide for the dumping of the contents of the basket, the sector plates 11 are individually hinged at 47 to the bottom edges of the partitions 9.

Normally each sector plate is supported in closed position by the supporting track 22 upon which rides a wear portion 48 at the end of the plate, but at a suitable location with respect to the discharge opening 4 of the bottom 2 of the tank 1 the track 22 is interrupted at 49 (Figures 10 and 11) to permit the sector, no longer supported by the track, to swing about the hinge 47 and dump. Ordinarily the plate will dump under the load, but

to ensure positive operation the track is provided with an overhang 50 with a projection 51 to contact a projection 52 on the plate and turn the plate. The plate is returned to normal position by the travel of the projection 48 up the cam incline 53, this being located to return the plate prior to the same reaching position under the charging chute 12.

As to the water supply system (Figures 1 to 5): the same comprises the storage tank 54 provided with the valved inlet pipe 55 from any suitable source of supply (not shown), with an overflow pipe, and with the cleanout pipe 56, suitably valved (not shown). A flow pipe 57 leads to a pump 58 that raises the water through the riser pipe 59 to a constant-head tank 60 from which the water is supplied to the water inlets 3<sup>a</sup> to 3<sup>e</sup>, and also to the tank 1 above the discharge 4, and above the center of the tank.

The open-topped tank 60 presents partitions 61 and 62 extending the length of the tank, the partition 62 constituting an overflow weir determining the height or head of the liquid in the tank. As illustrated (Fig. 4) it preferably is provided with a level adjuster 63—64 (Fig. 4) like that previously described in connection with the troughs 6<sup>a</sup> to 6<sup>f</sup>, and 24, and extending the length of the partition 62. The overflow is conducted by the pipe 65 to the screen 32 whence it returns to the tank 54.

The partition 61 is comprised of a series of independently vertically adjustable gates as 66. Between each gate and the next is a dividing partition 67 by which the space forward (below in Figure 1) of the partition 61 is divided into a series of independent bays 68. From the bays lead the pipes 69<sup>a</sup>—69<sup>e</sup> delivering to the inlets 3<sup>a</sup>—3<sup>e</sup> at the bottom of the tank 1, and also lead the pipes 69<sup>f</sup> and 69<sup>g</sup> delivering to the top of the tank above the discharge 4, and above the center, respectively. The latter two supplies are for further insurance that the tank 1 will be filled to full level in all parts, despite any effect of the rotating rotor and/or any clogging effect of the mass of coal in the tank.

The gates 66 are mounted in slideways 70 for individual vertical adjustment by the hand wheels, as 71. It will be evident that in this way the flow through any outlet may be made such as desired, and that by proper adjustment of the gates the upward currents from inlets 3<sup>a</sup>—3<sup>e</sup> and hence the hydraulic columns in the spaces between the discharge troughs 6<sup>a</sup>, 6<sup>b</sup> and so on, may be made of such volume, and corresponding velocity, as desired.

Various other ways for the control of the water flow may be adopted, and, by way of example, one such is shown in Figure 22. In this case, the pump 58 delivers to a header 72 from which individual pipes 73, each with an adjusting valve 73<sup>a</sup>, lead directly to the various inlets 3<sup>a</sup>—3<sup>e</sup> to the bottom of the tank 1 and to supply 69<sup>f</sup> and 69<sup>g</sup> for the tank above its discharge 4 and at its center respectively, as in the previously described case.

In further reference to Figure 22 (and Figures 21 and 25), this figure presents an arrangement in which the basket and the zoner are without the detachable sections 7<sup>b</sup> and 8<sup>b</sup>, and the tank side 14 is of corresponding reduced height, thus giving a device with hydraulic columns of less height. Also in this figure, gear sets 42<sup>a</sup> and 43<sup>a</sup>, and the drives therefor, somewhat different from gear sets 42 and 43 of Figure 5, are shown, the differences being evident; and somewhat different provisions 20<sup>a</sup> and 20<sup>b</sup> and 40<sup>a</sup> for taking the thrust loads or

weights are also used. Also the webwork for the basket and zoner is shown in greater detail. (It will be understood that web parts, e. g. 35<sup>a</sup> and 35<sup>b</sup> may be attached to each other in any approved manner, as by welding; similar comment applies to the connections of the webworks with the inner rims as 74 and 75 of the basket and the zoner, the attachment of the radiating partitions 9 and 10 to the outer rims 76 and 77 of the basket and zoner, and to the constructions of the various other parts.) As also indicated in this Figure 22, the conveyor housing 17 may be provided with a bottom draw-off valve 78 for cleaning purposes or what not.

As to the dewatering screen 32 (Figures 1, 2): the screen is of a usual shaker type mounted for shaking reciprocation upon hickory supporting arms 79, 79 at each side and reciprocated by a hickory driving arm, as 80, at each side, the latter being driven in the usual manner by the eccentric drive 81, driven from the motor 82. The screen drains into the open top of the water storage tank 54, and the coal is discharged from the screen at 83. If it be desired to use an additional screen, as a sizing screen, it can be arranged as indicated at 84 in dotted lines, to receive the coal from discharge 83 and be given a shaker drive from the drive 81. In the event that it should be desired to utilize the dewatering screen as a sizing screen also, a screen to receive such fine material as is passed by the screen 32 may, of course, be placed beneath the screen 32 so that, as is the general case, only water (with such slimes as it may carry) is passed to the tank 54. As previously indicated, such slimes are ultimately removed through the cleanout 56 and the water carrying them treated as called for in the circumstances. If desired, suitable means may be provided, as in a hopper collecting water beneath the screen, for settling out the fine material and removing it from the circuit.

The various driven units may be driven in any suitable manner. As here illustrated (Figures 1, 2 and 5) the drives are by electric motors. In addition to the motor 82 for driving the screen 32 as described above, are the motors 85, 86 and 87. The motor 85 drives the sprocket 88 through a reduction gear 89 of any suitable type (detailed showing of which is omitted for brevity), and the sprocket 88 drives sprocket 41 (Figure 5) previously referred to, by chain 90, thus driving the basket and zoner as previously described. (Comparable and suitable arrangements for driving the gear sets 42<sup>a</sup> and 43<sup>a</sup> (Figure 22) may also be made, as will be understood.) The motor 86 drives the pump 58 through the coupling 91. The motor 87 drives the conveyor 18 through the drive 92.

#### MODIFICATIONS

As illustrative of the many modifications of which the present apparatus is susceptible, certain of these, additional to that relating to the water feed and already discussed above with reference to Figure 22, will now be discussed, particular reference being made, in turn, to Figures 23 and 24, Figure 26, and Figure 27.

Figures 23 and 24. It is sometimes desirable, in order that the velocity of the hydraulic column shall be somewhat reduced as it rises, to give the column structure a conical form increasing in width (radially of the rotor elements 7 and 8) from bottom to top. The illustrated structure provides for this, the inner rims 74<sup>a</sup> and 75<sup>a</sup> slanting, from the bottom upward, toward the

axis of rotation and the outer rims 76<sup>a</sup>, 77<sup>a</sup> slanting outward.

When this construction is used it is preferable to also resort to means for individually equalizing the flow from each top space, as 6<sup>a</sup>—6<sup>b</sup>. In the present instance, the top 5 is divided at each of the spaces between the troughs 6<sup>a</sup> to 6<sup>b</sup> by arcuate partitions 93 and 94 so radially spaced from the inner rim 23 and the inner rim of the trough 24, and from each other, that the resulting spaces 95, 96 and 97 are all of the same overall area. Furthermore, the partitions 93 and 94, and each of the corresponding lengths, as 98, 99, and 100 of the trough, are made individually adjustable in height, as by the arrangement 63—64 previously described, and illustrated in Figure 12. With this arrangement the discharge flows can be conveniently adjusted. Particularly, the device 63—64 for the middle division as 96 may be lower than the corresponding devices for the other divisions, thus properly accommodating the flow therefrom to the fact that the portion of the column which rises through said middle space is least affected by the slanting of the rims 74<sup>a</sup>, 75<sup>a</sup>, 76<sup>a</sup> and 77<sup>a</sup>. This lower position of the length 99 is indicated by the showing at 99 in Figure 24.

Figure 26. The structure here shown provides for the removal at the bottom of the basket 7 of not only the heavies, but also such material as still remains in the zoner 8 at the close of the treatment and which, in the previously described forms, is carried out at the top 5 of the tank 2 by the current from the water inlet 3<sup>a</sup>. To this end, a partition 101 (conveniently mounted fast with the side 14 of the tank 1) is placed between the top of the basket and bottom of the zoner. It extends the effective radial width of these parts, that is, from the inner rims as 74—75 to the outer rims as 76—77 (or rather to the side 14), is desirably of a truncated sectoral shape comparable to the shape of the spaces between the partitions 9 and 10, and is at a circumferential location and of a circumferential length to effectively prevent the discharge of the material in the zoner through the outlet 16<sup>a</sup> for the material in the basket. The exact position and length of the partition 101 so that it will effectively fulfill its purpose will of course depend on particular circumstances such as water flow, speed of rotor travel, amount of material, and so forth; but, generally speaking, I have found that it may have its rear (left-hand in Figure 26) edge somewhat behind the rear portion of the rim of the outlet 16<sup>a</sup>. I have further found that its front edge may, in consideration of the natural "throw" or cascading of the material, be somewhat in rear of the front portion of the rim of the outlet 16<sup>a</sup>, and all material from the zoner will yet be carried to the discharge outlet 16.

With this arrangement, the discharge outlet 16 and conveyor 18 now take care of the discharge from the zoner, instead of that from the basket as previously described. To take care of the discharge from the basket, an additional conveyor 18<sup>a</sup> is provided, and, if desired and as shown, may take the place of the final water inlet as 3<sup>a</sup>. It may be noted that while the illustrated arrangement exemplifies the possibility of reducing the number of water inlets as 3<sup>a</sup> etc. to four, the number of these may be held to five, or increased to any desired number by, in designing the apparatus, shifting the discharge outlets 16 and 16<sup>a</sup> (and the partition 101) sufficiently forward (to the right in the figure) to provide for the introduction of the desired number of water inlets to

the left of the discharge 16<sup>a</sup>. Conversely, a further reduction in the number of water inlets may call for a shifting of the parts 101, 16 and 16<sup>a</sup> to the left.

Conveniently, the apparatus is so arranged that the bottom sector plates 11 over both discharges 16<sup>a</sup> and 16 are all open at the same time, thus providing for continuous simultaneous discharge from the basket and zoner. This is, of course, readily provided for by proper location and length of the interruption 49 of the cam track 22. If desired an additional water supply may (as in any of the various structures) be provided, as by the valved pipe 102. This not only functions as an additional source for the replacement of any water that might be removed by a conveyor, but also is an aid in forcing any floating or delayed particles of material downward into the discharge 16.

It will be noted that, in certain cases wherein there is sufficient cascading of the zoner material, and wherein the number of open sectors and/or the width of the outlet 16<sup>a</sup> is such that the discharges from the zoner and basket will remain sufficiently distinct, the partition 101 may be omitted and the two outlets 16 and 16<sup>a</sup> still used to advantage.

Figure 27. Should it be desired to agitate the contents of the tank or to merely introduce air thereinto without material agitation, the arrangement shown in this figure provides for both. Agitation may be particularly desirable in the event that fine particles are introduced to, in effect, increase the specific gravity of the liquid, and the creation of air bubbles is called for when the method includes froth flotation; as referred to in greater detail hereinafter. As here shown, the water inlet as 3<sup>a</sup> has its neck provided with a circular series of small air ports 103 therethrough and communicating with the manifold 104. This latter is supplied with air from the blower 105, through the valved pipe 106, in any suitable quantity and pressure for the effect desired. Obviously this arrangement may be repeated at as many of the water inlets as required to meet circumstances and requirements in any particular case.

As mentioned above, flotation, e. g. froth flotation, may be incorporated in the present method, its use in combination with the general method, practiced preferably with the use of the present apparatus, presenting peculiar advantages, particularly when the lights are quite fine. The desired agents may be added to the hydraulic liquid in any suitable manner as from the container 107 (Figure 2) supplying the tank 54. The specific agents and their amounts will of course depend on circumstances, but with material of the type above mentioned by way of specific example, a small proportion, e. g. ¼ to ½ pound of e. g. cresol as a frothing agent with or without 1 to 4 pounds of e. g. kerosene oil as a froth stabilizing agent, may be used per ton of crude coal to be treated. Air from the blower 105 is of course supplied to give the required agitation and frothing. The froth may be treated in any of the suitable ways of the art to recover the coal therefrom. As will be evident, it may be of advantage in some circumstances to operate substantially entirely by froth flotation, the water supplies 3<sup>a</sup> etc. being reduced to the extent called for, for operation in this way.

However, the combination of hydraulic and flotation effects by the use of flotation in connection with the present method (and apparatus) is highly important as will be evident, as

it permits the concentrating of large material not possible by straight flotation, and also permits a great reduction in the amount of reagents required; and furthermore the capacity when separating by this combination method may be as much as 50 to 100 times that of a regular flotation cell. As further illustrating the advantages of the present combined treatment:

- If for example, the upward current required to raise coal, working without flotation, is, say, 15 feet per minute, it is evident that particles of refuse which have a falling velocity less than 15 feet per minute will not sink in such current. Now, if the particles of coal are made more buoyant by the use of reagents and the addition of air (even though the amount of reagents is not, of itself, sufficient to float the coal) there is readily created a condition wherein the upward current can be reduced say to  $7\frac{1}{2}$  to 10 feet per minute, and yet will still lift the desired coal over the top, and by reducing the current to these lower velocities there is avoided the lifting out over the top of higher gravity refuse pieces that would otherwise be lifted out. When flotation conditions are used some of the currents may or may not, as desired, be such as to be sufficient to lift the coal if flotation conditions were not used. (In the case of anthracite coal, it is not absolutely necessary to have a visible froth. What happens in this case is that the rising air bubbles naturally cling to the material coated with oil and the effect is that the air is assisting in the lifting of these particles.)

- When, as also mentioned above, it is desired to increase the apparent specific gravity of the liquid by the suspension therein, of fine particles, e. g. sand, the same may be introduced to the liquid, and such amount as is carried over the top with the coal recovered, in any of the suitable ways of the art, the present apparatus and method presenting particular advantages in connection with the "suspended solids" method. Agitation to aid in maintaining the suspension may be by air introduced as above described. Also, and in this same connection, the fine solids used for the suspension may be provided by the return to the apparatus of some of the fine coal or slate that has been isolated by the apparatus previously.

- While the invention has been described with more particular reference to a separation in which coal is washed to separate it from slate, it is plain that coal may be similarly separated from other materials, as pyrites, quartz, feldspar, heavy clays and so forth. It is likewise evident that the invention is not confined to a separation involving the washing and classification of coal. Plainly it is applicable to the separation of any of the many materials amenable to hydraulic separation, as mineral values from gangue, washing of sand, concentrating of non-metallic materials such as phosphate ore, limestone and feldspar, and so forth. Also while the invention has been specifically exemplified in connection with the separation of coal of small size, it is also applicable to the larger sizes.

- In the separation of materials wherein the values are the heavies and hence are collected in the basket, the classification of the lights and intermediates constituting the gangue may be of minor significance and, in such case, mere adjustment of the liquid supply to ensure full raising and removal of the gangue without raising of the values may meet all requirements. Furthermore, and more particularly in the treatment of

this type of materials, it may be advisable to increase the velocity through the zoner and top, over that through the basket; and to this end the zoner may be given a conical form, with the larger diameter of cone at the bottom thereof, i. e. the reverse of that shown for the zoner in Figures 23 and 24.

Further as to the use of quiescent liquid in a separating column and to the use of currents of increasing velocities in successive columns:— While the invention has been described with more particular reference to the use of quiescent liquid in the first separating column only, and to the use of increasing velocities in immediately successive columns, it will be understood that, should it be found desirable in any case, more than one separating column with quiescent liquid could be used and/or two or more columns of like velocity. For example, the latter might be of advantage when, as heretofore mentioned, treating materials wherein the values are the heavies and are collected in the basket and mere full raising of the gangue without classification of the raised material meets all requirements. That is, in such a case, for example, two of the columns, as two immediately successive columns, might each be of a given high velocity instead of but one of them being of high velocity and the other (and prior) of lower velocity; and the two columns of high velocity would permit of running a separator of a given capacity at a higher speed than otherwise desirable, since the arrangement would provide for the earlier imposing of a current that would more quickly remove the gangue from the basket.

As many apparently widely different embodiments of this invention may be made without departing from the spirit and scope thereof, it is to be understood that I do not limit myself to the specific embodiments thereof except as defined by the appended claims.

I claim:

1. In a separator device, in combination, a tank for hydraulic liquid, an upper and a lower travelling transporting element arranged the one above the other in said tank for transporting material to be separated in said tank and each consisting of a compartment having upstanding side walls and moving in a horizontal path through said tank, said upper element being open from top to bottom and provided with an upstanding crosswise wall, and said lower element being open at its top and having a perforated bottom wall, and also having means to discharge material from the bottom of the compartment of said lower element, said tank being provided with an upper means for the discharge of material therefrom, and being provided below said lower element with lower means for the discharge of material, means for supplying to said elements, the material to be separated, said material-supplying means and said lower means being spaced from each other in the direction of travel of said elements, means for supplying to said tank, hydraulic liquid for the production of an upward hydraulic current and located below said upper discharge means and lower transporting element and in alignment with said upper discharge means thereby to direct said current through said elements and to and through said upper discharge means, thereby to lift portions of said material through said upper discharge means, means for driving said elements at different speeds, and means for the operation of said discharge means of the said lower element when said means is in

discharge relation to said lower materials-discharge means.

2. In a separator, in combination, a tank for hydraulic liquid, a receptacle for transporting materials to be separated mounted in said tank for horizontal travel therein and having a top open to provide for the discharge therethrough of hydraulically lifted material and also having a perforated bottom, such bottom including a dumpable section hinged to said receptacle thereby to provide for the swinging of said section in respect to said receptacle, means for supplying to said receptacle, the materials to be separated, means for supplying to said tank, hydraulic liquid to immerse said receptacle therein, such means including provisions for supplying such hydraulic liquid to said tank to flow upward therein through said receptacle, means for collecting said liquid and the raised material from the top of the tank, means for the discharge of separated material from the bottom of said tank and spaced from said materials-supply means in the direction of travel of said receptacle, and means in the character of a cam for controlling the position of said dumpable section and providing for holding the same closed during loading and for swinging of the section at said hinge to dump the section when the same is in dumping relation to said materials-discharge thus to provide for the passage of separated material from said receptacle into the bottom discharge of said tank.

3. In an apparatus for the separation of materials by the application thereto of hydraulic currents, in combination; an open-topped tank for holding a hydraulic liquid; a series of spaced division walls positioned within said open-topped tank and arranged transversely of the top of the tank, said division walls dividing said tank into a plurality of hydraulic columns; a series of spaced hydraulic inlets positioned adjacent the bottom of said tank, the units of said series being spaced in correspondence with and in vertical registry with bays between units of said spaced division walls; means for transporting materials to be separated in said apparatus, said transporting means being arranged in said tank to travel over said liquid inlets and through and transverse the currents issuing therefrom to carry the material being transported thereby through said currents; means to supply hydraulic liquid to said inlets, said hydraulic liquid being adapted to flow in upward currents through said materials transporting means and through the material being transported thereby, material being thereby raised directly from said transporting means to and through said bays; and means for separately collecting the discharges through said bays; said means for supplying hydraulic liquid to said inlet being adapted to permit the different hydraulic currents being given velocities different from each other, thus to provide hydraulic currents of different lifting effects in said bays.

4. In a separator, in combination, a tank for hydraulic liquid, a rotary basket element and a rotary zoner element received in said tank for independent rotation therein, means to drive said elements at different speeds, said zoner element being mounted immediately above said basket element and in axial alignment therewith, each said element being in the character of an annulus with inner and outer upstanding walls and each said element including means to compel the forward movement of the contained material to be separated and being thus constructed to cir-

cumferentially and forwardly move the material to be separated in said tank, with the space between its inner and outer walls mated with the corresponding space of the other, means to supply to said tank, hydraulic liquid for the immersion of said elements, means to charge to said elements, the materials to be separated, and means for the discharge of separated materials therefrom.

5. In a separator, in combination, a tank for hydraulic liquid, a rotary basket element and a rotary zoner element received in said tank for independent rotation therein, means to drive said elements at different speeds, said zoner element being mounted immediately above said basket element and in axial alignment therewith, each said element being in the character of an annulus with inner and outer upstanding walls and each said element including means to compel the forward movement of the contained material to be separated and being thus constructed to circumferentially and forwardly move the material to be separated in said tank, with the space between its inner and outer walls mated with the corresponding space of the other thus to give a combined annulus, means to supply to said tank, hydraulic liquid for the immersion of said elements, means to charge to said elements, the materials to be separated, and means for the discharge of separated materials therefrom and including means arranged above said combined annulus to receive the flow therefrom and having provisions for the equalization of such flow.

6. In a separator, in combination, a tank for hydraulic liquid, a rotary basket element and a rotary zoner element received in said tank for independent rotation therein, means to drive said elements at different speeds, said zoner element being mounted immediately above said basket element and in axial alignment therewith, each said element being in the character of an annulus with inner and outer upstanding walls and each said element including means to compel the forward movement of the contained material to be separated and being thus constructed to circumferentially and forwardly move the material to be separated in said tank, with each wall equally radially distant from the axis of the element throughout the height of said wall, with the space between its inner and outer walls mated with the corresponding space of the other, thus to give a combined annulus of constant radial width throughout the height thereof, means to supply to said tank, hydraulic liquid for the immersion of said elements, means to charge to said elements, the materials to be separated, and means for the discharge of separated materials therefrom.

7. In a separator, in combination, a tank for hydraulic liquid, a rotary basket element and a rotary zoner element received in said tank for independent rotation therein, means to drive said elements at different speeds, said zoner element being mounted immediately above said basket element and in axial alignment therewith, each said element being in the character of an annulus with inner and outer upstanding walls and each said element including means to compel the forward movement of the contained material to be separated and being thus constructed to circumferentially and forwardly move the material to be separated in said tank, with its inner wall inclined from bottom to top toward the axis of the element and its outer wall inclined from bottom to top from the axis of the element, with the

space between its inner and outer walls mated with the corresponding space of the other to give a combined annulus increasing in radial width throughout the height thereof, means to supply to said tank, hydraulic liquid for the immersion of said elements, means to charge to said elements, the materials to be separated, and means for the discharge of separated materials therefrom.

8. In a separator, in combination, a tank for hydraulic liquid, a rotary basket element and a rotary zoner element received in said tank for independent rotation therein, means to drive said elements at different speeds, said zoner element being mounted immediately above said basket element and in axial alignment therewith, each said element being in the character of an annulus with inner and outer upstanding walls and constructed to circumferentially and forwardly move the material to be separated in said tank and provided with radial dividing partitions, with its inner wall inclined from bottom to top toward the axis of the element and its outer wall inclined from bottom to top from the axis of the element, with the space between its inner and outer walls mated with the corresponding space of the other to give a combined annulus increasing in radial width throughout the height thereof, means to supply to said tank, hydraulic liquid for the immersion of said elements and including provisions for the upward flow of such liquid through said combined annulus, means to charge to said elements, the materials to be separated, and means for the discharge of separated materials therefrom and including means arranged above said combined annulus to receive the flow therefrom and having provisions for the equalization of such flow and comprising radial partitions bridged by sectional partitions to receive the flow in the truncated segmental bays therebetween.

9. A separator as recited in claim 8 wherein certain of said partitions are provided with means for the adjustment of the height thereof.

10. In a separator device, in combination, a tank for hydraulic liquid and presenting a series of circumferentially spaced open divisions adjacent and transverse the top thereof, with the walls of said divisions depending a substantial distance downward in said tank, a basket element and a zoner element, both elements being in the character of an annulus with inner and outer upstanding walls and each said element including means to compel the forward movement of the contained material to be separated and being thus constructed to circumferentially and forwardly move the material to be separated in said tank and being received in said tank for independent rotation with respect to each other therein, said zoner element being mounted above said basket element and between it and the ends of said depending walls, means for supplying to both said elements, the material to be separated at one portion of said tank and directly into said liquid, such means being immediately related to one of said open divisions, means for supplying to the tank, the hydraulic liquid, such means including means for supplying such liquid to said tank to flow upward therein to effect hydraulic conditions of different character than those in the first-named portion, and sufficiently vigorous to carry portions of the material upward into certain of said open divisions, said means for supplying such liquid presenting a series of circumferentially spaced outlets at a series of circumferentially spaced portions of said tank and cir-

cumferentially spaced from said first-named portion and successively immediately related to successive units of said open divisions, and means to independently rotate said basket element and said zoner element, in the direction from said first-named portion to and along said series of portions, at different speeds, thereby to move the elements from said first-named portion to and along said series of portions at different rates, thus to move, with a speed differential therebetween, given portions of said elements, and the material immediately associated with such given portions from vertical alignment with said one open division to successive vertical alignment with units of said open divisions and said series of portions, to permit discharge of portions of such material upward into successive open divisions.

11. The method of separating from each other bodies that are amenable to hydraulic separation which method comprises: introducing a mass of such bodies into the upper portion of a body of liquid of less specific gravity than said bodies, and permitting said bodies to arrange themselves under the influence of the hydraulic conditions obtaining thus to form zones containing bodies of varying settling characteristics in said liquid and, while at least one of said zones still contains bodies hydraulically separable from each other, independently of the hydraulic conditions imposed bodily in bulk shifting and conveying positively and thus at a speed and time selectable independently of the physical characteristics of the bodies, another zone to a position so far distinct from that of the one zone that such one zone may be hydraulically treated substantially uninfluenced by the presence in the process of such other zone, and continuing the hydraulic separation of the bodies in the one zone.

12. The method of separating from each other bodies that are amenable to hydraulic separation which method comprises: introducing a mass of such bodies into an upward hydraulic current sufficient to lift over the top thereof but part of said bodies, and permitting said bodies to arrange themselves under the influence of the hydraulic conditions obtaining thus to form zones containing bodies of varying settling characteristics in said liquid and, while at least one of said zones still contains bodies hydraulically separable from each other, independently of the current bodily in bulk shifting and conveying positively and thus at a speed and time selectable independently of the physical characteristics of the bodies, another zone to a position so far distinct from that of the one zone that such one zone may be hydraulically treated substantially uninfluenced by the presence in the process of such other zone, and continuing the treatment of the bodies in said one zone by said upward hydraulic current.

13. The method of separating from each other bodies that are amenable to hydraulic separation which method comprises: introducing a mass of such bodies into the upper portion of a body of liquid of less specific gravity than said bodies, and permitting said bodies to arrange themselves under the influence of the hydraulic conditions obtaining thus to form zones containing bodies of varying settling characteristics in said liquid and, while at least one of said zones still contains bodies hydraulically separable from each other, independently of the hydraulic conditions imposed bodily in bulk shifting and conveying positively and thus at a speed and time selectable

independently of the physical characteristics of the bodies, such zone to a position so far distinct from that of another zone that such shifted zone may be hydraulically treated substantially uninfluenced by the presence in the process of such other zone, and there subjecting the bodies in the shifted zone to conditions of hydraulic separation more vigorous than those imposed thereon prior to the said shifting and sufficient to lift bodies from said zone.

14. The method of separating from each other bodies that are amenable to hydraulic separation which method comprises: introducing a mass of such bodies into an upward hydraulic current sufficient to lift over the top thereof but part of said bodies, and permitting said bodies to arrange themselves under the influence of the hydraulic conditions obtaining thus to form zones containing bodies of varying settling characteristics in said liquid and, while at least one of said zones still contains bodies hydraulically separable from each other, independently of the current bodily in bulk shifting and conveying positively and thus at a speed and time selectable independently of the physical characteristics of the bodies, such zone through a series of positions so far distinct from that of the remaining contents of the current that such shifted zone may be hydraulically treated substantially uninfluenced by the presence in the process of said remaining contents, and at the successive units of said series of positions subjecting the bodies in the shifted zone to upward hydraulic currents successively more vigorous than that applied prior to said shifting and sufficient to lift further bodies from such zone.

15. The method of separating from each other bodies that are amenable to hydraulic separation which method comprises introducing a mass of such bodies into the upper portion of a hydraulic column containing liquid of less specific gravity than that of said bodies; permitting said bodies to arrange themselves under the influence of the hydraulic conditions obtaining in said column so that zones containing bodies of varying settling characteristics in said liquid are formed in said column; while at least two of said zones contain bodies which are still capable of hydraulic separation from each other, moving said zones and their contained bodies in bulk by positive conveyance, independently of the hydraulic conditions imposed, at different speeds through a series of hydraulic columns so distinct from each other and with the speed difference between the said two zones such that each of said zones and their contained bodies may be hydraulically treated in each of said hydraulic columns of said series substantially uninfluenced by the presence in the process of the other zone or of said other hydraulic columns; and in the successive units of said series of hydraulic columns, subjecting the bodies in said displaced zones to conditions of hydraulic separation successively more vigorous than those imposed thereon prior to said movement, said conditions being sufficient to lift bodies from said shifted zones.

16. The method of separating from each other bodies that are amenable to hydraulic separation which method comprises introducing a mass of such bodies into the upper portion of a hydraulic column containing liquid of less specific gravity than that of said bodies wherein they are subjected to an upward hydraulic current sufficient in intensity to lift over the top of said column but part of said bodies; permitting said

bodies to arrange themselves under the influence of the hydraulic conditions obtaining in said column so that zones containing bodies of varying settling characteristics in said liquid are formed in said column; while at least two of said zones contain bodies which are still capable of hydraulic separation from each other, moving said zones and their contained bodies in bulk by positive conveyance, independently of the hydraulic conditions imposed, at different speeds through a series of hydraulic columns, said hydraulic columns being so distinct from each other and the speed difference between said moving zones being such that each of said displaced zones may be hydraulically treated in said hydraulic columns substantially uninfluenced by the presence in the process of other displaced zones or of other contents of said hydraulic current; and, in the successive units of said series of hydraulic columns, subjecting the bodies in said displaced zones to upward hydraulic currents successively more vigorous than that applied prior to said movement of said zones, said currents being sufficient in intensity to lift further bodies from said displaced zones.

17. The method of separating from each other bodies that are amenable to hydraulic separation which method comprises: introducing a mass of such bodies into the upper portion of a body of liquid of less specific gravity than said bodies, and permitting said bodies to arrange themselves under the influence of the hydraulic conditions obtaining, thus to form zones containing bodies of varying settling characteristics in said liquid and, while at least one of said zones still contains bodies hydraulically separable from each other, independently of the hydraulic conditions imposed bodily in bulk shifting and conveying positively and thus at a speed and time selectable independently of the physical characteristics of the bodies, another zone to a position so far distinct from that of the one zone that such one zone may be hydraulically treated substantially uninfluenced by the presence in the process of such other zone, and continuing the hydraulic separation of the bodies in the one zone; and meanwhile incorporating flotation procedures by creation of gas bubbles and addition to the hydraulic liquid of material to promote the selective affinity of the bodies under treatment for gas bubbles and the liquid and the resultant adhesion of particles of certain species to gas bubbles and the adhesion of other species to the liquid.

18. The method as recited in claim 16 wherein flotation procedures are incorporated by creation of gas bubbles and addition to the hydraulic liquid of material to promote the selective affinity of the bodies under treatment for gas bubbles and the liquid and the resultant adhesion of particles of certain species to gas bubbles and the adhesion of other species to the liquid.

19. The method of separating from each other bodies that are amenable to hydraulic separation which method comprises: introducing a mass of such bodies into the upper portion of a body of liquid of less specific gravity than said bodies, and permitting said bodies to arrange themselves under the influence of the hydraulic conditions obtaining, thus to form zones containing bodies of varying settling characteristics in said liquid and, while at least one of said zones still contains bodies hydraulically separable from each other, independently of the hydraulic conditions imposed bodily in bulk shifting and conveying positively and thus at a speed and time selectable

independently of the physical characteristics of the bodies, another zone to a position so far distinct from that of the one zone that such one zone may be hydraulically treated substantially unin-  
5 fluenced by the presence in the process of such other zone, and continuing the hydraulic separation of the bodies in the one zone; and using appreciably coarse granular material in the hydraulic liquid to encrease the apparent specific  
10 gravity thereof.

20. The method of hydraulically separating the constituent bodies of crude coal which method comprises: introducing such coal into the upper portion of a body of liquid of less specific gravity  
15 than such coal and permitting the constituent bodies of such coal to arrange themselves under the influence of the hydraulic conditions obtaining, thus to form zones containing bodies of

varying settling characteristics in said liquid and, while at least one of said zones still contains bodies hydraulically separable from each other, independently of the hydraulic conditions imposed bodily in bulk shifting and conveying positively and thus at a speed and time selectable independently of the physical characteristics of the bodies, such zone to a position so far distinct from that of another zone that such shifted zone may be hydraulically treated substantially unin-  
10 fluenced by the presence in the process of such other zone, and there subjecting the bodies in the shifted zone to conditions of hydraulic separation more vigorous than those imposed thereon prior to the said shifting and sufficient to lift  
15 bodies from said zone.

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