

Feb. 19, 1952

F. P. SMITH

2,586,574

HIGH-FREQUENCY JIG

Filed May 10, 1946

2 SHEETS—SHEET 1

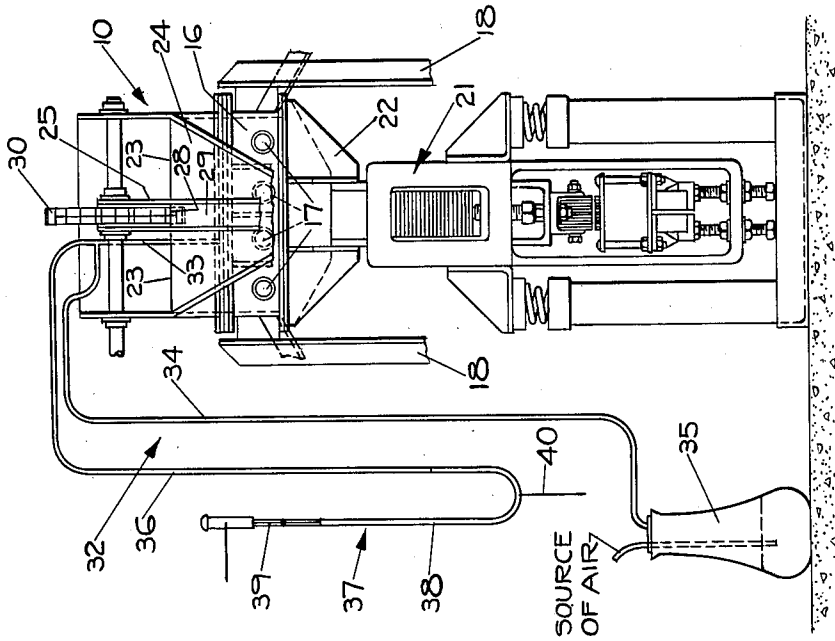


Fig. 1

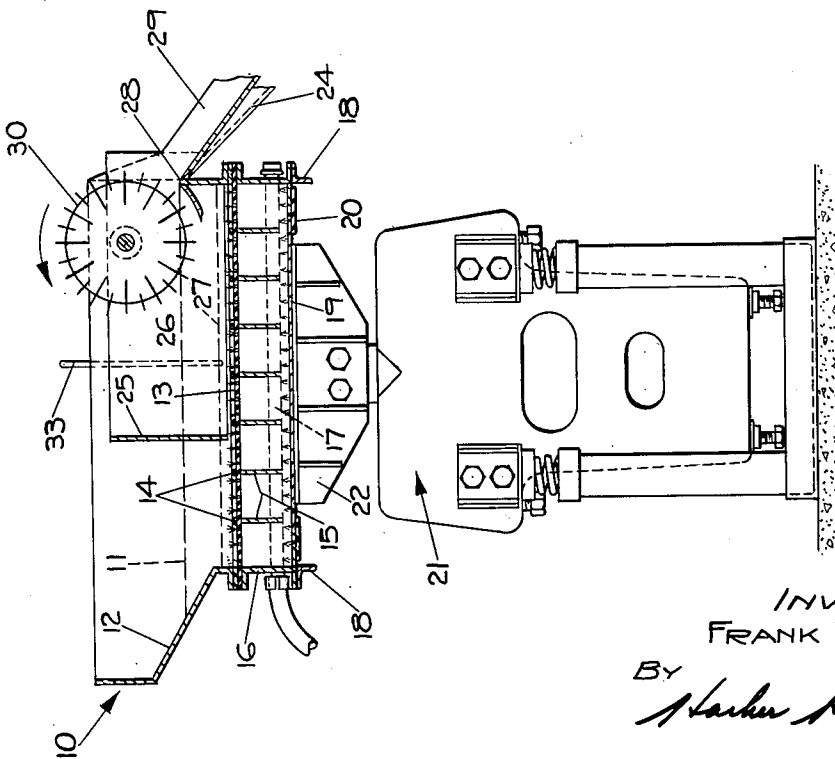


Fig. 2

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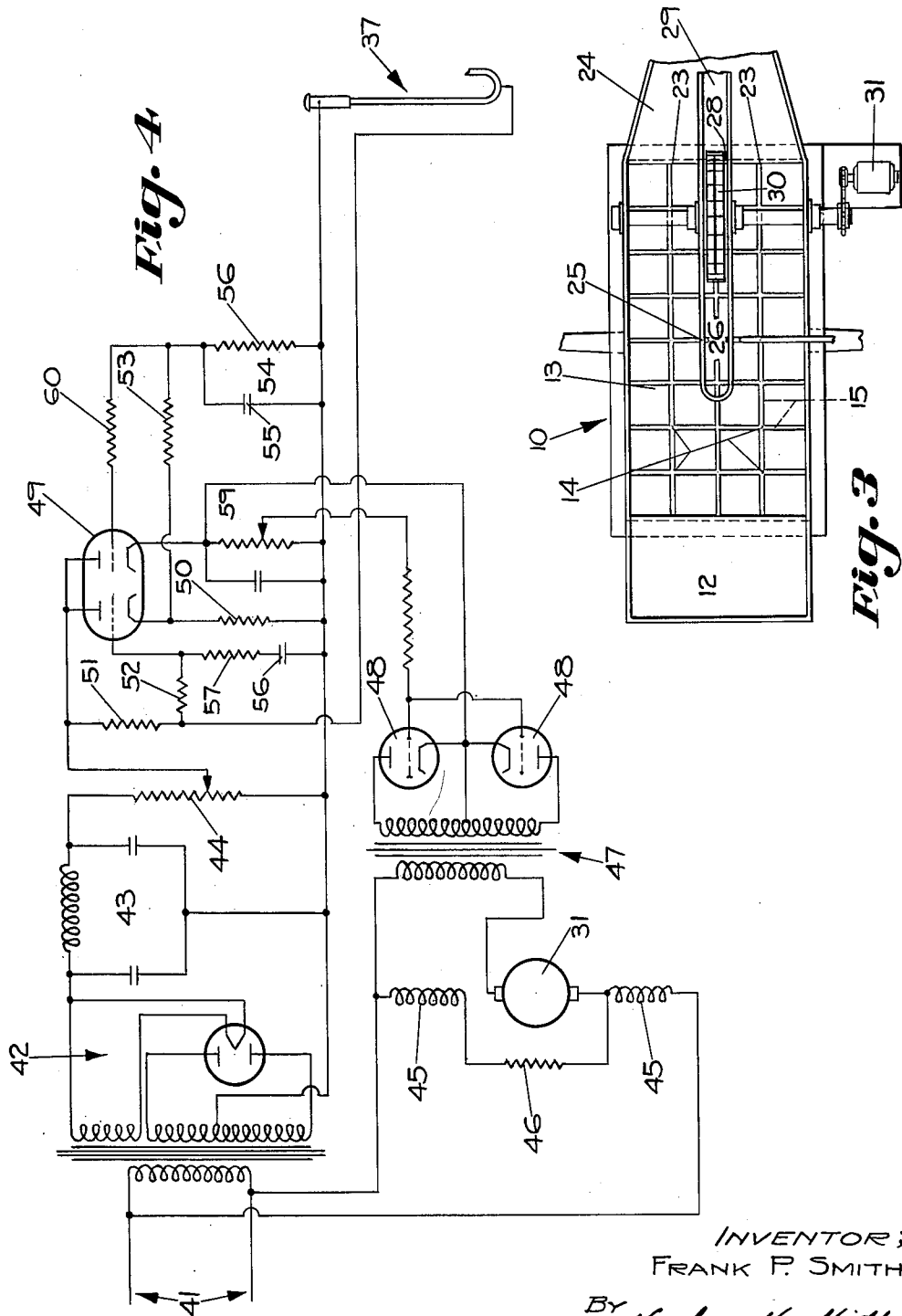
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2,586,574

Filed May 10, 1946

2 SHEETS—SHEET 2



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UNITED STATES PATENT OFFICE

2,586,574

HIGH-FREQUENCY JIG

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mesne assignments, to The Jeffrey Manufac-
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Application May 10, 1946, Serial No. 668,845

10 Claims. (Cl. 209-496)

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This invention relates to a high frequency jig or vibratory classifier.

An object of the invention is to provide an improved device of the above mentioned type which will treat granular mineral material, particularly of small sizes, to effect a separation according to specific gravity.

A further object of the invention is to provide an improved device of the above mentioned type with a dam and seal type of draw in which mechanical means or mechanism, operable independently of the vibration of the material, is provided to effect a controlled removal of the concentrates or heavy gravity material.

A further object of the invention is to provide a jig or classifier with automatic means to remove concentrates so as to maintain a predetermined depth of concentrate stratum or bed, particularly involving a dam and seal type of draw, and which, in the preferred embodiment of my invention, also includes a skimming device such as a paddle wheel for removing concentrates from a concentrates cell.

A further object of the invention is to provide an improved jig in which fine sizes of granular mineral materials are separated according to specific gravity by vibration which is applied to the diaphragm preferably on the bottom of the container which supports said bed of materials in a pulp and in which high frequency vibration is applied preferably at low amplitude.

Other objects of the invention will appear hereinafter, the novel features and combinations being set forth in the appended claims.

In the accompanying drawings:

Fig. 1 is a front elevational view of apparatus incorporating the features of my invention;

Fig. 2 is a side view of said apparatus, with parts shown in section;

Fig. 3 is a plan view of the apparatus, with parts omitted; and

Fig. 4 is a wiring diagram of one form of electrical circuit which may be employed to control the skimmer mechanism.

The jig or classifier of my invention includes a stationary deck, container or tank 10 which provides a compartment or receptacle for receiving granular mineral which is to be separated into two groups of particles according to specific gravity. The apparatus is designed particularly for treating a relatively wide range of small size particles. The apparatus, for example, is designed to treat a size range from 65 to 325 mesh. As a specific illustration of one type of mineral which has been treated, I have success-

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fully treated iron ore of size range from 80 mesh to 270 mesh with a high order of efficiency, having produced a very pure concentrate of iron ore and gangue or silicon refuse containing very little ore. A shot bed may also be used.

It is, of course, evident that the jig may treat other materials than iron ore, as it may be used for various ores and furthermore may in some instances be employed to separate coal from its refuse, in which case the high gravity material will be the refuse, which is the reverse of the condition when ore is treated. In the subsequent description I shall refer more specifically to iron ore as the illustrated material which is being treated.

The fine iron ore to be separated from its gangue, particularly silicon, is fed to the deck 10 with an appreciable quantity of water so as to provide an ore pulp which will have a normal level in the container or compartment 10, as indicated at 11 in Fig. 2 of the drawings. The pulp will flow freely down an inclined feed chute 12 into the main part of the compartment 10. The container 10 is provided with a false bottom 13 in the form of a screen which is held down by appropriate hold-down means 14 in co-operation with a supporting egg-crate partition which helps distribute the water through the perforation in the false bottom screen 13. In one successful form of the invention the screen or false bottom 13 was a multipore rubber screen. It is preferably a very fine mesh screen and in treating the size range of 80-270 mesh I have successfully used screens 13 with a mesh varying from 65 to 115.

The egg-crate partitions 15 are contained in a hutch compartment 16 which is formed as a part of the container 10 and below the screen 13. Hutch compartment 16 is provided with a plurality of longitudinally extending water feed pipes 17 by which a relatively small amount of water is introduced into the various cells of the egg-crate partition 15, which water flows upwardly through the screen plate 13 into the pulp compartment 10. The hutch compartment 16 and through it the container 10 is supported on a stationary frame 18.

The central bottom portion of the hutch compartment 16 is in the form of a diaphragm 19 which is attached to the adjacent bottom portion by means of a rubber ring 20 which provides a fluid-tight bottom for said hutch compartment 16 but which allows reciprocation of the diaphragm 19 rectilinearly upwardly and downwardly. This rectilinear vibratory motion is de-

livered to the diaphragm 19 by a vibratory electro-magnetic motor 21, the armature head 22 of which is rigidly attached to said diaphragm 19. The motor 21 preferably follows the structure shown in the patent to James A. Flint, No. 2,094,698, dated October 5, 1937, for a Device for Packing Materials.

Adjacent the discharge side of the container 10, which is to the right, as viewed in Figs. 2 and 3, there is a weir 23 over which the gangue or refuse flows, being guided therefrom by gangue discharge chute 24. Preferably located along the longitudinal center of and within the container or compartment 10 and provided by a substantially U-shaped upstanding wall, plate or partition 25 is a concentrate or high gravity material cell or compartment 26. As is clearly illustrated, particularly in Figs. 2 and 3 of the drawings, the plate 25 extends both above and below the normal pulp level 11, and the bottom edge thereof is close to but slightly above the false bottom or screen 13.

As hereinafter described more completely, the bottom edge of the plate 25 also extends slightly below the level of the bed of concentrates or high gravity material which forms in the bottom of the compartment 10 under the classifying or jiggling action which takes place. The depth of a typical concentrates bed is illustrated at 27 in Fig. 2 of the drawings. A weir 28 having preferably the same height as the weir 23 is provided for the concentrates cell or compartment 26 and the concentrates which flow over the weir 28 are received by a trough 29.

It is evident from the above description that the cell 26 formed by the plate or partition 25 provides what is, in effect, a dam and seal concentrates draw. I have found, however, that the dam and seal type of concentrates draw may have its efficiency very vastly improved so as to prevent all land-sliding, which such draws tend to produce, by providing a skimmer means or other functional equivalent mechanism for removing concentrates from the concentrates cell or compartment 26. In the illustrated form of mechanism for thus removing concentrates and causing them to flow over the weir 28 I provide skimming mechanism in the form of a skimming paddle wheel 30 which is preferably continuously operating at a variable speed, as hereinafter described more completely, the wheel 30 being preferably rotated in a counter-clockwise direction, as viewed in Fig. 2 of the drawings, so as to skim the top of the concentrates from the cell 26 and to cause it to flow over the weir 28 into the trough 29. Within the scope of my invention, in some of its broader aspects, other means may be employed to remove concentrates from the cell 26 preferably by a positive and continuous action.

Mechanism for controlling the rate of withdrawal of concentrates from the cell 26 will now be described. A small electric motor 31 (see Fig. 3) is provided to drive the shaft of the paddle wheel 30 at a controllable rate which is varied so as to maintain the concentrates bed 27 at approximately a predetermined depth, or, stated another way, the concentrates are removed at a variable rate so that the density of the pulp at a predetermined level in the pulp bed will tend to remain approximately constant. To this end I provide a density probe 32 which in its general characteristics is of well known construction and includes one or more pipes 33 which extend downwardly into the bed 11 with the bottom of the pipe 33 at a predetermined position, preferably slightly above the bottom of the partition

or plate 25. A small amount of air is then continuously forced through the pipe 33 from a source of air, indicated in Fig. 1 of the drawings, which is delivered to pipe 33 by way of pipe 34 and flask bubble indicator 35.

Branching from the pipe 33 is a manometer pipe 36 leading to manometer 37 which contains a saline solution 38. At the top of the manometer 37 is a platinum contacting wire 39 and at the bottom thereof is another conductor 40. It is obvious that the manometer 37 will measure the density of the pulp at the bottom of the pipe 33 and whenever this density reaches a predetermined amount the saline solution 38 will contact the platinum conductor 39, connecting it with conductor 40. This is in effect, therefore, a manometer type switch. Whenever the density of the pulp at the bottom of the pipe 33 falls below a predetermined value the manometer switch will be opened. The opening and closing of said manometer switch 37 is employed to control the electrical circuit, as illustrated in Fig. 4, to adjust the speed of rotation of the motor 31 and thus the rate of removal of concentrates from the cell 26; the circuit being such that the motor 31 preferably runs continuously, with its speed of rotation being adjusted so as to maintain a relatively constant density at the selected position in the pulp bed 11 by controlling the rate of removal of said concentrates from cell 26.

The particular electrical circuit, shown in Fig. 4, which has been found to be best suited for controlling the motor 31, is the invention of Francis C. Todd and is disclosed in his application Serial No. 676,883, entitled Electrical Circuit, filed June 15, 1946, now Patent No. 2,461,131, granted February 8, 1949.

The electrical circuit of said Fig. 4 includes a main source of alternating current 41 which supplies a full-wave rectifier 42 and associated filter 43, the output of which is delivered to a high resistance potentiometer 44.

Conductors 41 also supply split fields 45 of a Merkle-Karff type series alternating current motor 31 which has a resistor 46 connected in series with said fields.

The rate of rotation of the motor 31 is controlled by placing a variable impedance in series with the armature thereof, this variable impedance being in the form of a secondary of a transformer 47. The current delivered to said secondary of the transformer is controlled by controlling the grid voltage on a pair of vacuum tubes 48 connected across the terminals of the primary of said transformer 47, as clearly illustrated in Fig. 4 of the drawings.

To produce this variable and gradually changing voltage on the grids of tubes 48 I provide a double tube 49, the left hand portion of which derives cathode-anode voltage from a variable tap on the potentiometer 44 over an obvious circuit which includes resistor 50 in series with the cathode. This resistor 50 may have a value, for example, of approximately 500,000 ohms.

When the monometer switch 37 is open, indicating the pulp density is below the normal desired value, the control grid of the left-hand half of tube 49 will be in effect connected to said plate by way of resistors 51 and 52. Under such conditions the current flow through resistor 50, which is the cathode-anode current of said left-hand portion of tube 49, will be a maximum.

The voltage thus developed across resistor 50 is supplied through an obvious circuit, including resistor 53, to a floating time control circuit 54

which includes a relatively large condenser 55 and a relatively high ohm resistor 56 in parallel.

As an illustration of workable values, resistor 53 may have 4,000,000 ohms and resistor 56 may have 5,000,000. Obviously when there is voltage across resistor 50 because of a cathode-anode current flow through the left-hand portion of tube 49, the condenser 55 will tend to charge and this charge will build up at a relatively slow rate so long as said voltage persists. On the other hand, as soon as this charging voltage disappears from resistor 50, the charge on condenser 55 will gradually decrease since it will discharge through the resistor 56 in parallel with the two resistors 50 and 53 in series. Because of this fact the discharge rate of the condenser 55 will be greater than its charging rate and this is desirable because, as hereinafter described, the speed of the motor 31 and thus the rate of withdrawal of concentrates is directly proportional to the charge on condenser 55 and it is desired to increase the speed of said motor 31 at a faster rate than it decreases.

When the manometer switch 37 closes its contacts in response to a production of a predetermined density of the pulp at the selective position, a negative charge is put on the grid of the left-hand portion of tube 49 since resistor 51 is thus connected directly across the portion of potentiometer 44 which is being used. This closing of manometer switch 37 will also effectively connect grid condenser 58 and grid resistor 58 in parallel with the megohm resistor 52.

It is thus seen that resistor 50 is a follow resistor in that the voltage drop across it is either a maximum or a minimum, depending upon whether manometer switch 37 is open or closed.

The right-hand side of tube 49 includes follower resistor 59 connected in its cathode circuit, and the current flow through this resistor 59 and thus the voltage drop across it is directly proportional to the charge which exists on the time control circuit 54, or, in other words, the charge on condenser 55. This charge on condenser 55 is applied to the grid of the right-hand portion of tube 49 through a grid resistor 60. Thus there is a smooth variation in the flow of current through the follower resistor 59 directly proportional to the fluctuations of the charge on condenser 55.

Resistor 59 is employed as a potentiometer and a variable portion of the voltage drop thereacross is applied to the grids of the control vacuum tubes 48 over an obvious circuit whereby the current flow in the transformer 47 is directly proportional to this voltage drop across said resistor 59 which in turn is directly proportional to the charge on condenser 55.

It is thus evident that by controlling the opened and closed condition of the manometer switch 37 there is a gradual change produced in the speed of the motor 31. Furthermore it is to be noted that the time circuit 54 will automatically continue increasing the speed of the motor 31 or decreasing it until a changed condition is produced by the skimming mechanism 33 to change the switch from open to closed condition or vice versa. Under such conditions there will be a continuous removal of the concentrates and the rate of removal will vary from time to time. In fact it will vary almost continuously, but the average or mean rate will be such as to maintain a substantially constant depth of concentrates, or, in other words, a substantially constant density of the pulp bed at a pre-selected position.

This continual hunting of the skimming type

concentrates removing mechanism has been found to be very efficient in operation because it prevents undesirable building up of density of concentrates with a sudden removal thereof or land sliding which has been a problem generally present in dam and seal draw types of concentrates or heavy gravity discharge mechanisms heretofore known.

In the operation of the device, to effect a gravity separation of material, such as very fine iron ore, the iron ore with a liberal supply of water is fed into the container 10 and forms a pulp bed, as indicated by the line 11 in Fig. 2 of the drawings. This bed is subjected to the combined action of upwardly flowing current of water or liquid through the screen 13 and electrical vibration, preferably rectilinear and upward, provided by the diaphragm 19, which is delivered by the motor 21. This vibration is preferably relatively small so as to give mobility to the bed but being insufficient to produce any packing action which is found to occur if the amplitude is too high.

As an illustration of one practical frequency of jigging employed, for materials of a size range of 80 mesh to 270 mesh of iron ore, I have operated successfully with the frequency of vibrations at 3600 vibrations per minute at an amplitude of $\frac{1}{64}$ of an inch. Experiments indicate that if the frequency is increased, for example, to 7200 vibrations per minute, the amplitude may be further decreased, for example, cut in half or made $\frac{1}{128}$ of an inch. Furthermore, tests indicate that if the size range of material is decreased the amplitude may also be decreased. Furthermore, the water supplied in the hutch 16 is preferably relatively small. In the example given it may be approximately two gallons per minute. If more water is employed in the hutch the amplitude may also be decreased.

If the frequency is appreciably decreased the amplitude may be proportionally increased, but I have found that the apparatus is particularly adapted for relatively high frequency vibration and by this I mean a frequency in excess of 1000 vibrations per minute. Actual tests have been conducted with vibrations as low as 1800 per minute at which an amplitude of $\frac{1}{32}$ of an inch was found satisfactory on fine material of the size range above specified.

The tests also indicate that for larger sizes, for example, a size range from 10 mesh to 65 mesh, as an illustration, the amplitude may be increased over that amplitude for smaller size materials. Furthermore the hutch water is preferably increased for larger sizes.

The bed of material undergoing jigging or classification tends to form concentrates in the bottom of the bed or, in other words, in the bottom stratum of the bed of material, which stratum of concentrates is supported by the screen 13 and the depth of these concentrates is preferably substantially as indicated at 27 in Fig. 2 of the drawings, or, in other words, above the bottom of the wall 25 forming the concentrates cell 26, or, in other words, which forms the dam and seal draw. As the concentrates are skimmed off or otherwise removed from the concentrates cell, for example, as they are skimmed off by the skimmer 30, the level of the pulp or liquid in the cell 26 will, of course, fall below that outside said cell and in the classifying compartment 10. This difference in hydraulic head will, of course, force the concentrates under the lower edge of partition 25 and into the concentrates cell 26. This concentrates pulp in the concentrates cell 26 will be

quite fluid and mobile and thus the skimmer 30 will continuously remove the concentrates and deliver it over the weir 23 to the concentrates chute 29.

I have found in practice that the efficiency of the dam and seal draw as here employed has been very greatly increased by the positive removal of the concentrates from the concentrates cell 26 because, in the absence of such positive removing mechanism, such as the wheel 30, there is a tendency for the dam and seal draw to operate erratically. That is, it tends to build up a predetermined head and then slough off or land slide, with a consequent discharge of an appreciable amount of gangue or low gravity refuse with the concentrates.

By the positive removal of said concentrates, particularly at a controllable rate so as to maintain a predetermined concentrates bed 27, this erratic operation has been eliminated completely, with very great improvement in the overall efficiency of the device for continuously separating two materials of different specific gravity, such as iron ore from its gangue.

Obviously those skilled in the art may make various changes in the details and arrangement of parts without departing from the spirit and scope of the invention as defined by the claims hereto appended, and I therefore wish not to be restricted to the precise construction herein disclosed.

Having thus described and shown an embodiment of my invention, what I desire to secure by Letters Patent of the United States is:

1. A vibratory classifier including a container adapted to receive fine mixed mineral materials and to separate the materials of different specific gravity, said container having a perforate false bottom constructed to support a bed of material undergoing separation and to support the concentrates developed, means for producing a flow of liquid upwardly through said false bottom, means applying high frequency rectilinear and vertically upward vibration to the liquid, said vibration having a frequency of at least 1000 vibrations per minute, all whereby a stratum of high gravity concentrates is formed on said false bottom, means providing a concentrates cell having a wall a lower edge of which is spaced above and near said false bottom whereby said edge is in the lower part of said bed of material and extends below the normal top of said stratum of concentrates and the high gravity material in said container is forced to flow under said wall by hydraulic pressure of material in said container, and skimming means for skimming the top off the concentrates in said concentrates cell, said skimming means being positioned entirely above said false bottom and operating to skim the top only of said concentrates in said concentrates cell.

2. A high frequency jig including a stationary container adapted to receive a bed of mixed fine particle minerals to be separated according to specific gravity, means for applying vibration to said bed at a frequency in excess of 1000 vibrations per minute while said container remains substantially stationary, a dam forming a concentrates cell and having a lower edge adjacent the bottom of said bed below which the high gravity particles in said container is forced to flow into said concentrates cell, and skimming means including a motor driven paddle wheel positioned entirely above the bottom of said bed

and operable for skimming concentrates only from the top of said cell.

3. A high frequency jig including a container adapted to receive a bed of mixed fine particle minerals to be separated according to specific gravity, means for applying vibration to said bed at a frequency in excess of 1000 vibrations per minute, a dam forming a concentrates cell and having a lower edge adjacent the bottom of said bed below which the high gravity particles in said container may flow into said concentrates cell, and skimming means located within said concentrates cell and operable to skim concentrates only from the top of said cell.

4. A high frequency jig including a container adapted to receive a bed of mixed fine particle minerals to be separated according to specific gravity, means for applying vibration to said bed, a dam forming a concentrates cell in said container and having a lower edge adjacent the bottom of said bed below which the high gravity particles in said container may flow into said concentrates cell, and skimming means located within said concentrates cell and operable to skim concentrates only from the top of said cell.

5. A classifier including a container providing a classifying compartment, a dam and seal draw providing a concentrates cell, and continuously operating mechanical skimming means located in the top of said concentrates cell and operable to skim only the top off material in said concentrates cell.

6. A classifier including a container providing a classifying compartment, a dam and seal draw providing a concentrates cell, and mechanical skimming means for skimming only the top off material in said concentrates cell.

7. A classifier including a classifying compartment, a dam and seal draw providing a high gravity cell, and continuously rotating paddle wheel skimming means operable to skim only the top off the material in the high gravity cell.

8. A classifier including a classifying compartment, a dam and seal draw providing a high gravity cell, and continuously rotating paddle wheel skimming means operable to skim only the top off the material in the high gravity cell, said means including mechanism operable at a variable rate determined by the density of pulp adjacent the bottom of said classifying compartment.

9. A classifier including a classifying compartment, a dam and seal draw providing a high gravity cell, and positively acting mechanical skimming means operable to skim off only the top of the material in the high gravity cell, said means including mechanism operable at a variable rate determined by the density of pulp adjacent the bottom of said classifying compartment.

10. A high frequency jig including a classifying compartment, a screen providing a material pulp bed supporting bottom, means for delivering liquid to flow upwardly through said screen including a hutch compartment below said screen, a diaphragm in said hutch compartment, means for vibrating said diaphragm relative to said classifying compartment, said means including a vibratory motor operable at a high frequency of at least 1000 vibrations per minute, a dam and seal draw providing a concentrates cell including a wall having its lower edge slightly above said screen, mechanical skimming means including a rotating paddle wheel for skimming only the top

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off the concentrates in said concentrates cell, and means responsive to the density of the pulp in the material bed for adjusting the rate of operation of said skimming means.

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