March 25, 1958 R. G. OSBORNE, JR., ET AL 2,828,016

DRY CONCENTRATING METHOD AND MACHINE THEREFOR

Filed Aug. 3, 1953 4 Sheets-Sheet 1

Fig. 1.

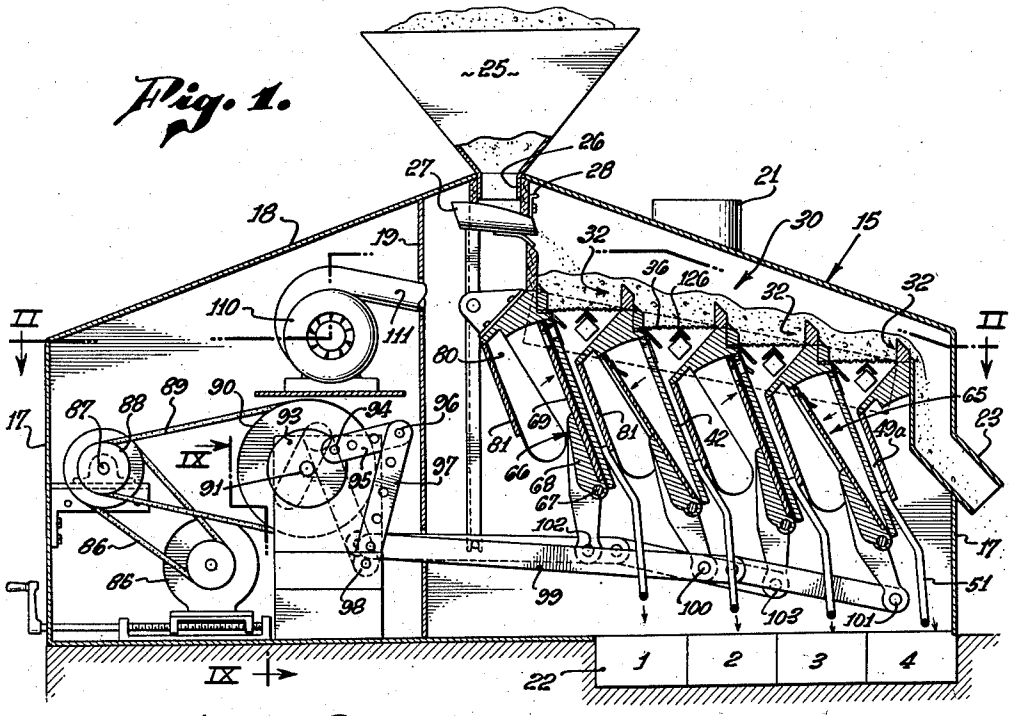


Fig. 2.

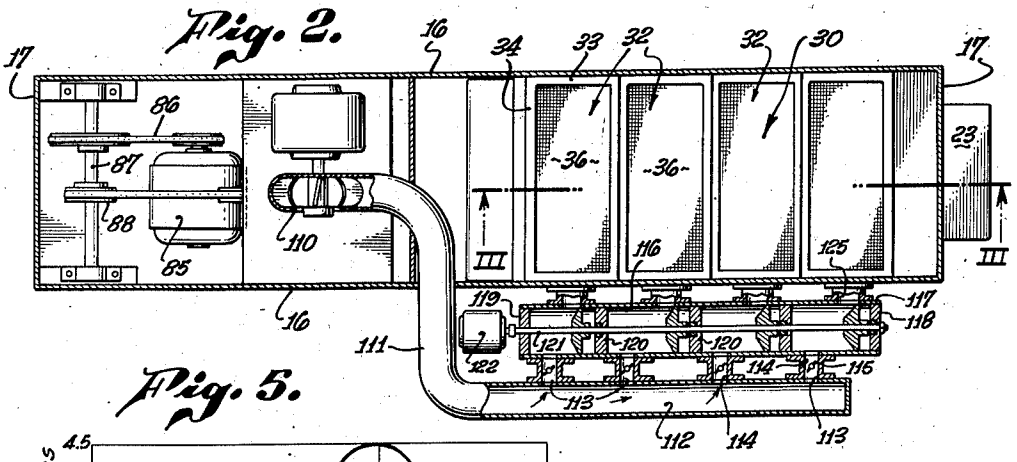
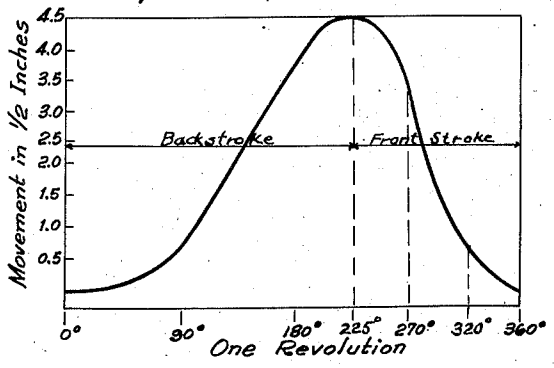


Fig. 5.



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Fig. 3.

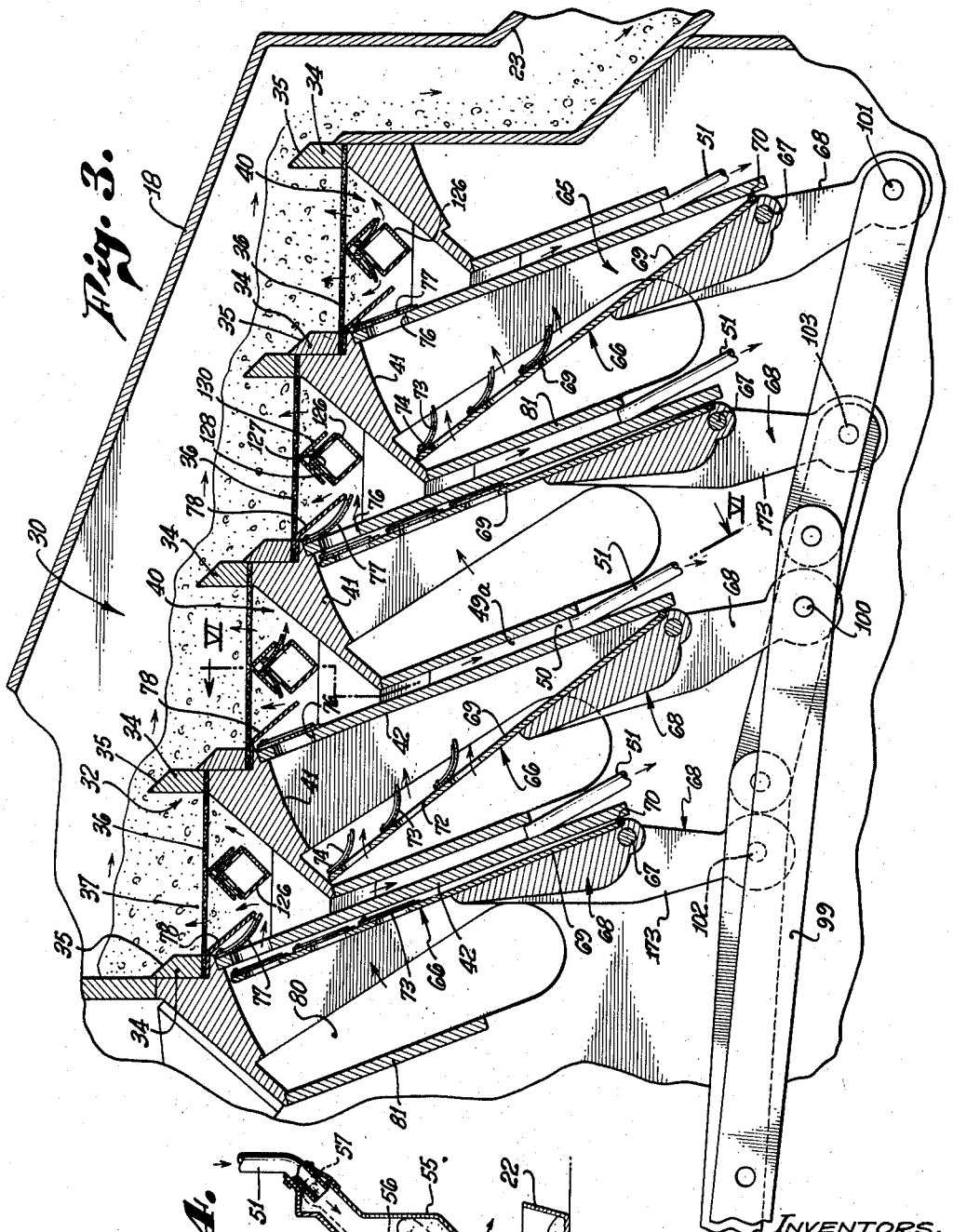
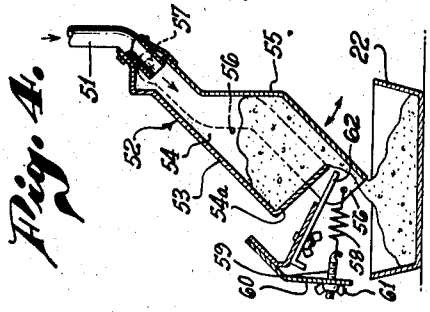


Fig. 4.



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Fig. 6.

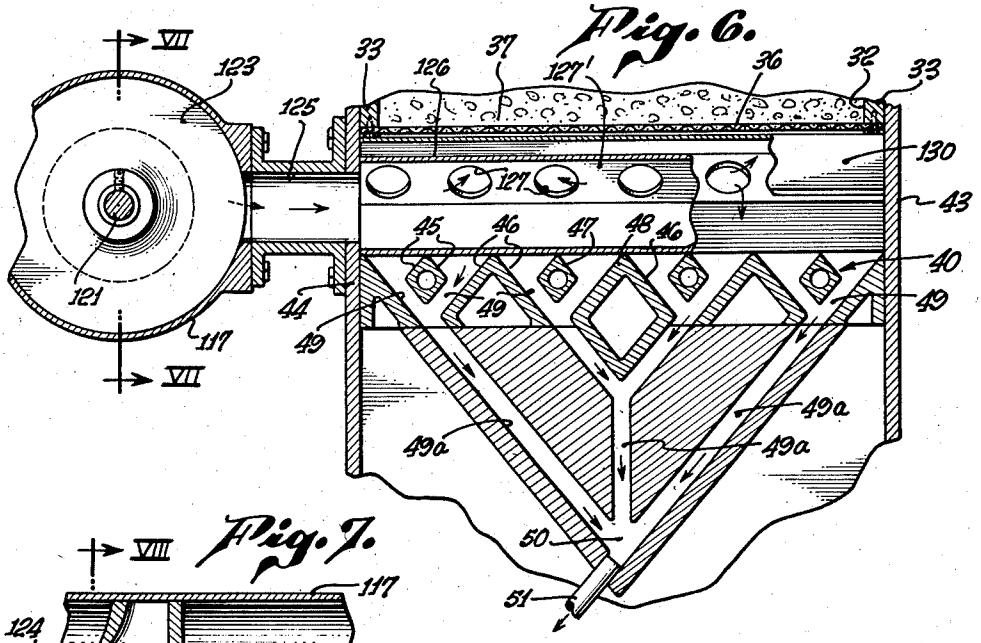


Fig. 7.

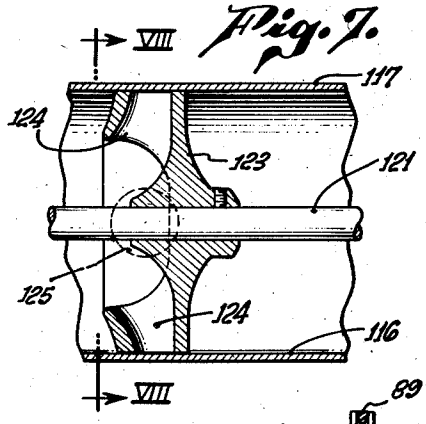


Fig. 8.

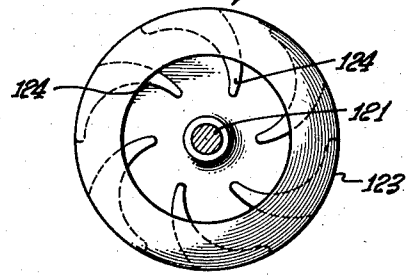
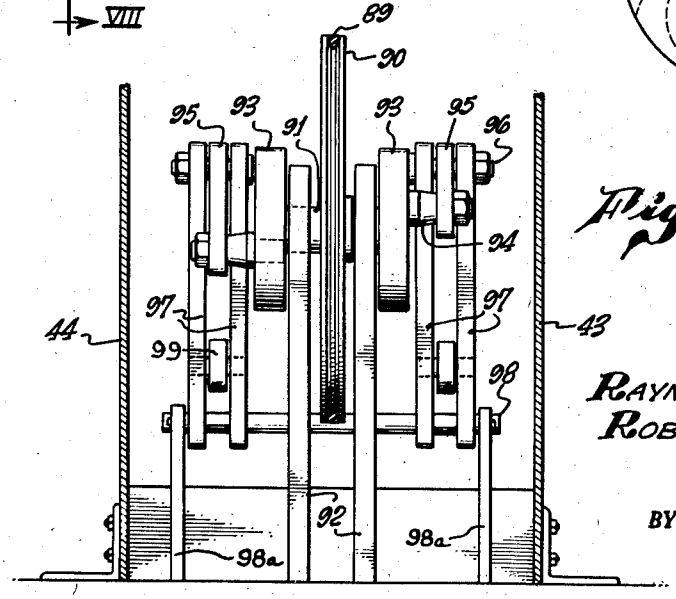


Fig. 9.



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Fig. 10.

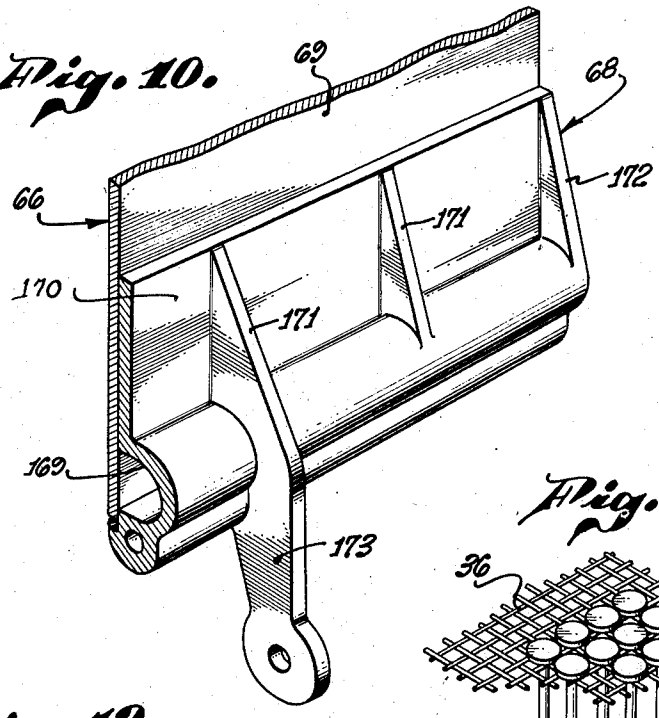


Fig. 11.

Fig. 12.

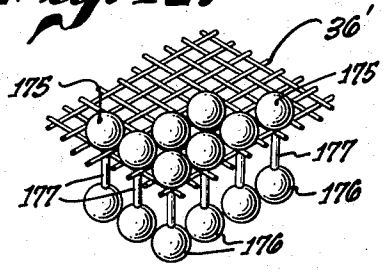
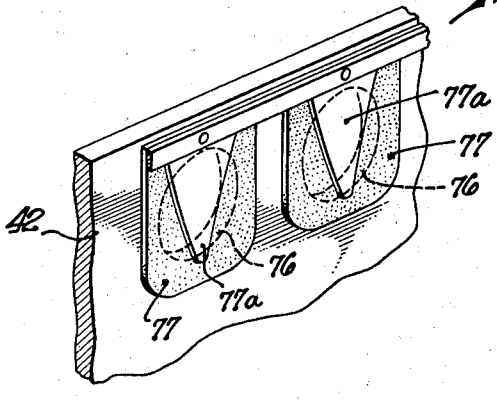


Fig. 13.



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DRY CONCENTRATING METHOD AND MACHINE THEREFOR

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Application August 3, 1953, Serial No. 372,084

23 Claims. (Cl. 209—475)

This invention relates to means and methods for concentrating or separating selected particles of material such as valuable minerals from a mass of material such as ore which contains various other constituents usually identified as waste or gangue. In particular, the invention relates to the working of low grade ores and the separating therefrom of selected minerals by a dry method of operation, that is, without the use of water.

Separation of a selected mineral particle from an ore containing other constituents may be accomplished by utilizing the difference in specific gravity of the selected mineral and the various constituents found with it in the ore. Separation of such minerals has heretofore been relatively efficiently accomplished in areas where water was readily available. Mineral deposits in such water-plentiful areas could be economically worked by prior proposed separating or concentrating machines.

Such prior separating machines which required the use of water obviously could not be used in areas where water was not plentiful. Usually mineral deposits in such relatively arid regions could not be worked unless they were of unusually high grade so as to justify costwise the importation and transportation of water thereto. Medium and low grade mineral deposits in arid regions were not worked because the costs were prohibitive.

In order to meet the problem of working low grade mineral deposits in arid regions, various separating machines have been proposed which do not use water. Such prior machines usually included the use of air to agitate a crushed or ground mass of ore. Such prior machines generally resembled the separating machines which utilized water and some included a pervious deck with a plurality of riffle means thereon, the deck being agitated by suitable well-known means. Air was blown through the deck at a relatively low pressure and in constant flow for further agitating the material on the deck. Such prior machines were not as efficient as the separating machines which utilized water.

The primary object of this invention is to design and provide a means and method for separating selected particles from a mass of different particles, the various particles having different specific gravity.

Another object of this invention is to disclose an economical method for processing low grade mineral deposits and for deriving a suitable high grade concentrate therefrom which may be transported to other areas for final processing.

Another object of this invention is to design and provide a novel method of separating heavy mineral particles from lighter mineral particles by subjecting said particles to pulsations of air of different superposed frequencies.

A further object of this invention is to design and provide a machine for separating particles of greater specific gravity from particles of less specific gravity without the use of water and in which novel utilization is made of air impulses for separating the particles.

A still further object of this invention is to design and

provide a means and method of separating heavy particles of minerals from lighter particles wherein the separated particles are caused to fall through an upwardly directed air stream which imparts different pulsations to the ore mass containing said particles.

A still further object of the invention is to design and provide a machine for separating heavy particles from light particles wherein the separated particles are collected and utilized to partially close and seal an opening in an air chamber through which the particles fall.

The invention contemplates a novel means for agitating a mass of crushed ore by imparting thereto pulsations of selected and adjustably varied frequencies.

The invention further contemplates the utilization of a preselected bedding material or media having a specific gravity lying between the specific gravity of the selected heavy particle and the specific gravity of the light particle or waste for supporting the ore mass and which reacts to certain of said pulsations of air in the manner of a heavy fluid.

The invention further contemplates the use of superimposed pulsations of different frequencies to agitate crushed ore containing the selected mineral particles in such a manner that selected heavy particles are quickly and efficiently separated therefrom.

Other objects and advantages of this invention will be readily apparent from the following description of the drawings in which an exemplary machine embodying this invention is shown.

In the drawings:

Fig. 1 is a diagrammatic sectional view taken in a vertical plane passing through a machine embodying this invention.

Fig. 2 is a top view taken in the planes indicated by line II—II of Fig. 1.

Fig. 3 is an enlarged fragmentary sectional view of the separating machine shown in Fig. 1.

Fig. 4 is a fragmentary sectional view of a discharge gate means employed with the separating machine shown in Fig. 3.

Fig. 5 is a chart indicating thereon a curve illustrating a characteristic stroke of the piston means employed in the separating machine shown in Fig. 1.

Fig. 6 is a fragmentary, enlarged sectional view taken in the planes indicated by line VI—VI of Fig. 3.

Fig. 7 is a fragmentary sectional view taken in the plane indicated by line VII—VII of Fig. 6.

Fig. 8 is an end view taken from the left of Fig. 7.

Fig. 9 is an end view of the driving means for the separating machine taken from the planes indicated by line IX—IX of Fig. 1.

Fig. 10 is a perspective view of a bellows piston means employed with this invention.

Fig. 11 is a perspective fragmentary view of a modification of the bedding media.

Fig. 12 is a perspective fragmentary view of a different modification of the bedding media.

Fig. 13 is a fragmentary perspective view of valve means and ports for the bellows chamber.

As illustrated in Figs. 1 and 2, the separating machine of this invention may preferably be enclosed within a housing **15** comprising side walls **16**, end walls **17**, a roof **18** and an internal partition wall **19**. The roof may be provided with a vent **21** for discharge of dust resulting from the separation process and to provide an air outlet. The housing may be supported upon any suitable type of floor, and as illustrated, the floor may include a plurality of bins **22** therein for collecting the several concentrates resulting from the process. One of the end walls **17** of the building may be provided with a discharge outlet **23** for the tailings or waste from the ore processed.

Means for feeding crushed ore to the separating ma-

chine may include a funnel-shaped hopper 25 adapted to receive ore from a suitable supply of ore previously crushed to a selected particle size. In the exemplary embodiment and operation, the ore may be crushed or granulated to a maximum particle size of about 3/16 inch. The hopper 25 may be continuously fed by any suitable conveyor means. Crushed ore in hopper 25 flows by gravity downwardly through throat 26 therein and to a deflecting spout 27 supported by suitable frame structure of the housing. The spout 27 may be adjustably inclined to a suitable angle so as to discharge crushed ore at a selected rate from throat 26. Discharge of ore may be further controlled by an adjustable gate 28 provided on the lower portion of the hopper adjacent to and above the mouth of the spout 27.

Means for separating the selected heavy particles from the crushed ore may comprise an exemplary separating machine generally indicated at 30. Before describing in detail the separating machine 30, it will be understood that the separation process contemplates utilization of the difference in specific gravities of the various particles of ore to be treated. For example, ore containing scheelite which is a source of tungsten has a specific gravity of about 6.0. Scheelite is found in combination with limestone and quartz which has a specific gravity of about 2.65. While the separating machine is described with respect to the process of separating ore containing scheelite, it is understood that the separating machine is adapted to be employed for separating various other minerals or any other material in which separation may be based upon the difference in specific gravity characteristics of particles making up the mass of material.

Generally speaking, the separating machine 30 comprises a means for supporting ore containing the selected particles to be separated along a selected path of travel and means for agitating said ore, the means for agitating said ore comprising a means imparting low frequency range pulsations to the ore mass and means for imparting high frequency range pulsations to the ore mass over the low frequency pulsations. The separating machine includes means for adjustably varying the frequency of the superposed pulsations imparted to the ore mass so as to provide the most effective and efficient type of agitation to the ore mass being processed whereby the selected heavy particles are separated in a quick and efficient manner.

Means for supporting the ore mass may comprise a plurality of material holding receptacles or rectangular baskets 32 arranged in tandem and providing a straight path of travel for flow of the ore mass discharged from the spout 27. The baskets 32 are positioned at decreasing levels, the highest basket 32 being the first basket to receive ore from the feed spout. Each basket may comprise spaced, parallel, end walls 33 connected by spaced transverse side walls 34. As best seen in Fig. 2, the end walls 33 lie against the side walls 16 of housing 15 so that spilling of crushed ore over end walls 33 is prevented by said housing side walls. The transverse side walls 34 are of substantially the same height and each is provided with a downwardly inclined top edge face 35 directed toward the tailing end of the separating machine to facilitate flow of material. The end walls 33 and side walls 34 form a rectangular frame for carrying screen means 36 extending across and between bottom margins of said walls 33 and 34. The screen means may be secured to said bottom margins by suitable means, such as screws. The screen means 36 may be of suitable selected mesh depending upon the particle size to which the ore is crushed. The screen mesh may be varied in size for the several baskets depending upon the concentrate desired and the characteristic ore mass being worked. Each basket 32 is removably mounted on the separating machine, the means for securing said basket to the machine being of any suitable type and not shown.

The screen means 36 may support a bedding material 37 of selected depth having a specific gravity lying between the specific gravities of the heavy particles and the lighter waste particles. The bedding material 37 serves as a media which may act with characteristics of a heavy fluid when subjected to high frequency range pulsations as later described. The bedding material 37 may comprise particles of the crushed ore which have a specific gravity lying between the heavy and light particles or it may comprise particles of ore of selected specific gravity placed upon the screen before the introduction of crushed ore to be treated to the machine. The specific gravity of the bedding material in the latter instance may be carefully and accurately selected so as to produce desired separation results.

Other substitutes for the bedding material 37 may comprise a plurality of relatively wide-headed aluminum or lightweight nails (Fig. 11) inserted in the openings of the screen mesh and supported therein by the heads of the nails which are of greater size than the mesh openings. Another suitable bedding material 37 (Fig. 12) may comprise a plurality of loosely interconnected spaced balls of suitable diameter similar to elements of a ball-type chain. The particular function and operation of the bedding material will be described later.

The means for agitating an ore mass supported upon the bedding material carried in the plurality of baskets 32 includes a means for imparting low frequency vibrations or pulsations to the mass of material, said low frequency vibrations being in the range of infrasonic or low sonic vibrations. Each basket 32 is supported above an air chamber 40 defined by downwardly converging transverse side walls 41 and 42 and vertical end walls 43 and 44 (Fig. 6). The bottom of chamber 40 may comprise a plurality of downwardly inclined diverging surfaces 45 and 46 provided respectively on suitably shaped spaced polygonal members 47 and 48 respectively extending across and joining the side walls 41 and 42. The surfaces 45 and 46 terminate in top apices which are spaced apart in the same plane, the members 47 and 48 being spaced to provide downwardly directed openings in the bottom wall. These openings lead to a plurality of converging inclined passageways 49 which merge into intermediate downwardly inclined passageways 49*a*. The several passageways 49 and 49*a* may be provided by suitable filler plate members secured to and confined between the walls 42 and 81 below the members 47 and 48. The passageways 49*a* may merge at a common point 50 in a common discharge tube 51 which leads to a discharge gate means generally indicated at 52. The inclination of the surfaces 45 and 46 and the passageways 49, 49*a*, and 51 are sufficient so that gravity flow is permitted of heavy particles which are passed through the screen means. The heavy particles initially collect in a discharge gate means 52 at the end of tube 51.

Each discharge gate means 52 is especially constructed for the purpose of maintaining a selected quantity of concentrate therewithin, as indicated in Fig. 4, so that each air chamber 40 is provided with a substantially closed bottom opening. The discharge gate means 52 may comprise a fixed top cover 53 having downwardly extending side walls 54 and end wall 54*a* received within a bottom spout 55 having upwardly extending side walls 56. The spout 55 is pivotally attached as at 57 to frame structure adjacent to the end of discharge tube 51 and the bottom wall of spout 55 is normally inclined at a suitable angle. The spout 55 may be biased toward completely closed position by a suitable spring 58 connected at one end to a side wall of the spout and at its other end to a hook 59 carried by a plate 60. The hook 59 is threadedly adjustable in plate 60 to vary the tension of spring 58 and is held by means of a wing nut 61. The plate 60 carries an inwardly extending deflector plate 62 which limits the discharge of heavy particles collected in the discharge gate means 52. It will be apparent that since cover 53 is fixed in position, and since the spout 55 is biased toward

closed position, a selected amount of separated heavy particles may be collected in the gate means in order to virtually close the bottom end of the air chamber **40**. When the weight of the particles in the discharge gate means reaches a selected amount, the spout **55** will be urged downwardly and away from the cover by the weight of said particles to permit discharge of a selected amount therefrom while at the same time maintaining a selected quantity of material in the discharge gate means.

Adjacent to each air chamber **40** may be provided a bellows-type pump means, said air pump means including a bellows air pump chamber **65** defined by one wall **42** of the air chamber and by the contiguous bottom surface of the inclined wall **41** of the adjacent air chamber **40**. The bellows pump chamber **65** may be further defined by vertical end walls **43** and **44** which extend downwardly from the ends of the air chamber **40**. A bellows air piston means **66** may be mounted for reciprocal movement on a transverse pivot shaft **67** mounted in suitable bearing means provided in end walls **43** and **44**. The shaft **67** lies adjacent to the bottom edge of the cylinder wall **42** and is carried by a piston lever means **68**. The piston lever means **68** may comprise an integral casting comprising a transverse partially circular cross-section portion **169** and an upwardly extending, transversely elongated flat portion **170** integrally connected to the upper marginal edge of the transverse member. The flat portion **170** may be reinforced by a plurality of spaced intermediate ribs **171** integrally merging with the transverse portion **169** and end wall portions **172**. The intermediate reinforcing ribs **171** are nonuniformly spaced from the end walls **172** and one of said ribs lies in the planar zone of a downwardly extending lever portion **173** which affords connection to a crank arm **99**. Alternate piston lever means **68** are provided with lever portions **173** adjacent to opposite ends of the transverse portion **169** so that in operation the parallel crank arms and the motor load are substantially uniformly balanced.

The bellows piston means **66** includes a flat rectangular piston plate **69** secured to the flat portion **170** in any suitable manner as by welding. The piston plate **69** extends between the inner surfaces of end walls **43** and **44** and the top edge of plate **69** is closely fitted for reciprocal movement with respect to a bottom curved surface of wall **41**. The lower transverse edge of plate **69** may carry a suitable sealing strip **70** adapted to be compressed between the adjacent bottom margin of the cylinder wall **42** and the piston plate so as to provide a seal therefor while the piston is reciprocated.

The piston plate **69** may be provided along its upper portion with a plurality of transversely extending rows of circular air inlet ports **72** each having a flexible valve element **73** of suitable material such as rubber composition or leather. Each valve element **73** may be secured to the piston plate above its respective port **72** by a suitable pin **74**. The valve elements **73** are secured on the inner face of the piston plate **69** so that when the piston is moving toward closed position, the valve elements **73** will be urged to port closing position by the compression of air in the pump chamber, and while the piston is moving to open position, the valve elements will automatically be moved to open port position by the inrush of air through said ports.

The air chamber wall **42** is provided with a row of transversely extending air chamber inlet ports **76** arranged above the apices of the surfaces **45** and **46**. Each port **76** is likewise provided with a flexible valve element **77** secured to wall **42** on the inner surface thereof in the air chamber **43**, said valve elements **77** being adapted to be opened when the piston means **66** is being closed and to permit discharge of compressed air in the pump chamber **65** into the air chamber **40**. Positive closing of valve elements **77** is facilitated by depending spring fingers **77***a* which overlie elements **77** (Fig. 13).

A deflector **78** formed of suitable plate material is secured beneath a side wall **34** of each basket and extends over the valve elements **77** and in spaced relation thereto so as to limit opening of the valve elements **77**. The bottom edge of the deflector plate **78** is spaced above the apices formed by the surfaces **45** and **46** of the bottom wall.

The bellows piston means **66** in its open position extends into an enlarged open auxiliary chamber **80** formed rearwardly of the bellows pump chamber **65** and defined by a portion of wall **41** and a downwardly inclined wall **81** forming with the wall **42** a portion of the discharge passageways **49** and **50**. The chamber **80** is open to atmosphere at the bottom and along the sides thereof so that when piston means **66** is at its outermost open position, the bellows pump chamber **65** is substantially open to atmosphere.

The means for driving the bellows piston means **66** in reciprocal pivoted movement may include a suitable motor means **85** (Fig. 2) provided with a drive pulley means **86** for rotating a countershaft **87**. The countershaft **87** is provided with a centrally located pulley **88** which drives through a pulley belt **89**, a pulley wheel **90** mounted axially of the machine and forwardly of the motor **85**. The pulley wheel **90** (Fig. 9) may be mounted upon a shaft **91** carried by a pair of spaced upstanding standards **92**. The driving means on each side of the pulley wheel **90** is virtually similar and for brevity the details of only one side is described in detail.

Each end of shaft **91** extends beyond the adjacent standard **92** for mounting thereon a drive wheel **93**. Each drive wheel **93** carries an eccentric pin **94** to which may be pivotally connected one end of drive crank **95**. The drive crank **95** is pivotally connected at its other end as at **96** to a pair of parallel connector links **97** which are pivotally connected at their other end to a shaft **98** mounted in upstanding frame members **98***a*. A forwardly extending drive arm **99** may be pivotally connected at one end to link **97** above and spaced from shaft **98**. The drive arm **99** on one side of the machine may be pivotally connected as at **100** and **101** respectively to piston means **66** for the second and fourth piston means as illustrated in Fig. 1. The drive arm **99** on the other side of the machine may be pivotally connected as at **102** and **103** to the piston means **66** for the first and third piston chambers. The eccentric wheels **93** are disposed with their eccentric pins **94** disposed at about 180° spaced relationship so that the piston means on the first and third piston chambers will be in closed position when the piston means and the second and fourth chambers are in open position. The alternate action of alternate piston means thereby afforded provides a more uniform and even loading of the drive means.

The particular action of the piston means **66** should be noted because the eccentric crank driving means is so arranged that a sudden, sharp impulse or blast of air is transmitted from the pump chamber **65** to the air chamber **40**. In Fig. 5 a curve is illustrated showing the movement of the piston means in inches during one revolution of the drive wheel. The movement in inches is marked on the ordinate axis and the number of degrees of rotation of the drive wheel is marked on the abscissa axis. As exemplarily illustrated, the point 0° may be considered the beginning of the backstroke of the piston means from its ultimate closed position in pump chamber **65**. At approximately 225° of rotation of the drive wheel the backstroke of the piston is completed and the forward compression stroke of the piston is begun. Between about 225° and 270° the piston means moves forwardly in the open, auxiliary chamber **80**. At 270° the piston means reaches its maximum forward speed and at that point enters the pump chamber **65**. The rate of speed continues as is illustrated by the substantially straight, downward line formed by the curve to approximately 320° when the rate of movement of the piston means begins to decrease, and finally at 360° the piston

means reaches its ultimate, closed position. It will thus be apparent that the maximum rate of forward movement of the piston is provided by the particular drive wheel and linkage arrangement so that air compressed in the bellows pump chamber **65** is rapidly, suddenly and sharply compressed and forcibly ejected through ports **76** into air chamber **40**. The ejected blast of air is deflected downwardly by deflector **78** and then is reflected upwardly by inclined surfaces **45** and **46**. The inclination of these surfaces tends to uniformly distribute the air blast over the screen means **36** and a sharp air blow or pulsation is delivered to the ore mass carried on top of the screen means. The pulsations delivered by each piston **66** are preferably in the infrasonic or lowsonic range so that relatively slow, heavy forceful impulses are transmitted and imparted to the ore mass.

Means for further agitating the ore mass by means of high frequency impulses of air may be provided by a motor-driven blower **110** of well-known make and manufacture and provided with a discharge duct **111** downwardly inclined and mounted exteriorly of the side walls of the housing. The duct **111** forms an exterior manifold **112** which is provided with a plurality of outlets **113** each generally opposite to a basket **32**. Each outlet **113** leads to a valved passageway **114** provided with an adjustable valve element **115** of any suitable type, illustrated here as a butterfly valve. Each passageway **114** opens into an air compartment **116** provided in an elongated cylinder **117** having closed ends **118** and **119**. The compartments **116** may be formed by a plurality of longitudinally spaced partitions **120**. Extending axially through the cylinder **117** and partitions **120** may be a drive shaft **121** connected at one end to an exteriorly mounted motor **122**. Air-chopping member **123** provided with a plurality of curved centrically directed blades **124** may be mounted on shaft **121** for rotation within each compartment.

Opposite blades **124**, a discharge port **125** leads to a hollow square section duct **126** extending transversely across air chamber **40** below screen means **32** and slightly above the bottom wall of the air chamber. The duct **126** is arranged to present upwardly inclined contiguous surfaces **127'** to the blast of air entering the chamber **40**. The top contiguous surfaces **126** of the duct may be downwardly inclined and may be provided with a plurality of longitudinally spaced discharge ports **127**. Each discharge port **127** may be provided with a flexible valve element **128** mounted thereof. To prevent separated particles of the ore mass from falling upon valve elements **128**, an inverted V-shaped deflector cap **130** may be suitably mounted above and spaced from said ports.

When the blower **110** supplies air to manifold **112** and said air is controllably introduced into compartments **116**, the rotating air chopper elements **123** impart relatively high frequency pulsations to the air stream. Thus a high frequency pulsating air stream is ejected through ports **127**, into the air chamber **40**, and is deflected from the walls of the air chamber **40** upwardly through the screen means into the ore mass carried thereby. The high frequency air pulsations are transmitted to and impart further agitation to the ore mass, subjecting the ore mass to continuous rapid vibration, the result of which causes the bedding material **37** to act in the nature of a heavy fluid. Thus the agitation of the ore mass by relatively high frequencies, and the superimposed low frequency impulses, causes the heavy particles of a specific gravity greater than the bedding material to be shaken loose from the ore mass and to fall through the bedding material, through the screen, the air chamber, and into the discharge tube. The lighter particles having the specific gravity of, for example 2.65, are blown upwardly from the bedding material, through the ore mass, and are passed over side walls **32** of the baskets onto the ore mass in the adjacent basket. These lighter particles are continually moved down the stepped basket arrangement until they are discharged as tailings from the discharge duct **23**.

In operation, ore which has been crushed or granulated to the selected mesh is fed through the adjustable feed spout **27** to the separating or concentrating machine **30**. The gravity feed of the ore causes the ore to flow in a path of travel longitudinally of the machine and along the downwardly stepped baskets. Ore flowing into each basket **32** is supported by a preselected bedding material **37** of approximately one-half to three-fourths of an inch in thickness, said bedding material having a specific gravity between that of the waste material and that of the heavy particles to be separated. The bedding material **37** and the ore supported on top thereof is then subjected to high frequency air pulsations developed by the blower **110** and the rapidly rotated air chopping device **123**. The effect of these high frequency pulsations upon the bedding material and upon the ore mass is to shake or rapidly vibrate the same so that it moves and acts in the nature of a heavy fluid. At the same time lower frequency air pulsations developed by the bellow air pump means are imparted and transmitted to the mass of material. The effect of the closing of each of the bellows piston means **66** is such that a heavy powerful blow or shock is imparted to the quivering ore mass with the result that the heavier particles of the mass are jolted from association with the remainder of the mass and fall through the bedding material, through the screen means, and into air chamber **40**. The heavier particles are then conducted by gravity through the inclined discharge tubes to the discharge gate means. The application of this heavy powerful shock or blow to the ore mass together with the subjection of said mass to the air pulsations of high frequency range produces a very effective separation of the heavy particles from the waste or gangue. The waste particles are conveyed by these air pulsations upwardly through the ore mass and over side walls of the baskets for discharge eventually as tailings from duct **23**.

It should be noted that immediately after the deliverance of heavy powerful low frequency air pulsations by the bellow piston means to air chamber **40** the commencement of the rear stroke of the piston means produces momentarily a partial vacuum or reduction of air pressure in air chamber **40** so as to further facilitate the withdrawal and separation of the selected heavy particles from the ore mass. The deflection of the air shock waves produced by both the low and high frequency range air compression means from the inclined bottom wall surfaces causes the pulsations to rebound upwardly into virtually even distribution across the screen means **36**. The force or impact of these two relatively widely separated frequency ranges of pulsations upon the ore mass is maintained at relatively high efficiency by reason of the particular arrangement of the discharge gate means which reduces loss of air through the discharge tubes to a very minimum. It should be particularly noted that the effectiveness of the air pulsations is maintained even while discharging limited quantities of concentrate from the discharge gate device.

In the modification of the bedding material illustrated in Fig. 12 each screen means **36'** is provided with a plurality of spaced pairs of balls **175** and **176** interconnected by means of a link **177**, a ball or link assembly being provided for each opening in the screen. Preferably the ball and link assemblies are made of a suitable metal coated with a wear resistant surfacing such as chrome or the like. The specific gravity of the bedding material is particularly selected so that it will be most effective in providing a vibrating fluid mass through which heavier particles may fall. It is contemplated that when a separating machine embodying this modification is in operation the ball and link assemblies will react to pulsations of selected frequency in such a manner that the top ball **175** will be spaced above the screen means **36'** a distance

high enough so that the selected heavy particle may pass around adjacent balls 175 and downwardly through the openings in the screen. The lower ball 176 is normally spaced below the mesh a sufficient distance to allow passage of such a particle. Obviously the action of the ball and link assemblies throughout the area of the mesh will not be exactly uniform so that they thereby may afford further agitation of the mass particularly where the density of the ore mass thereabove is not completely uniform.

The exemplary embodiment of this invention has been illustrated having in mind separation of scheelite from an ore mass containing limestone and quartz. Obviously other selected minerals may be separated on the machine disclosed. Since other minerals have different specific gravities and may be found in ore having waste or gangue of different specific gravities than those mentioned above, such variations in selected minerals may be correlated to operation of the separating machine by varying, for example, the specific gravity of the bedding material, by changing the particular size of the ore, by changing the size of mesh of the screen, by progressively decreasing the mesh size of the screen in the several material holding receptacles, and as by regulating and controlling the frequency ranges of the superposed low and high frequency air pulsations so that a most efficient and economic separation of waste and gangue from the valuable minerals is accomplished. The low frequency air pulsations may be readily varied by changing the rate of rotation of the eccentric drive wheels. The high frequency pulsations may be controlled by the valved ports 114 and by the speed of rotation of shaft 121 which carries the several air chopping means. These adjustments can be readily made so that a most efficient ore concentration of the selected minerals can be accomplished.

It is understood that the volume of air displaced from the bellows piston chamber may be varied so as to facilitate changes in pulsation frequency in order to produce desired results on the ore being processed. Such volume changes may be accomplished by modifying the volume of the piston chamber and by varying the length of travel of the piston means.

The alternate action of adjacent bellows piston means not only uniformly loads the driving means but the alternate heavy pulsations created thereby facilitate movement of the ore being processed from basket to basket. A pulsation acting on the first basket, for example, puffs or expands the ore mass carried above the basket, that is the voids between the discrete ore particles become larger. The adjacent basket, not under the influence of a pulsation, has its ore mass lying in a relatively contracted condition. The alternate raising and lowering of levels of the ore mass in adjacent downwardly stepped baskets contributes to the movement of the ore mass through the machine.

It is understood by those skilled in the art that numerous modifications may be made in the disclosed separating machine which come within the spirit of this invention, and all such modifications and changes coming within the scope of the appended claims are embraced thereby.

We claim:

1. In an apparatus for separating heavy particles from light particles, the combination of: means for feeding a mass of material including heavy and light particles along a selected path; a plurality of material holding receptacles arranged along said path and at progressively decreasing levels; each receptacle having a bottom screen; means forming an air chamber beneath each of said screens and including downwardly converging side walls and a means at the bottom of said chamber comprising spaced members having inclined walls extending between said side walls and defining a plurality of inclined converging discharge passageways; a common discharge tube beneath each air chamber joined with said passageways at their point of convergence; a bellows type air pump positioned adjacent each air chamber and including a pump chamber; a bellows piston operable in said pump chamber; a valved port between said pump chamber and air chamber for passage of air therethrough to said air chamber; driving means for said bellows piston arranged to operate at a relatively low frequency for forcibly ejecting sharp impulses of air through said air inlet port to said air chamber to agitate said mass of material; a valved duct in each chamber; means connected to each duct for producing relatively high frequency air pulsations to be superposed over said low frequencies in said air chamber to further agitate said mass of material; and means to collect and discharge heavy particles which fall through said common discharge tube so as to virtually seal the end of said discharge tube during operation while affording limited discharge of selected particles.

2. In an apparatus for separating heavy particles from light particles, the combination of: means for feeding a mass of material including heavy and light particles along a selected path; a plurality of material holding receptacles arranged along said path and at progressively decreasing levels; each receptacle having a bottom screen; means forming an air chamber beneath each of said screens and including downwardly converging side walls and a means at the bottom of said chamber comprising spaced members having inclined walls extending between said side walls and defining a plurality of inclined converging discharge passageways; a common discharge tube beneath each air chamber joined with said passageways at their point of convergence; a bellows type of air pump positioned adjacent each air chamber and including a pump chamber; a bellows piston operable in said pump chamber; a valved port between said pump chamber and air chamber for passage of air therethrough to said air chamber; driving means for said bellows piston arranged to operate at a relatively low frequency for forcibly ejecting sharp impulses of air through said air inlet port to said air chamber to agitate said mass of material; and means to collect and discharge heavy particles which fall through said common discharge tube so as to virtually seal the end of said discharge tube during operation while affording limited discharge of selected particles.

3. In a concentrating machine, the combination of: means for directing flow of material to be treated along a path; a plurality of material-holding baskets aligned with the flow path of the material, said baskets being arranged at progressively decreasing levels along said path; each basket being provided with a bottom screen means; an air chamber provided beneath each screen means, each air chamber having a valved air inlet port; bellows piston means adjacent to each air chamber and in communication with the respective air inlet port for the associated chamber; means for driving said bellows piston means at a selected rate to produce air pulsations of low frequencies, said air pulsations being transmitted through said ports to said air chambers to material in said recaptacles; an air blower means; a plurality of valved ducts in said air chambers, each duct being connected with said air blower means; and means associated with said air blower means for producing air pulsations of high frequency transmitted to said valved ducts and superposed on said low frequency pulsations; and discharge means leading from each air chamber for separated particles of material which fall through said screen means.

4. In a concentrating machine, the combination of: means for directing flow of material of different specific gravities along a path; a material-holding receptacle in the flow path of the material and including a bottom screen means; an air chamber beneath said screen means and provided with an air inlet port; an air pumping means adjacent to said air chamber and communicating with the inlet port; means for driving said air pumping means at a selected rate to produce air pulsations of low frequency; a valved duct in said air chamber beneath and

adjacent to the screen means; means connected to said duct for producing air pulsations of high frequency superimposed on said low frequency pulsations, said high and low frequency air pulsations being transmitted through said air chamber to material in said receptacles for agitation of said material; and discharge means below the air chamber for separated particles of material falling through the screen means.

5. In a concentrating machine, the combination of: means for directing flow of material of different specific gravities along a path; a material-holding receptacle in the flow path of the material and including a bottom screen means; an air chamber beneath said screen means and provided with an air inlet port; an air pumping means adjacent to said air chamber and communicating with the inlet port; means for driving said air pumping means at a selected rate to produce air pulsations of selected low frequency, said air pulsations being transmitted through said inlet port to said air chamber and to material in said receptacles; a valved duct extending longitudinally of and beneath the screen means and having inclined surfaces; means connected to said duct to produce high frequency pulsations for transmission through said duct to said air chamber; and discharge means below the air chamber for separated particles of material falling through the screen means.

6. A concentrating machine as claimed in claim 5 wherein said discharge means includes a discharge passageway from said air chamber for flow of separated particles therealong, and discharge gate means at the end of said passageway for collecting a selected amount of said particles to maintain said passageway normally closed while discharging selected quantities of said particles.

7. A machine as defined in claim 5 wherein the discharge means includes a spring-biased, adjustable gate member for limiting discharge of particles from said passageway.

8. A machine as claimed in claim 5 wherein the discharge means includes a plurality of spaced bottom members having downwardly inclined surfaces arranged to deflect low frequency impulses of air received from said inlet port upwardly to the material in said receptacle.

9. In a concentrating machine, the combination of: means for directing flow of material of different specific gravities along a path; a material-holding receptacle in the flow of the material and including a bottom screen means; an air chamber beneath said screen means and provided with an air inlet port; an air pumping means adjacent to said air chamber and communicating with the inlet port; and means for driving said air pumping means at a selected rate to produce air pulsations of selected low frequency, said air pulsations being transmitted through said inlet port to said air chamber and to material in said receptacles; and means in communication with said air chamber to produce high frequency air pulsations superimposed over said low frequency pulsations.

10. A method of separating heavy particles from light particles, comprising the steps of: feeding a mass of material including heavy and light particles along a selected path of travel; providing and supporting a bedding material of a specific gravity less than the heavier particles and greater than the lighter particles; imparting high frequency pulsations to the bedding material and to the mass of material to be separated whereby said bedding material acts in the nature of heavy fluid; imparting low frequency pulsations to the bedding material and mass of material to cause the heavy particles to drop through said bedding material; and guiding the separated heavy particles to a discharge means.

11. A method of concentrating selected ore particles comprising the steps of: feeding an ore mass ground to selected particle size along a selected path of travel; supporting said ore mass on a bedding material of preselected specific gravity not exceeding the specific gravity of the selected ore particles; imparting pulsations of low frequency to the ore mass and bedding material; simultaneously imparting pulsations of high frequency to the ore mass and bedding material; and guiding particles separated by agitation of said ore mass by said superposed pulsations to a discharge means.

12. In a concentrating machine, the combination of: means for directing flow of material to be treated along a path; a material holding basket aligned with the flow path of the material and provided with bottom screen means; means providing an air chamber beneath said screen means and having an air inlet port; valve means for said port; means limiting opening of said valve means; a bellows piston means adjacent to said air chamber in communication with said inlet port; means for driving said bellows piston means at a selected rate to produce air pulsations of low frequency; air blower means; a valved duct in said air chamber adjacent to and beneath said screen means, said duct being connected to said air blower means in communication therewith; means associated with said air blower means for producing air pulsations of high frequency for transmission to said valve duct for super-imposition on said low frequency pulsations; and discharge means in communication with said air chamber for separating particles of material.

13. In a concentrating machine, the combination of: means for directing flow of material to be treated along a path; a material holding basket aligned with the flow path of the material and provided with bottom screen means; means providing an air chamber beneath said screen means and having an air inlet port; valve means for said port; a bellows piston means adjacent to said air chamber in communication with said inlet port; means for driving said bellows piston means at a selected rate to produce air pulsations of low frequency; air blower means; a valved duct in said air chamber adjacent to and beneath said screen means, said duct being connected to said air blower means in communication therewith; means associated with said air blower means for producing air pulsations of high frequency for transmission to said valved duct for superimposition on said low frequency pulsations; discharge means in communication with said air chamber for separating particles of material; and deflector means extending over said valved duct.

14. In a concentrating means, the combination of: a material holding basket provided with bottom screen means; means providing an air chamber beneath and coextensive with said basket; downwardly converging side walls defining sides of said chamber; valved ports in one of said side walls adjacent to and beneath the screen means; deflector means inclined downwardly over said ports and in spaced relation thereto; a bellows chamber adjacent to said one side wall in communication with said port; a valved bellows piston operable in said chamber to produce low frequency pulsations of air for transmission through said ports into said chamber; means extending beneath and adjacent to said screen means for transmitting high frequency air pulsations to said chamber; means connected to said means in said chamber for producing high frequency air pulsations; and discharge means in communication with said air chamber for guiding separated particles of material which fall through said screen means.

15. In a concentrating machine, the combination of: means for directing flow of material to be treated along a path longitudinally of the machine; a plurality of material-holding receptacles aligned with the flow path of the material and arranged transversely thereof at progressively decreasing levels along said path; each receptacle being provided with a screen means; means providing an air chamber beneath each screen means and including a wall having a valved port in communication with said chamber; a bellows piston means adjacent to each air chamber and including a bellows chamber having one

side thereof defined by said ported wall, and a bellows piston pivotally mounted adjacent one end of said wall, said bellows piston having a plurality of valved bellows ports; means for driving said bellows piston at a selected rate to produce air pulsations of low frequencies transmitted through said valved ports leading to said air chambers and to material in said receptacles; and discharge means leading from each air chamber for separated particles of material which fall through said screen means.

16. A concentrating machine as stated in claim 15 including means in each air chamber to transmit pulsations of high frequency to said air chambers and to material in said receptacles.

17. A concentrating machine as stated in claim 16 including means providing pulsations of high frequency in communication with said transmitting means in said chambers.

18. In a dry concentrating machine, the combination of: means for directing flow of material to be separated along a selected path; a material-holding receptacle in the flow path of the material to be separated and including a screen means; means providing an air chamber with an inlet port below the screen means; means for producing pulsations of low frequency in communication with the inlet port; means for producing pulsations of high frequency in communication with said chamber; said high and low frequency pulsations being transmitted through the air chamber to the material in said receptacle for agitation of said material; and discharge means for separated particles falling through the screen means.

19. In a concentrating machine as stated in claim 18 including a bedding material carried on said screen means.

20. In a concentrating machine as stated in claim 18 including a bedding material carried on said screen means, said bedding material having a specific gravity not exceeding the specific gravity of material to be separated.

21. In a concentrating machine as stated in claim 18 including bedding material comprising a plurality of ball and link assemblies cooperable with the screen means.

22. A dry method of separating heavy particles from light particles, comprising the steps of: feeding dry material including heavy and light particles along a selected path of travel onto a dry bedding material; imparting pulsations of high frequency to the bedding material and to said particles; simultaneously imparting pulsations of low frequency to the bedding material and to said particles; and collecting the particles separated thereby.

23. A dry method of separating heavy particles from light particles, comprising the steps of: feeding a dry mass of material including heavy and light particles along a selected path of travel onto a bedding material of specific gravity greater than the light particles; subjecting said mass of material and said bedding material to pulsations of high frequency; subjecting said mass of material and said bedding material simultaneously to pulsations of low frequency to cause the heavy particles to drop through said bedding material; and collecting the separated heavy particles.

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