July 26, 1960 F. W. HACK 2,946,442

MULTI-CONE ORE CONCENTRATION APPARATUS

Filed Dec. 20, 1954 2 Sheets-Sheet 1

Fig. 1

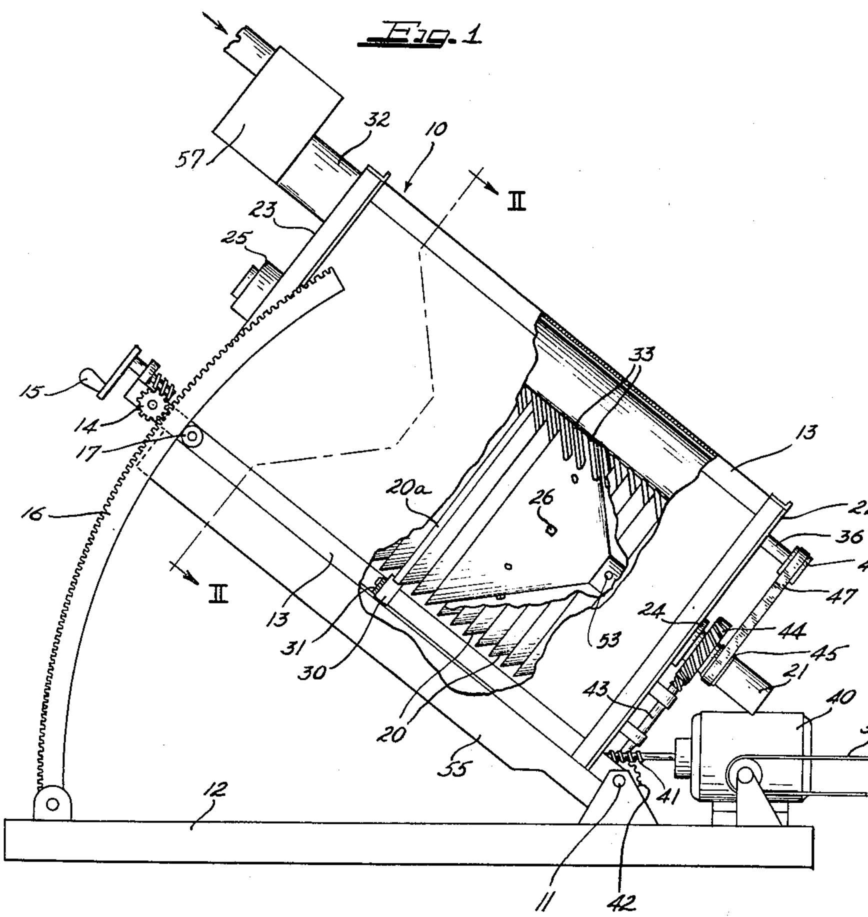
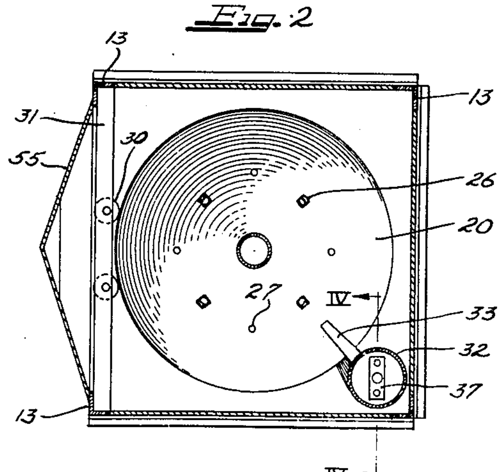


Fig. 2



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MULTI-CONE ORE CONCENTRATION APPARATUS

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Fig. 3

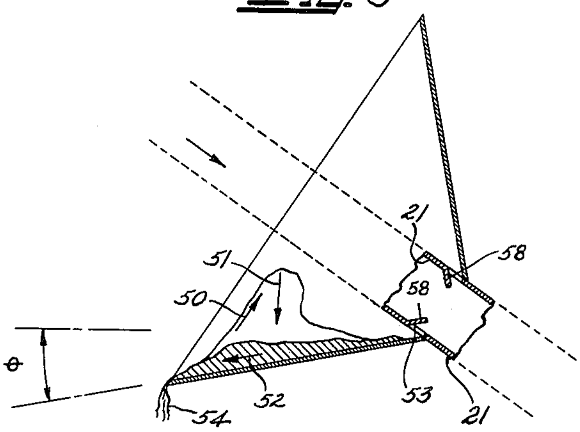


Fig. 4

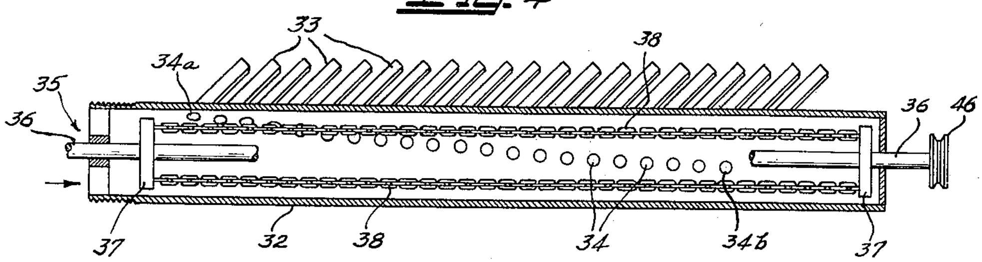
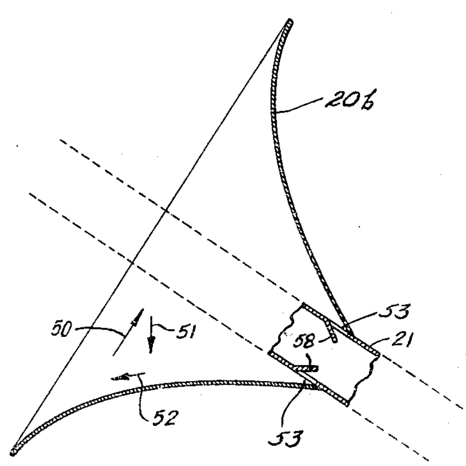


Fig. 5



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MULTI-CONE ORE CONCENTRATION APPARATUS

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5 Claims. (Cl. 209—482)

The present invention relates to the art of processing mineral bearing ores to increase the concentration of valuable minerals in the ore relative to the valueless earth materials with which the minerals are mixed. More particularly, the invention relates to apparatus for concentrating the "values" of a mineral bearing ore in a completely dry state and in the absence of any chemicals or the like.

For many years persons active in the mining arts have attempted to perfect an apparatus for effectively concentrating mineral ores. The search for such an apparatus has been intensive since there are large areas in the United States, and the rest of the world, where fair grade ores are available but where water is almost impossible to obtain. Even in localities where some water is to be had, the difficulty of obtaining it is such that low grade ores have not been commercially exploited as a result of the excessive costs involved. Further, existing ore treatment apparatuses and methods have failed, even though utilizing liquids, to satisfactorily remove valuable minerals from extremely low grade ores or to remove some of the lighter, yet valuable, minerals from ore.

In addition to the general demand for an apparatus for concentrating ore as outlined above, it has also been desired that a substantially portable arrangement be utilized which is independent of water or other liquids. This has been considered extremely desirable since in many instances mine openings are at very high altitudes and otherwise inaccessible, so that it is highly advantageous to be able to concentrate mineral ores efficiently at the mine entrance to reduce the tonnage of material that must be laboriously shipped out to a smelter. In the past, as a result of the lack of satisfactory portable equipment capable of ore treatment or concentration without external ingredients such as water, large numbers of otherwise valuable mining properties have gone unworked as inaccessible for practical purposes and hence commercially impracticable.

The present invention on the other hand provides an apparatus for ore treatment whereby dry ore is concentrated to many times the concentration of the ore as mined or previously discarded. According to the present invention, ore containing valuable materials to be removed therefrom is crushed to an extremely fine condition. This fine ore, preferably of a size permitting 100% passage through a 60 mesh screen and a substantial passage through a 200 mesh screen, is then agitated in a manner which I prefer to term a "mechanical backwash." By this agitation, wherein the ore is moved from a first position to a second position by means of a series of cyclical oscillations or agitations, the portions of the ore not bearing minerals are, in effect, moved or washed backwardly and the mineral bearing portions of the ore progress to the second point for removal to a smelter.

The cyclical mechanical backwash is preferably pro-

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vided, in accordance with the present invention, by means of distributing the ore onto the inside surface of a frusto-conical element constructed of sheet metal and which is rotating about its conical axis which is in turn inclined substantially from the vertical. In practice, it has been found that such a sheet metal cone rotating about an axis of inclination such that material lying on the inside surface of the cone must travel slightly upwardly to reach the axis of the cone, will effectively discard a substantial percentage of non-mineral bearing elements of the ore out through the open end of the cone and will direct the remaining, concentrated, mineral bearing elements upwardly toward the axis of the cone for collection. This concentrated ore may then be removed and smelted, and as a result of its high concentration, it may be readily shipped at a small fraction of the cost of transportation ordinarily incident to conventional mining practice. Further, in view of its great fineness, the transportation is simplified and in many instances where the mining operations are to be carried on at high altitudes it becomes practical to transport the dry, extremely fine, concentrated ore through small diameter pipes under the influence of gravity either unaided or aided by means of forced air.

It is therefore an object of the present invention to provide a novel method of ore concentration.

Another object of the present invention is to provide a method of ore concentration whereby ore may be mechanically worked in a dry state to decrease the proportion of non-mineral bearing material therein.

Still another object of the invention is to provide an apparatus for ore concentration wherein a mechanical backwash is provided.

Yet a further object of the present invention is to provide mechanical agitation means for removing non-mineral bearing elements from ore originally containing such non-mineral bearing elements in combination with mineral bearing elements.

Yet a further object of the present invention is to provide an extremely efficient apparatus for the refinement of mineral bearing material.

A feature of the invention is a rotary sheet metal conical structure having an axis of rotation substantially inclined from the vertical.

Yet a further feature of the invention resides in the provision of means for directing unconcentrated ore to a position in the middle of an internal conical surface for separation into mineral bearing and non-mineral bearing elements.

Still a further object of the present invention is to provide a means for removing even minute traces of valuable minerals from ores having mineral contents heretofore considered too low for practical processes.

Yet another object of the present invention is to provide apparatus for treating dry material to thereby remove, selectively, the heavy, relatively fine, portions thereof.

Still other and further objects and features of the present invention will at once become apparent to those skilled in the art from a consideration of the attached sheets of drawings wherein preferred embodiments of the present invention are shown by way of illustration only and, wherein:

Figure 1 is a side elevational view of ore concentrating apparatus constructed according to one form of the present invention;

Figure 2 is a cross-sectional view of the apparatus shown in Figure 1 taken along the line II—II thereof;

Figure 3 is a somewhat enlarged diagrammatic view of a single conical element of the apparatus shown in Figure 1;

Figure 4 is a cross-sectional view, partially broken away, of the feed mechanism utilized in connection with the apparatus shown in Figure 1 taken along line IV—IV; and

Figure 5 is a modified form of the structure shown in Figure 3 and capable of further concentrating certain types of ore or the like.

As shown on the drawings:

As was noted above, the present system envisages the concentration of mineral bearing ores after the ore has been initially crushed. Preferably, ore to be treated is first passed through a high speed rotary crusher of the type described in my Patent No. 2,607,539, granted August 19, 1952. Such a crusher very satisfactorily crushes lump quartz or similar materials from chunks 10 inches in diameter to a crushed product having a maximum dimension of ¼ inch. The material is then passed through a series of grinding rolls in which it is reduced to a minus 60 mesh, or material capable of 100% passage through a 60 mesh screen. This material which in practice will consist of particles from slightly under 60 mesh size down to approximately 250 mesh size, is then concentrated in the apparatus shown in the drawings. While my own crusher, set forth in the above identified patent, is admirably suited to the work of crushing mineral bearing materials, it will be understood that any crushing apparatus capable of supplying ore at a size of approximately 60 mesh and smaller will adequately satisfy the requirements of the present system.

As shown in Figure 1, a multi-cone concentrator, generally indicated at **10** is pivotally mounted at **11** to a rigid base frame member **12**. As may be seen, the concentrator **10** is provided with a sub-frame **13** which cooperates with the pivot shaft **11** at one end and which carries an adjustable supporting mechanism at the other. The adjustable supporting mechanism comprises a gear **14** driven through reduction gearing, preferably of the worm and worm wheel type, by means of a manual hand crank **15**. The gear **14** cooperates with gear teeth on the rack **16** which is maintained against the gear **14** by means of a reaction roller **17**. The rack **16** is in turn pivotally secured at **17** to the frame **12**. While only one rack and gear set is shown, it will be understood that a second similar set is provided on the back side of the machine to provide for uniform support of the left hand end of the sub-frame **13**.

The concentrator apparatus carried by the sub-frame **13** comprises a series of generally conical elements **20** secured, preferably by welding, to a tubular core **21** supported in the end walls **22** and **23** of the closure housing, by means of antifriction bearings **24** and **25**, respectively. Each of the cones **20** is constructed of relatively thin sheet metal and the cones are maintained in supported alignment by interconnection with each other through cross braces. These braces comprise bolts **26** which extend from each cone to the next adjacent cone. Preferably all the cones **20** are identical, and each cone is accordingly provided with eight apertures **27** as shown in Figure 2, such that four of the apertures **27** are on a first diameter circle and the other four are on a second circle. Each of the brace bolts **26** thus extends from an aperture on an inner circle of one cone to an aperture on the outer circle of the next, and so on moving from left to right as viewed in Figure 1. In this manner, each of the cones is braced to the cone preceding it as well as the cone succeeding it in position on the hollow, tubular, core **21**. This bracing structure coupled with bracing structure rigidly securing the cone **20** at the left hand end of the series of cones to the core **21** provides an extremely rigid core assembly.

Additional support for the system is provided by means of a heavy duty cone **20a** secured to the tubular core **21** in the manner identical to that described above relative to the remaining cones **20**. The cone **20a** is,

however, preferably constructed of either heavy plate material or is a casting. Either of these constructions permits the cone **20a** to provide a load carrying function and as such it is supported by a pair of roller bearings **30** secured to the sub-frame **13** by means of cross member **31**. While only such brace with support bearings **30** is illustrated, it will be understood that if additional bracing of the series of cones intermediate the length of the core **21** is desired, additional heavy bracing cones **20a** may be provided at spaced intervals. This bracing substantially eliminates fatigue failures of the tubular core **21**, as well as failures of the sheet metal cones **20** through continued flexing at the brace bolts **26** which would occur in the absence of suitable support bearings **30**.

The mineral containing ore of approximately minus 60 mesh is fed into each of the cones **20** individually by means of a main feed tube **32** and individual feed tubes **33**. It is desired, that the material be fed into the individual tubes **33** on a substantially equal basis and in view of the inclination of the main feed tube **32**, provision is made for preventing the bulk of the material from being fed into the first few tubes **33**. This is accomplished in the present invention, as shown in Figure 4, by means of positioning the metering apertures **34** for the individual feed tubes **33** along a slightly helical path relative to the axis of the tube **32**. Thus, as shown in Figures 2 and 4, with the agitator **35** rotating in a clockwise direction, the first opening **34a** is positioned adjacent a horizontal line drawn through the axis of the tube **34** while the succeeding openings **34** approach closer and closer to the bottom of the tube **32** until the final opening **34b** is on an axis substantially vertical relative to the axis of the tube **32**. As a result of this relatively helical positioning of the openings **34** in the tube **32** it is somewhat more difficult for the ore to pass out through the initial openings than through the later ones and accordingly a relatively even distribution of materials into the series of cones **20** is provided.

In addition to the helical arrangement of the openings **34** distribution is materially aided by means of the rotary agitator **35**. This agitator comprises, as shown in Figure 4, a shaft **36** carrying a pair of cross members **37** between which a pair of link chains **38** are secured. It has been found that the perforate nature of the chains, as well as their flexibility provides an extremely efficient apparatus for the controlled movement of the ore. Besides eliminating any tendency of the ore to form lumps, the chains prevent the ore from moving too rapidly down the tube **32** to thereby overload the lower feed tubes **34**.

Drive mechanism, for rotating the tubular shaft **21** and the agitator **35**, is preferably provided by means of an electric motor **40** secured to the base **12**. Although it will be apparent that numerous drive connections may be employed for transmitting the power from the motor **40** to the shafts **21** and **36**, one satisfactory method is shown in Figure 1. As may there be seen, the motor is provided with a worm shaft **41** which rotates a worm wheel **42** loosely mounted on the pivot shaft **11**. A second worm wheel is secured to the worm wheel **42** and rotates in turn a second worm **43** which cooperates with the worm wheel **44** secured to the shaft **21**. The shaft **36** is then driven from the shaft **21** by means of a pair of variable pulleys **45** and **46**, and the V-belt **47** to provide selectively variable flow through the metering apertures **34**. This drive construction is operative independently of the angle assumed by the concentrator structure since power is delivered from the motor to the concentrator at a point coaxial with the pivot **11**. It will be understood, however, that various types of drive systems, including variable speed flexible drive shafts or V-belt connections can successfully be utilized without departing from the scope of the present invention.

The operation of the concentrator apparatus may be understood from consideration of Figure 3 wherein a single cone is shown in operating position. With the cone rotating clockwise as viewed in the direction of the arrow shown in Figure 3, material is deposited on the cone and is immediately moved, with the surface of the cone, upwardly in the direction of the arrow **50**. After a movement upwardly and forwardly in the direction of the arrow **50**, the individual grains of the ore material fall away from the wall of the cone, as a result of the pull of gravity, and accordingly drop the path straight toward the earth, as shown by arrow **51**. Since, as indicated above, the axis of the cone is adjusted so that the wall of the cone lies at an angle θ to the horizontal, gravity will continue to move the particles in the direction of the arrow **52**. As a result of the above tendency for particles to move first upwardly and forwardly, then downwardly, and then backwardly, a mechanical backwash is achieved.

It has been found that the backwash above described is highly selective in its operation. Actually, the movement of any individual particle along the paths indicated by the arrows **50**, **51** and **52** depends upon gravitational forces, centrifugal forces, frictional forces between the cone surfaces and the material, the hardness and bounce characteristics of the individual particle as well as the effects of cohesion and adhesion between particles and the center of gravity of the individual particle. In mining practice, it has been found that the pure mineral, such as gold, silver or the like, as well as its oxides or other compounds in which it appears in nature, have fairly high effective frictional coefficient characteristics and relatively little bounce. Additionally, the compounds containing the minerals are ordinarily substantially heavier than the non-mineral bearing components with which they are ordinarily mixed in the known ores. As a result of this fact, the minerals and their compounds have a decided tendency to advance up the inclined wall of the cone in a direction opposite to the arrow **52**, toward openings **53** in the tube **21**.

In moving toward the openings **53**, the heavier elements, containing the minerals, tend to sift down against the surface of the cone where they frictionally grip the cone surface and ride along with the surface of the cone in the direction of the arrow **50** a longer distance than the lighter, undesirable elements. Accordingly, the undesirable elements stay on the top of the mass of material and, as a result of their high bounce characteristic and light weight fall downwardly onto the top of the mass of material and bounce downwardly toward the left. In view of the relatively high bounce characteristics of non-mineral bearing materials such as, for example, quartz, there is a strong tendency for such materials to bounce, in a series of bounces, off the left hand lip of the cone as at **54** into the discard trough **55** immediately under the cones. On the other hand, the heavier materials bounce to a substantially lesser degree and as a result of their rather increased frictional coefficients, tend to remain much less mobile than the lighter non-mineral bearing components. Accordingly, while the mineral containing portions of the ore will follow the cycle shown by the arrows **50**, **51** and **52**, the frictional tendencies will prevent movement of the ore backwardly, or toward the left as shown in Figure 3 to a very appreciable extent and as a result the minerals will continually, through recycling, move upwardly toward the openings **53**. Although oftentimes the differentials in weight and coefficient of friction between mineral compounds and the valueless portions of the ore are slight, it has been found that the conical apparatus above described is extremely critical in its operation and will satisfactorily separate materials having only slight physical differences. Such materials may require slightly different angular settings of the axis of the cones and, accordingly, an extremely fine adjustment is provided in the form of the gearing **14** which is associated with the rack **16**. In actual practice, for concentrating ores having a combination of minerals such as gold, silver, lead, etc., it has been found that an angle of θ equaling approximately 4° is quite satisfactory.

The operation of the series of cones is substantially identical to that described above, except that in view of the fact that each individual cone will dispense concentrated ore into the tube **21**, deflector, or cover, plates **58** must be provided for covering the apertures **53**. These cover plates satisfactorily prevent concentrated ore from moving back outwardly through the openings **53** under the pressure of accumulated concentrate in the tube **21**. It will thus be apparent that the individual cones operate substantially in parallel and, accordingly, the output of the concentrating apparatus is directly proportional to the number of individual cones **20** used therewith. While approximately thirty such cones in a single machine have been found to operate at a high level of efficiency it will be understood that more or less cones may be utilized, and that if desired a single cone may be used. In fact, it is to be noted that in the case where a single cone is to be used, the "heads," or crushed ore, may be introduced into the cone in a batch and the minerals may be individually taken off at the center of the cone sequentially as separate compounds, while the "tails" pass off over the outer lip of the cone. For example, in experimental mining operations, it was found possible to mechanically remove concentrates of lead and zinc separately from ore containing both elements in compound. Such selectivity is, of course, not used when a large series of cones are used together and the continuous output is removed by way of a single rotating tubular core such as shown at **21** in the drawings.

Additionally, when a single cone **20** is to be used, or when cones are to be operated in series rather than in parallel, the apertures **53** may be placed in the cones **20** immediately adjacent the cone support tube **21** rather than in the tube **21**.

When the equipment above disclosed is to be utilized with a specific ore or to concentrate materials having a particular substance therein to be removed, it may be desirable to provide a concentrator cone of somewhat different configuration from that shown at **20**. Thus, the somewhat more critical structure shown in Figure 5 may be found desirable in such instances. The concentrator cone shown in Figure 5 comprises a generally bell-shaped structure having a curvature substantially logarithmic in nature. Thus, the bell-shaped construction is substantially conical at its point of attachment to the tube **21** and flares outwardly substantially adjacent its outer rim or lip, with the rate of outward curvature increased as the rim is approached. It has been found that such a structure provides a somewhat sharper line between the tails, or discards, and the material fed into the openings **53**. Although the adjustment of the cone or bell **20*b*** shown in Figure 5 is much more critical than that of the straight cone shown in Figure 3, it may be adjusted to accurately concentrate on a more selective basis.

Still further modifications may be employed in the concentrator structure shown in Figure 3, without departing from the scope of the present invention. For example, it will be understood that corrugations may be provided in the surface of the cones for increasing the frictional contact of the materials with the cone. While such a step is not necessary to one handling most ores, it will be found in some cases to improve the separation characteristics, especially where the tails, or nonvaluable portions of the ore have a very great tendency to bounce freely, relative to the material having minerals in high concentration.

As above described, the concentrator **10** may be utilized with substantially any type of prior crushing equipment capable of supplying crushed ore of approximately minus 60 mesh at the upper or left hand entrance to the feed tube **32** as viewed in Figure 1. Additionally, in order to assure ready flow of the material into and through the tube **32**, an impactor is preferably provided, as at **57**, at the tube inlet. This impactor scours the ore as it enters the concentrator **10** and assures that no lumps are present which might interfere with proper distribution through the tubes **33**. Power for rotation of the impact elements of the impactor **57** may be derived from the shaft **36** or, alternatively, from a separate motor drive.

The concentrating apparatus above described has been found in practice to provide a concentration of ores tested of at least 4 to 1 and in some cases as much as 10 to 1. In other words, it has been discovered that ores heretofore commercially unfeasible for profitable mining operations were concentrated to a point where the ore was well worth smeltering, and ores of an initially high value were concentrated to a dollar value at least four times that of the value of the ore as initially presented to the concentrating apparatus. In view of the relatively light nature of the machinery here involved, and its extremely efficient concentration of ore, it has been found that the present apparatus permits the operation of mines heretofore considered worn out or useless. Further, the equipment has proved effective in the treatment of marginal ores of such important elements as uranium where the mineral percentages in the ore have run relatively small in this country.

It will thus be understood that I have provided a novel and greatly improved structure for the treatment of ore, whereby the "values" or valuable minerals in an ore may be substantially increased per ton of concentrated ore, thereby permitting the reclamation of large amounts of valuable minerals heretofore considered unavailable to mankind.

It will further be understood that variations and modifications may be made in the structure above set forth without departing from the scope of the novel concepts of the present invention and it is accordingly my intent that the present invention be limited solely by the scope of the appended claims.

I claim as my invention:

1. A dry ore concentrator comprising a tubular shaft, a plurality of sheet metal elements of increasing diameter secured in nested relation to said shaft at their respective points of least diameter, means rotatably supporting said shaft at an angle to the horizontal for rotating said elements about an inclined axis whereby any given point on the inside surface of the respective elements moves from a position having a slight incline relative to the horizontal in the opposite direction to the incline of said shaft to a generally upright inverted position, means for placing finely divided ore on the inside surface of said element, apertures in said shaft adjacent the junctions of said elements therewith and a baffle plate positioned inside said shaft above each aperture therein for preventing material moving down said shaft from passing laterally out through said apertures.

2. A dry ore concentrator comprising a tubular shaft, a plurality of frusto-conical sheet metal elements of increasing diameter secured in nested relation to said shaft at their respective points of least diameter, means rotatably supporting said shaft at an angle to the horizontal for rotating said elements about an inclined axis whereby any given point on the inside surface of the respective elements moves from a position having a slight incline relative to the horizontal in the opposite direction to the incline of said shaft to a generally upright inverted position, means porting said shaft to the spaces between adjacent elements, baffle means preventing flow of ore from said shaft outwardly into the space as between adjacent elements, and means for adjusting the angle of inclination of said shaft.

3. A dry ore concentrator comprising a tubular shaft, a plurality of sheet metal elements of increasing diameter secured in nested relation to said shaft at their respective points of least diameter, means rotatably supporting said shaft at an angle to the horizontal for rotating said elements about an inclined axis whereby any given point on the inside surface of the respective elements moves from a position having a slight incline relative to the horizontal in the opposite direction to the incline of said shaft to a generally upright inverted position, means for placing finely divided ore on the inside surface of said element, apertures in said shaft adjacent the junctions of said elements therewith, a baffle plate positioned inside said shaft above each aperture therein for preventing material moving down said shaft from passing laterally out through said apertures, enclosure means surrounding said elements and having an aperture in the bottom thereof for discarding non-mineral bearing portions of said ore, and discharge means at the lower end of said tubular shaft for accumulating concentrated ore.

4. A dry ore concentrator comprising a tubular shaft, a plurality of sheet metal elements of increasing diameter secured in nested relation to said shaft at their respective points of least diameter, means rotatably supporting said shaft at an angle to the horizontal for rotating said elements about an inclined axis whereby any given point on the inside surface of the respective elements moves from a position having a slight incline relative to the horizontal in the opposite direction to the incline of said shaft to a generally upright inverted position, means for placing finely divided ore on the inside surface of said element, apertures in said shaft adjacent the junctions of said elements therewith and a baffle plate positioned inside said shaft above each aperture therein for preventing material moving down said shaft from passing laterally out through said aperture, said means for placing finely divided material on the inside surface of said elements comprising a main feed tube extending substantially parallel to said tubular shaft at a point thereabove and a plurality of individual feed tubes extending from said main feed tube toward said tubular shaft and extending between adjacent elements.

5. A dry ore concentrator comprising a tubular shaft, a plurality of sheet metal elements of increasing diameter secured in nested relation to said shaft at their respective points of least diameter, means rotatably supporting said shaft at an angle to the horizontal for rotating said elements about an inclined axis whereby any given point on the inside surface of the respective elements moves from a position having a slight incline relative to the horizontal in the opposite direction to the incline of said shaft to a generally upright inverted position, means for placing finely divided ore on the inside surface of said element, apertures in said shaft adjacent the junctions of said elements therewith and a baffle plate positioned inside said shaft above each aperture therein for preventing material moving down said shaft from passing laterally out through said aperture, said means for placing finely divided material on the inside surface of said elements comprising a main feed tube extending substantially parallel to said tubular shaft at a point thereabove and a plurality of individual feed tubes extending from said main feed tube toward said tubular shaft and extending between adjacent elements and means associated with said main feed tube for distributing said ore substantially evenly to said individual feed tubes.

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