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Deringer

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[54] **METHOD AND APPARATUS FOR CONCENTRATING ORE PULPS**

[75] Inventor: **Dewitt C. Deringer**, Golden, Colo.

[73] Assignee: **Ben H. Parker, Jr.**, Sao Paulo, Brazil

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[52] **U.S. Cl.** .... **209/434,** 233/1 D, 233/14 R

[51] **Int. Cl.** **B03b 3/10**

[58] **Field of Search**... 209/434, 453; 233/1 D, 14 R, 233/12, 27, 28

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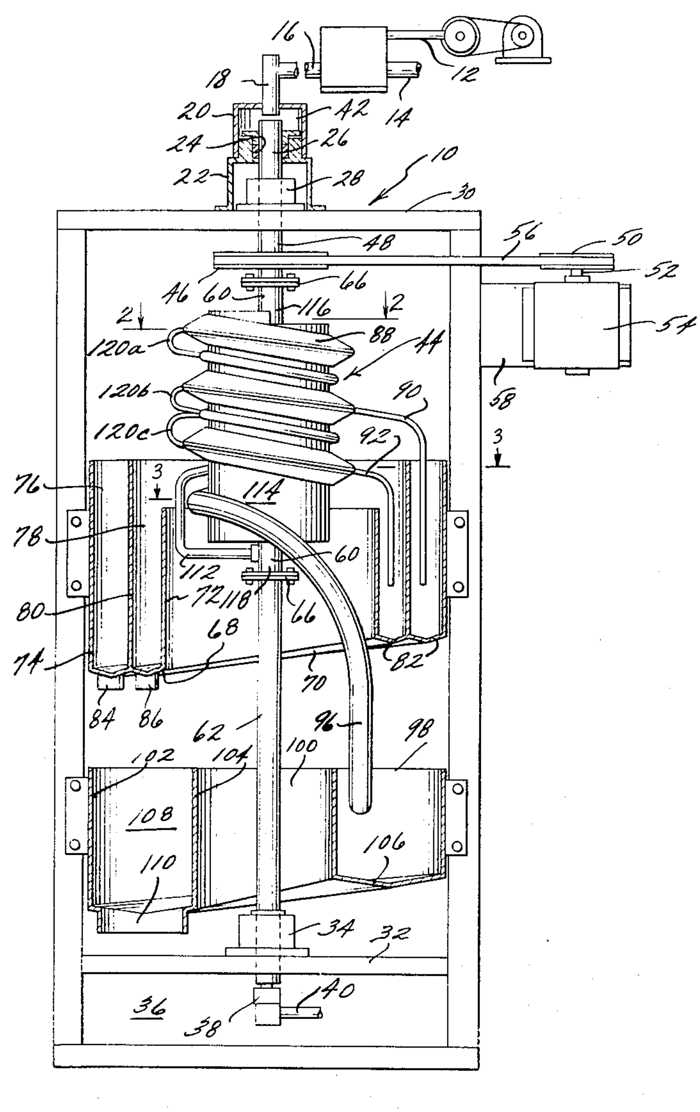
Primary Examiner—Frank W. Lutter
Assistant Examiner—Ralph J. Hill
Attorney, Agent, or Firm—Edwards et al.

[57] **ABSTRACT**

This invention relates to a centrifugal ore concentrator characterized by a spirally wound tunnel-forming member wound about a rotatable core into which an ore pulp is introduced. As the ore pulp gravitates, or is preferably forced, through the whirling spiral, the heavy minerals that have migrated to the outside of the tunnel under the influence of the centrifugal action are drawn off and separated from the lighter gangue particles that are similarly drawn off from the inside. The invention also encompasses the novel method of concentrating ore pulps which comprises feeding the pulp through a rotating spirally disposed tunnel with a pulsating action, dividing the stream and drawing off the heavier material from the outside and the lighter material from the inside.

5 Claims, 6 Drawing Figures



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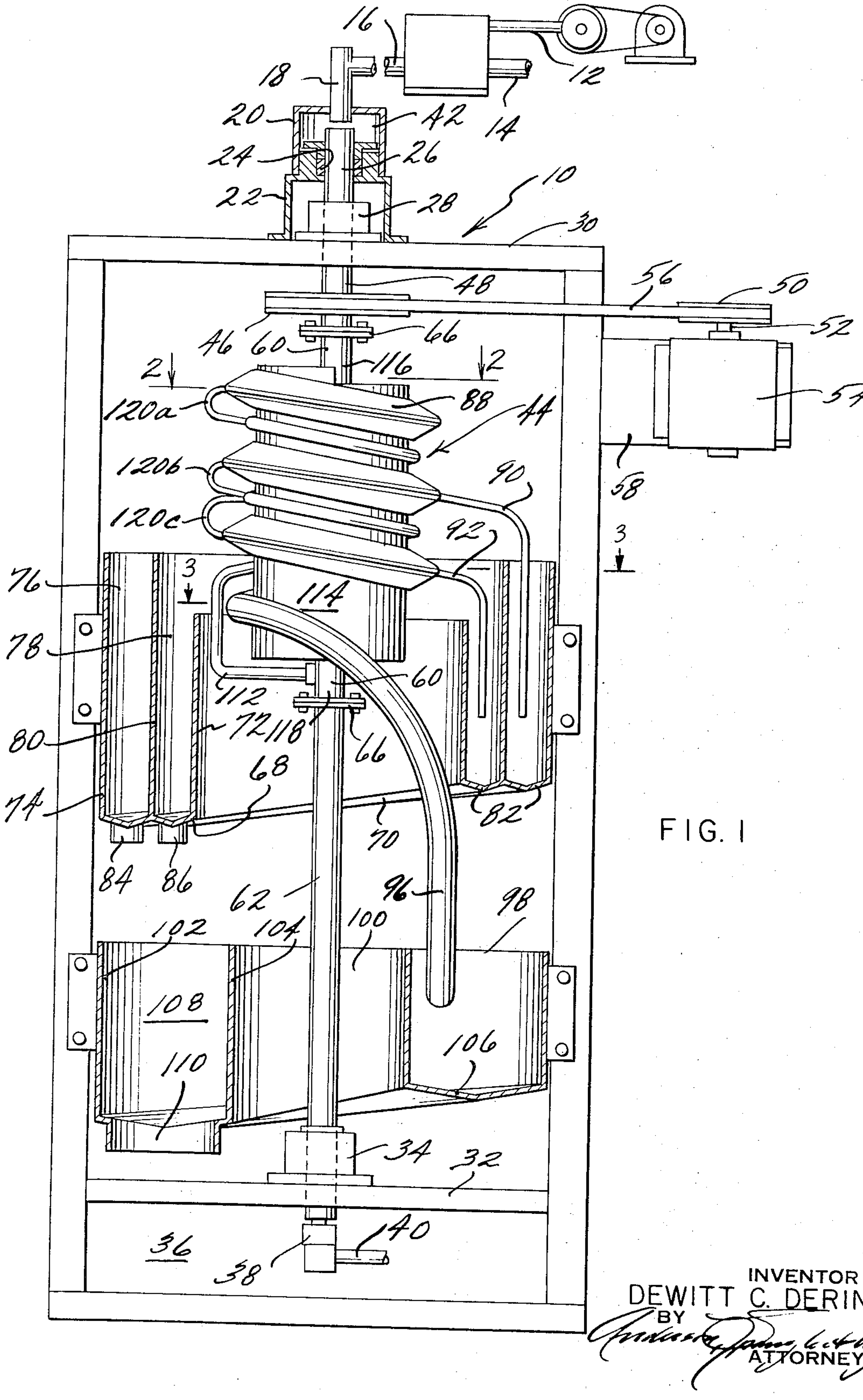

FIG. 1

INVENTOR
DEWITT C. DERINGER
BY
ATTORNEYS

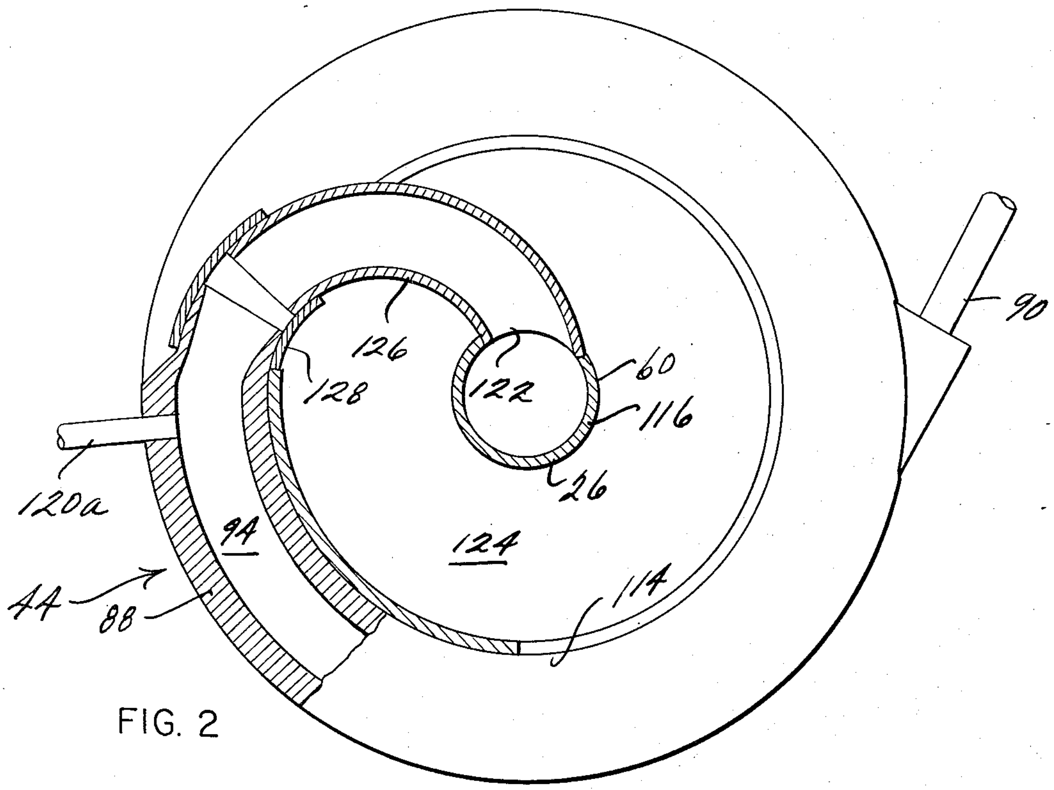

FIG. 2

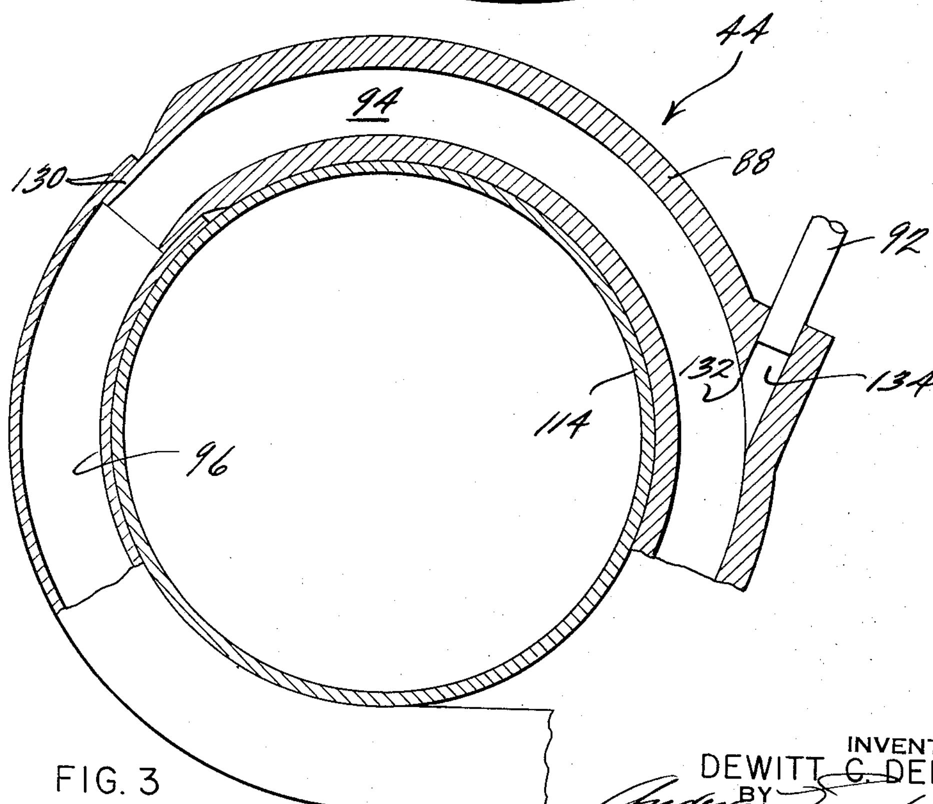

FIG. 3

INVENTOR
DEWITT C. DERINGER
BY
ATTORNEYS

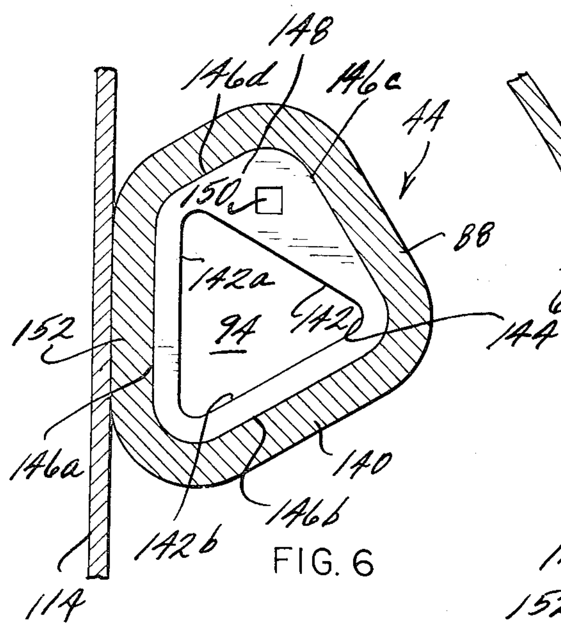

FIG. 6

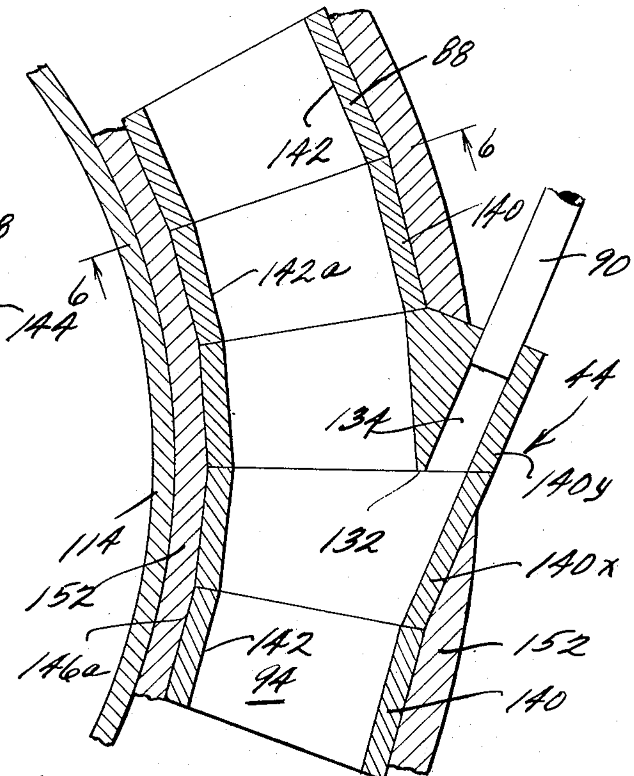

FIG. 5

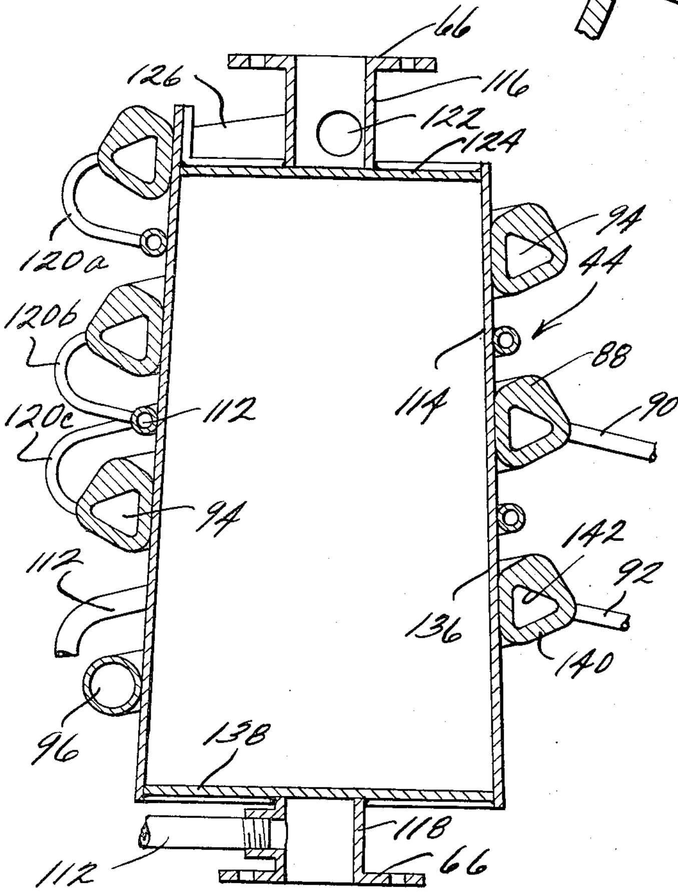

FIG. 4

INVENTOR
DEWITT C. DERINGER
BY
Anderson, Luedeka, Fitch, Even & Tabin
ATTORNEYS

METHOD AND APPARATUS FOR CONCENTRATING ORE PULPS

Ore pulps or slimes containing mineral values and gangue particles of similar density have, for a long time, presented the oredressing engineers with a problem of considerable difficulty. Gravity separation has proven to be only nominally effective as a means for concentrating ores containing particulate materials of nearly the same size and density and it has long been suspected that centrifugal separation would be the better method; however, up to now, no commercially acceptable method or apparatus based upon this principal has been found. In fact, over 40 years ago, namely in 1929, the United States Bureau of Mines published Technical Paper 457 in which they suggested that centrifugal separation should prove better than gravity concentration with the difficult slimes and pulpy ones but, despite numerous attempts to implement this suggestion on the part of eminent mining engineers, few, if any, have proven to be much more than a laboratory curiosity.

It has now been found in accordance with the teaching of the instant invention that an effective method and apparatus for concentrating ores employing centrifugal separation techniques can, in fact, be achieved which are both efficient and practical. The unique apparatus involves a whirling spirally wound coil containing one, or more, gates dividing the stream into inner and outer branches which are directed into separate reservoirs or launders. In the preferred embodiment of the apparatus, the slurry is constantly diluted as it migrates through the coil in order to maintain its fluidity and prevent the solids from packing along the tunnel walls. The mobility of the mixture is preferably maintained by forcing it through the system with a pulsating action which tends to inhibit the build-up of solids while, at the same time, breaking up any dams that do form.

It is, therefore, the principal object of the present invention to provide a novel and improved ore concentrator.

A second objective of the within-described invention is the provision of a centrifugal concentrator especially suited for use in the separation of finely divided particulate materials of similar density.

Another object of the invention herein disclosed and claimed is to provide a centrifugal ore concentration method wherein the raw material is force-fed through the system with a pulsating action.

Still another objective of the invention forming the subject matter hereof is to provide a method and apparatus for continuously concentrating ore pulps and slimes that utilize the novel technique of diluting the raw material as it migrates through the system.

An additional object is the provision of a centrifugal ore concentrator in which the concentrates and tails are continuously deposited in separate stationary launders from which they can be withdrawn for further processing or disposal even while the coil is still turning.

Further objects are to provide a centrifugal ore concentrator that is versatile, efficient, compact, reliable, relatively inexpensive, easy to operate, and one that is readily adapted for use with ores of various types and characteristics.

Other objects will be in part apparent and in part pointed out specifically hereinafter in connection with the description of the drawings that follows, and in which:

FIG. **1** is a view, partly in elevation and partly in diametrical section showing the centrifugal ore concentration apparatus of the present invention, certain portions thereof having been broken away to conserve space while the pump that delivers the raw material has been illustrated schematically to a reduced scale;

FIG. **2** is a somewhat diagrammatic section taken along line **2—2** of FIG. **1,** greatly enlarged;

FIG. **3** is a similar section taken along line **3—3** of FIG. **1** to the same scale as FIG. **2**;

FIG. **4** is an enlarged fragmentary detail showing the rotating frusto-conical core of the concentrator encircled by the spirally wound tunnel-forming member and associated waterline, portions of the latter having been broken away to conserve space;

FIG. **5** is a still further enlarged fragmentary view showing a section of the segmented tunnel-forming member that includes a gate to divide the stream and means connected to the outside branch for separating the heavier mineral values from the lighter gangue material; and,

FIG. **6** is a section taken along line **6—6** of FIG. **5** and to the same scale as the latter.

Referring next to the drawings for a detailed description of the present invention and, initially, to FIG. **1** for this purpose, reference numeral **10** has been chosen to designate the concentrator in its entirety while numeral **12** similarly denotes a raw material pump operatively associated therewith. Conduit **14** is connectable to a supply of the raw material which requires beneficiation and it delivers same to the inlet of pump **12** or, alternatively, directly to the inlet of the concentrator in instances where no pump is used. Under some circumstances it is possible to effect a meaningful concentration by relying upon gravity flow alone of the raw ore through the whirling convolutions of the concentrator **10,** however, certainly the best results are realized when the raw material is force-fed through the unit by means of pump **12.** In fact, in accordance with the teaching of the preferred beneficiation method, the raw pulp or slime is pumped with a pulsating type of flow through the system rather than at a constant or near constant flow rate. In other words, pump **12** is preferably one of several commercially-available pulsating types capable of handling slurries with a substantial proportion of solids suspended therein while, at the same time, delivering same in intermittent surges at intervals of relatively short, but nevertheless discreet, duration. It has been found that a pulsating flow like that described above serves to both prevent the build-up of solids along the walls of the convoluted tunnel and, simultaneously, break down any dams or other obstruction that may have begun to form.

The outlet **16** of the pump is connected to the inlet **18** of the concentrator which terminates in an endcap **20** that mounts atop the cover **22** that carries the packing gland **24** within which hollow shaft **26** is sealed for rotation. Gland **24** has been shown somewhat sehematically as the details of its construction form no part of the present invention and such units are well known in the prior art. Shaft **26** is journalled in shaft bearing **28** that is mounted on top of the main frame **30** within cover **22.** Shaft **26** continues in one form or another all the way through the main frame and out the bottom of crossframe member **32** where a second journal **34** therefor is located. As the shaft opens into area **36** beneath crossframe member **32** in the frame, it connects into a packing gland **38** through which water from a water line **40** enters the system.

Back up at the top again, it will be seen that the inlet to the concentrator discharges into a fluid-tight sealed chamber **42** defined by endcap **20** and cover **22.** As this chamber fills, the slurry is forced under pressure into hollow shaft **26** preparatory to entering the helicoidal convolutions of the centrifuge subassembly that has been designated in its entirety by reference numeral **44.** Note in this connection that slurry does not pass directly into hollow shaft **26** from the pump, but instead, enters chamber **42** located therebetween which functions as a small surge tank to reduce the shock loads imposed by the repeated slugs of raw material that are fed into the system by pump **12** while, at the same time, maintaining the desired fluctuations in fluid pressure that have been characterized herein as "pulsating" flow.

A pulley **46** mounted on the upper section **48** of shaft **26** is connected to a second pulley **50** on shaft **52** of motor **54** by belt **56.** Motor **54** is supported outside the main frame on motor mount **58** and provides the drive for rotating the centrifuge. In the particular form shown, shaft **26** is in three sections, an upper section **48,** a middle section **60** and a lower section **62,** the adjoining ends of which are provided with flange-type shaft couplings **66.** It is middle section **60** that carries the centrifuge subassembly **44** to which all the remaining figures of the drawing are directed and which will be described in detail presently. Flow between the upper and lower sections of shaft **26** bypasses most of center section **60** and is directed instead through the centrifuge subassembly.

Still referring to FIG. **1,** mounted on the main frame in encircling relation to the lower end of the centrifuge subassembly is a stationary concentrate launder subassembly **68.** The latter subassembly has a large central opening **70** through which shaft **26** passes and within which it and the centrifuge subassembly rotate. In the particular form illustrated, the portion of subassembly **68** located between inner and outer concentric cylindrical walls **72** and **74** is divided into a pair of upwardly opening annular concentrate-receiving compartments **76** and **78** by partition wall **80** disposed therebetween and sloping bottom wall **82.** The latter wall slopes downwardly off in both directions to a diametrically opposed point where a pair of drains **84** and **86** are located, one of which opens into each of the two compartments and provides the means by which the concentrates are removed therefrom.

As illustrated herein, the helicoidal convolutions of the tunnel-forming member **88** of the centrifuge subassembly **44** are tapped into at two different points by concentrate drain tubes **90** and **92** whose function it is to draw off concentrates flowing along the outside wall of the tunnel **94.** These two tubes turn right along with the other elements of the centrifuge and their discharge ends terminate, respectively, within compartments **76** and **78.** It is obvious that by placing the axis of concentric annular compartments **76** and **78** essentially coincident with the axis of rotation of the centrifuge subassembly that the concentrate drain tubes can move around within their respective compartments without contacting the walls thereof. By drawing off the concentrates at two or more points as shown, the heaviest of the fractions comes off first or the farthest upstream while the next heaviest exists through tube **92** into the inside compartment **78,** and so on. If the apparatus is like that shown in FIG. **1** where only two taps are made and a two-compartment launder catches the concentrates, the second tap **92** should be made well along toward the end of the tunnel-forming member **88** where the ultimate achievable separation will take place. Since the initial fraction will, in all likelihood, be considerably larger than the second or any subsequent one except under very rare circumstances, outside compartment **76,** or whichever one receives the first fraction is preferably the largest.

Extending down through the central opening **70** in the concentrate launder subassembly **68** is the tailings drain tube **96** which empties into the tailings launder **98** disposed within the main frame. Tailings launder **98** also has a central opening **100** therein through which passes the lower section **62** of shaft **26.** The outer and inner cylindrical walls **102** and **104** of the tailings launder cooperate with one another and with the sloping bottom wall **106** to define a single tailings compartment **108** having a drain opening **110** at its lowest point. As was the case with the concentrate drain tubes **90** and **92,** the discharge end of the tailings drain tube whirls around within the confines of the stationary open-topped tailings compartment **108** as the centrifuge subassembly **44** rotates. While it might appear from FIG. **1** that the concentrate compartment drains empty directly into the tailings compartment therebeneath, this is obviously not the case and appropriate drain lines (not shown) are connected into these drain openings to direct the products wherever needed for further processing.

Before leaving FIG. **1** it will be seen that the stream of water that enters the lower end of shaft **26** through packing gland **38,** emerges near the bottom of the middle section **60** and is fed into an external supply line **112** which rotates with said shaft inside the central opening **70** in the concentrate launder **68** before spiralling upwardly around the drum-like support **114** that carries the tunnel-forming member **88.** As will appear presently in connection with FIG. **4,** support **114** is actually a greatly enlarged portion of shaft **26** located intermediate the flanged ends of its center section **60.** Neither the raw material nor the water coming up from the bottom enters this drum-like support because the short stubshaft portions **116** and **118** at the ends of the center section have blind adjacent ends (see FIG. **4**). Thus, external supply line **112** bypasses the interior of supporting drum **114** and spirals upwardly around the outside thereof between the descending convolutions of the tunnel-forming member **88.**

While the water circulating through the coils of supply line **112** ascends around the outside of drum-like support **114,** it actually enters the system and moves in concurrent flow relation to the slurry descending through the tunnel **94.** This is accomplished by tapping into supply line **112** with short branch tubes **120*a*, 120*b*** and **120*c*** that connect directly into the tunnel through the wall of tunnel-forming member **88.** While supply line **112** and its branches **120*a*, 120*b*** and **120*c*** are intended for use in diluting the slurry or pulp as it moves through the coils of the centrifuge, it can also be used for the purpose of introducing other ingredients into the system should the need therefor arise. For example, in the event of blockage, one may wish to introduce an appropriate solvent into the unit. The overall efficiency of the system may even be enhanced by introducing such chemical additives as wetting agents, agglomerating agents, and the like directly into the moving slurry.

Next, with reference to FIGS. **2** and **3**, the functional structures within centrifuge subassembly **44** will be set forth in detail. First, looking at FIG. **2** it will be seen that the middle section **60** of shaft **26** has an opening **122** in the wall thereof above the top **124** of the drum-like support **114** that defines one of the plugs blocking the latter. Connected into this opening in a manner to receive the raw material therefrom and deliver same to the inlet of the tunnel-forming member **88** is a curved delivery tube **126.** A short tubular coupling **128** forms the fluid-tight junction between adjacent ends of the latter.

Branch **120**a of the water line **112** has been shown connected into the tunnel in the tunnel-forming member **88** immediately downstream of its inlet although this location is not critical and it could just as well enter the system elsewhere. The concentrate drain tube **90** that carries off the first and heaviest of the fractions is shown located well downstream of the inlet in FIG. **2.**

In FIG. **3,** the manner in which the discharge end of the tunnel-forming member is fastened into the tailings drain tube by means of a simple male-female telescopic connection **130** is clearly shown. Immediately upstream of this connection is the gate **132** that divides the stream and allows the heaviest of the fractions remaining therein to be drawn off through tube **92** connected into concentrate discharge branch **134.** As previously mentioned, there may be several such concentrate drains positioned to remove concentrate fractions from various points throughout the centrifugal system.

Next, referring to FIG. **4,** it will be seen that drum-like support **114** is essentially a frustum of a right cone defined by conical wall **136,** the upper and lower ends of which are capped by top and bottom walls **124** and **138.** While entirely adequate separation would certainly take place if the support member were cylindrical rather than frusto-conical, the latter shape has the advantage of steadily increasing the centrifugal force acting upon the descending stream of material being treated due to its gradually moving farther out from the axis of rotation. In a system like the one shown where the heaviest and most easily separated fraction is removed about half way through the centrifuge, it is highly desirable to exert a greater centrifugal force near the downstream end of the system where the differentials one has to work with are narrower and further separation becomes more difficult for this reason.

Finally, with reference to FIGS. **5** and **6,** it can be seen that one specific type of tunnel-forming means **88** that can be employed to advantage is made up in segmented form from a plurality of individual molded ceramic blocks **140** having a triangularly shaped opening **142** therein that defines tunnel **94** when said blocks are connected together in end-to-end relation as shown. The use of ceramic blocks in preference to pipe or tubing of some sort has the advantage of making it possible to provide the tunnel with hard glazed walls better able to resist the abrading action of the solid particles suspended in the pulsating pulp stream. Along this same line, a glazed tunnel wall is less likely to resist the flow of material to a point where solids will collect along the outside thereof. Also, while the pulps and slurries being concentrated in the system are seldom corrosive, the flushing fluids used to clean same may well be.

The main tunnel-forming blocks **140** are all identical to one another and each has a more or less trapazoidal cross section having an equilateral triangular opening therein. One side of the triangular opening **142***a* is essentially parallel to the adjacent conical surface of the drum-like support **114** while the angle **144** opposite said side is located on the outside of the tunnel. In fact, tests have shown that angle **144** should either be bisected by a line normal to the axis of drum rotation or, preferably, such a line will divide this angle in such a way that the smaller of the two included angles is on top. For instance, with an equilateral triangular tunnel like that shown, the line normal to the axis will divide 60° angle **144** either in half or, when using a conical drum like that shown, the angles will be more like 25° on top and 35° on the bottom. If, on the other hand, the lesser of the two angles is on the bottom, the concentrates tend to stay up along the top of the tunnel and miss the gate **132** and associated discharge branch. As illustrated, the exterior wall **146***a* on the inside of the spiral adjacent drum **114** is also essentially vertical and parallel to tunnel wall **142***a* as is the case with the lower exterior wall **146***b* and bottom tunnel wall **142***b*. The top exterior surfaces **146***c* and **146***d*, on the other hand, do not parallel the top surface **142***c* of the tunnel, but instead, they cooperate therewith to encompass a thickened wall **148** having a passage **150** therethrough as shown. When the blocks are aligned to form the coils of the spiral, passages **150** are also aligned and, in fact, are for the purpose of receiving a cable or rod which, upon being threaded therethrough, holds the blocks in assembled helix-forming relation.

At each point in the convolutions of the tunnel-forming member **88** where concentrates are to be drawn off, two specially designed blocks **140***x* and **140***y* are used which cooperate with one another to define gate **132** and concentrate discharge branch **134** as shown. The seams between the blocks may, if desired, be caulked to reduce leakage and pressure losses and, in addition, the coils are preferably wrapped from end-to-end with a fibreglass tape **152** which is sufficiently resilient to allow the individual blocks to adjust relative to one another so that their adjacent ends mate properly. The wrapping also tends to seal the joints between blocks and, of course, insulate the coils. Obviously, ordinary helicoidal tubing could be substituted for the tunnel-forming element shown and the system would still function as intended.

Some idea of the capabilities of the unit described above can be appreciated from the fact that a slurry containing minus 200 mesh marble and minus 325 mesh ferrosilicon after being concentrated therein gave the following results:

	Percent Ferrosilicon	Recovery
Heads	1.56	
Concentrates	6.90	91.3
Tails	0.167	

As far as operating speeds are concerned, the best results have been achieved when the centrifugal force developed is upwards of 75 to 100 times that of gravity although, obviously, there is no sharply defined range and lesser speeds will still prove quite effective in terms of bringing about a centrifugal separation of the mineral values from the gangue.

The improved ore concentration method comprises pumping the slurry under pressure with a pulsating motion through one or more coils of a helicoidal tunnel while whirling same, dividing the stream into two branches downstream of the inlet and recovering the outside stream.

What is claimed is:

1. The centrifugal ore concentrator which comprises: tunnel-forming means defining a helicoidal passage having an inlet at one end and an outlet at the other mounted for rotation about a vertically-disposed axis; pump means connected to deliver an ore pulp under pressure into the inlet of the tunnel-forming means while it is rotating; drive means connected to the tunnel-forming means operative upon actuation to rotate same at a speed sufficient to bring about centrifugal separation of the heavier of two solid fractions suspended in the ore pulp circulating therethrough; gate-forming means disposed within the tunnel-forming means downstream of the inlet for dividing the ore pulp stream into an inside branch in which are suspended the major portion of the lighter of the two solid fractions and an outside branch containing primarily the heavier solid fraction; means defining a concentrate launder disposed adjacent the outlet of the tunnel-forming means; tubular means for removing the outside branch of the pulp stream from said tunnel-forming means and transferring same to the concentrate launder connected into the tunnel-forming means adjacent the gate-forming means for rotation therewith; and, a fluid line rotatable with the tunnel-forming means connected to introduce fluids therein at one or more points, said fluid means being connectable to a stationary supply of fluid under pressure.

2. The centrifugal concentrator as set forth in claim **1** in which: a shaft having a hollow inlet end, a hollow outlet end and a drum-like enlargement intermediate its ends is journalled for rotation in vertically disposed relation; a main fluid line is carried by the drum-like enlargement for rotation therewith; one or more branch fluid lines interconnect said main line and the interior of said tunnel-forming means; and, in which the hollow outlet end of the shaft is connected to receive fluid under pressure from a stationary source thereof while rotating and deliver same to the main fluid line.

3. The method of separating the heavier particulate fraction from a fluid suspension containing both heavy and light fractions which comprises: pumping the slurry under pressure with an intermittent pulsating motion through the coils of a whirling helicoidal passage, dividing the slurry stream into two branches, one flowing along the inside wall of the passage and the other flowing along the outside wall thereof, tapping off the outside branch and collecting same.

4. The method as set forth in claim **4** which includes the steps of dividing the stream at more than one place within the passage, tapping off the outside branch immediately downstream of each such division, and collecting the outside branches while keeping same separate from one another.

5. The method as set forth in claim **4** which includes the step of continuously diluting the slurry while it circulates through the passage.

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