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NUTATING HELICOID SEPARATING APPARATUS

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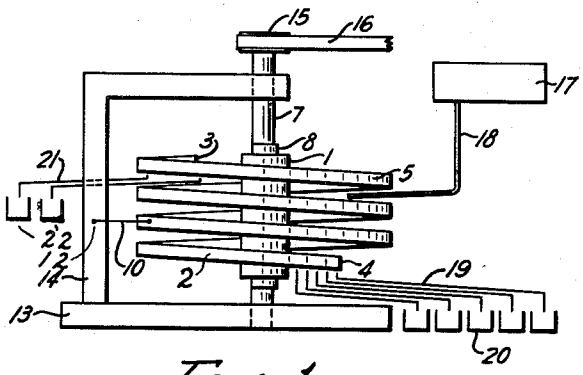


Fig. 1

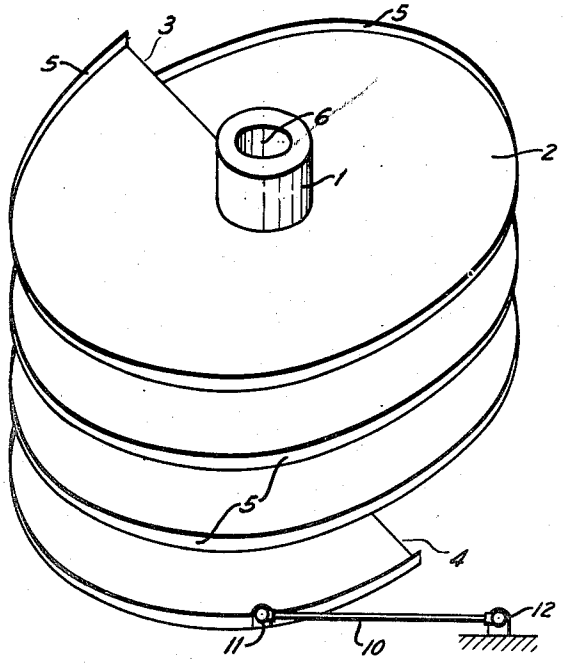


Fig. 2

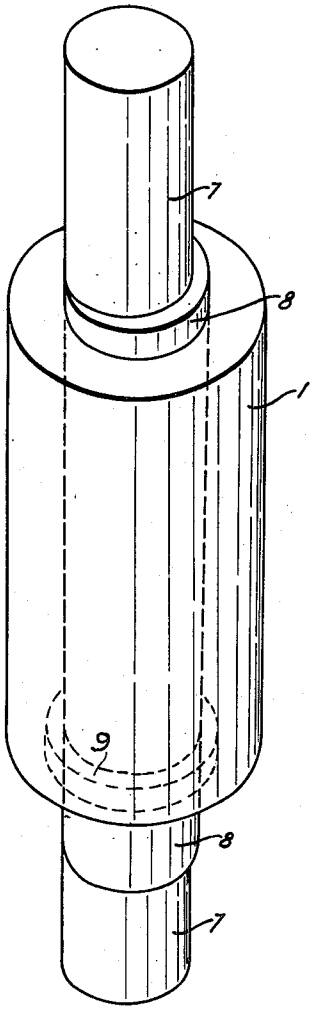


Fig. 3

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NUTATING HELICOID SEPARATING APPARATUS

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7 Claims. (Cl. 209—434)

This invention relates to a nutating helicoid separating device for particulate solid material and more particularly to a differentially offset helicoidal device for the separation of solid particles having different specific gravities.

The separation of solid particles of various densities by means of vibrating and oscillating tables is well known. I have invented a new form of separating table which is a considerable improvement over earlier types in that it takes advantage of a different kind of motion than has previously been used in separating tables, and in that much less space and much less power is required for any separation than has been the case with prior known types. My device effects a better separation on many ores than can be obtained by prior known devices. My device also effects a large-scale diminution in the requirement for floor space and in the size and cost of the buildings needed to house the equipment for any specific quantity of material to be handled. This saving in size and cost of buildings to house these devices is in itself a very important item.

This invention can best be described in connection with the accompanying drawings, in which

Figure 1 is an elevational view of the nutating helicoid separating device,

Figure 2 is a perspective view of the helicoid, and

Figure 3 is a perspective of the axial sleeve which constitutes the central and supporting construction of the helicoid and it also shows the drive shaft of the device and the eccentric mounted thereon.

Referring to Figure 1, element **1** is a hollow cylindric sleeve carrying a helicoid **2** extending from an upper terminal lip **3** to a lower terminal lip **4** and fitted with an upright flange or rim **5**, all of which appear also in Figure 2. The hollow cylindric sleeve **1**, which constitutes the core of the helicoid **2**, fits around an eccentric section **8** on shaft **7**, all of these being carried by the frame comprising base **13** and upper support **14**. A tie bar or cable **10** connects from helicoid **2** to frame **14** to keep the helicoid from rotating when drive shaft **7** is rotated. A pulley wheel **15** is fastened to shaft **7** and the device is driven by belt **16**. Or the shaft **7** may be driven by an electric motor or a steam turbine or other power source through any conventional power transmission device. In any case it is desirable that the power source or transmission device be capable of rotating the shaft at a wide range of revolutions per minute. A tank or bin **17** is provided to hold a supply of the slurry to be fed through conduit **18** to the helicoid **2**. A series of chutes **19** are provided to receive material discharged from the lower extremity or lip of the helicoid, the various chutes of the series being arranged to receive from a succession of points from the core **1** to the outer periphery of the helicoid and to conduct their various streams of separated material to a series of receptacles **20**. A similar series of chutes **21** are provided to similarly conduct streams of separated material from different sections of the upper lip **3** to a series of receptacles **22**. Considerations of space have limited the number of chutes shown in the

series **19** and in the series **21**, but any number of such chutes, either few or many, may be provided for each series, according to the material being processed and the number of cuts desired.

Referring to Figure 2, element **1** is a hollow cylindric sleeve with vertical axis which constitutes the central core around which a helicoidal surface **2** is symmetrically positioned and to which the said surface is fastened throughout its length. Helicoidal surface **2** is constructed in axial alignment with hollow cylindric sleeve **1** and it extends continuously from its upper extremity or lip at point **3** through several turns to its lower extremity or lip at point **4**. An upright flange around the periphery of helicoid **2** is indicated at **5**. Axial sleeve **1** is hollow through the center as shown at **6** to receive the eccentric portion **8** of drive shaft **7**, further described in connection with Figure 3, and to act as a bearing and transmit the power of the shaft to the helicoid **2**. A collar **9** supports sleeve **1**. A tie **10**, which may be either rod, cable, or chain, extends from a point **11** on the helicoid to a fixed point **12** of the adjacent floor or wall to prevent rotation resulting from the action of the eccentric **8** on sleeve **1**.

Referring to Figure 3, element **1** is the hollow cylindric sleeve previously mentioned which constitutes the core around which the helicoid surface **2** is constructed. Extending through the hollow center **6** of cylindric sleeve **1** is shaft **7**, advantageously constructed as shown with an integral eccentric section **8**. The eccentric section **8** may of course be constructed as a separate sleeve surrounding shaft **7** and keyed thereto. Drive shaft **7** is journaled solidly at the upper and lower ends in the frame comprising upper support **14** and base **13** and may be driven by any conventional source of power. A collar **9**, fastened to the lower part of eccentric section **8** supports the weight of sleeve **1** and helicoid **2**.

The degree of eccentricity of section **8** is less at the lower end of the helicoid than at the top. For instance the eccentric may be designed to give a horizontal motion of 0.15 inch to sleeve **1** at the top of the helicoid but only 0.03 at the base of the helicoid. Set up for various operations, the degree of eccentricity at the bottom of the helicoid may be anywhere from one-half to one-twentieth the degree of eccentricity at the top of the helicoid, but the eccentricity at the bottom will seldom be less than necessary to give a horizontal motion of 0.005 inch.

The oscillation of the helicoid of this invention by an eccentric which has a different degree of eccentricity at the top from that at the bottom—which we choose to call differential eccentricity—effects not only a lateral motion of the helicoid but also a vertical motion. This vertical motion, of no amplitude whatever at the axis, builds up with outward progression along any radius and tends to "float" or lift the particulate material being processed, thereby reducing the inter-particle friction and the friction of the particles with the helicoid surface, and so enhancing the efficiency of separation and the quantity that can be processed in unit time.

In the operation of my device the helicoid **2** does not rotate in any manner whatever, either about its own axis, or about the axis of the drive shaft, or about the axis of the eccentric. But rather the axis of the helicoid is, by means of eccentric section **8** of drive shaft **7**, revolved in small amplitude about the axis of drive shaft **7**. The result is what we may very well call non-rotative nutation, hereinafter referred to simply as nutation. The rotation of the eccentric **8** inside of sleeve **1** would tend to rotate sleeve **1** and its attached helicoid but such rotation is prevented by one or more restraining ties **10** extending from some portion of the helicoid, as indicated by numeral **11** on Figure 2 to some fixed point in the surroundings of the device such as a point on the ad-

jacent floor or wall, or to a point on the frame, as indicated by numeral 12.

In the operation of my device I customarily choose to feed the particulate material to the helicoid in a wet slurry, and this material is charged to the helicoid from a storage tank or bin 17 through conduit 18. A characteristic of my device is that some particles travel down the helicoid while other particles travel up the helicoid, and for that reason the charge material from bin 17 is introduced onto the helicoid at a point intermediate upper lip 3 and lower lip 4. In most instances the heavier particles will descend, while the lighter particles will rise. But the reverse can be true if the helicoid has inadequate pitch for the material being handled and the conditions of operation. The actual separation for any specific particulate material is best determined by a short run, and this is the only reliable manner in which one can determine the number and location of the streams to be removed through the chutes of series 19 and of series 21. The actual densities of the various components of a charge, their relative densities, the degree of friction between the various particles and the helicoidal surface 2, the degree of eccentricity of eccentric section 8, the degree of difference of eccentricity between the upper end and the lower end of eccentric section 8, and the speed of rotation of drive shaft 7 are all factors in determining the degree of separation, the rapidity of separation, and the point at which various components will be discharged from the lips of the helicoid. As has always been true with mechanical separatory devices, a few short tests are the most reliable guide in this matter, it being beyond the realm of possibility to here predict every purpose for which this device might ever be used and to specify the optimum factors for all such. At both the top lip 3 and the bottom lip 4, and on every other radius of the device, materials of different density can be obtained at different distances from the central core to the periphery of the helicoid. Heavy particles travel to the outside of the helicoid and the lighter particles remain nearer the center.

The helicoid 2 is shown in the accompanying drawings as descending from top to bottom by a contra-clockwise path. The ties 10, advantageously of flexible character such as cable or chain will be positioned in whatever direction is required to restrain the described tendency to rotate. Two or more ties 10 spaced equally about the circumference of the device are advantageous in that they result in more uniform separative force at all radii of the device.

The actual dimensions of my separating devices will of course vary according to the desired rate of separation, the degree of separation required, the density of the particulate material, and other obvious factors well known to those in the separatory arts. However the diameter will seldom exceed four feet.

The material fed to the helicoid separating device is ordinarily in the form of a slurry. Water is ordinarily quite satisfactory for preparation of the slurry, and it is advantageous that there be a deflocculating or wetting agent present. Other conventional mediums, including mineral oil, are also effective in varying degrees with different materials.

The preferred slurry density when working with pyrochlore ore and when an aqueous medium is used, is of the order of 1.3 to 1.4. Separation is satisfactory in the case of slurries having densities below this range, but a large throughput of liquid in proportion to solid reduces the efficiency of operation. Above this range, particularly with densities of 1.6 and upward, particle interaction is troublesome although differential wetting agents will sometimes extend the range somewhat.

By way of specific example I shall describe the use of this device in the separation of pyrochlore ore from Ontraio Province in Canada. The material to be separated is first ground to a size dictated by the dimension of the components of the material to be separated. If particles to be separated out are present in size of the order of one two-hundredth of an inch, little would be separated if this ore were fed to a separator at one-hundredth inch size. A feed of two-hundred mesh size or finer would be more appropriate. This of course is well known with respect to the sizing of feed for all mechanical ore-separating devices. In the instance of the ore under discussion I have used a helicoid with a diameter of from one-and-a-half feet to two-and-a-half feet in diameter and which had three full 360° turns from top to bottom. The eccentricity of the shaft produced a horizontal motion at the upper end of the helicoid varying from 0.007 inch to 0.17 inch and a horizontal motion varying from 0.005 to 0.015 inch at the lower end of the helicoid. The pitch of the helicoid was two inches per full 360° turn in the case of the one and one-half foot diameter helicoid. Operating this at shaft speed of 700 revolutions per minute and using a feed rate of three hundred pounds per hour I obtain a mineral beneficiation ratio ranging at different times from approximately 2:1 to 3:1. The beneficiated material from the above runs was charged to a second helicoid separator having a diameter of four feet, having three full turns from top to bottom, an eccentricity producing a horizontal motion of from 0.005 inch to 0.150 inch, and rotated at one thousand revolutions per minute. This operation effected a further beneficiation ranging from 2:1 to 3:1. Similarly, molybdenum tailings with an analysis of 0.1% molybdenum before separation has shown a beneficiation of 3 to 4 times when operating the helicoid at a speed of 900 revolutions per minute and with an eccentricity of 0.03 inch.

In determining the point at which to introduce the slurry from tank or bin 17 to the helicoid, a likely place to start trials is at a point approximately 30% of the length of the helicoid from lip 3 and about 70% of the length of the helicoid from lip 4. These figures are a rough approximation and the specific location will be selected as that at which it is possible to secure the most advantageous separation. That in turn will depend upon the densities of the various components of the particulate material charged, their size, and the precise point at which the operator desires to cut the separation.

The optimum diameter and number of turns of the helicoid depend on the material being separated, the desired rate of separation, the required degree of separation, its size, its density, all of these being obvious factors well known to those in the separatory arts, and also on the pitch and the degree of eccentricity of the helicoid, and on the speed of rotation of the eccentric shaft. By way of actual useful dimensions, for moderate throughput I have found that helicoids having a diameter of from one and one-half to four feet and having from one-and-a-half to three full turns are particularly well suited for most separations. However, helicoids having only one full turn of 360° are fully adequate when a high rate of throughput is not required and when the pitch and degree of eccentricity are low and the revolutions per minute are high. The use of helocoids having more than three full turns is desirable at times, particularly with high feed rates and a relatively high degree of eccentricity at the top of the eccentric section. Helicoids of smaller diameter are quite satisfactory for small rates of throughput, and I have found diameters substantially larger than four feet to be extremely effective and to give a high degree of separation together with an opportunity to successfully separate a greater number of cuts or fractions. Helicoids of large diameter are generally most effective in the separation of larger particles and ordinarily call for higher degrees of eccentricity.

Under any one set of conditions the particles will travel outward only so far, and if the helicoid used is greater in radius than the travel of the particles it is perfectly feasible to omit the raised rim on the helicoid, assuming that the

helicoid has sufficient rigidity without a rim. Rigidity of the helicoid is most necessary.

By way of specific information, for pyrochlore ore of two hundred mesh, a one-and-a-half to two turn helix of 2 to 3 feet diameter with a pitch of two and three inches respectively and an eccentricity producing a horizontal motion at the upper end of the device of 0.15 inch and a horizontal motion of 0.075 inch at the lower end of the device, with the eccentric shaft turning at a rate of the order of 700 revolutions per minute is satisfactory. This can ordinarily be depended upon with the above-mentioned ore to give a mineral beneficiation ratio of from 2:1 to 3:1.

In another instance pyrochlore ore of 200 mesh and finer gave a good separation on a helicoid having a diameter of one and one-half feet, two full turns of the helicoid, a pitch of two inches per full turn, an eccentricity producing a horizontal motion at the upper end of the helicoid of 0.10 inch, and a shaft speed of 1000 to 1200 revolutions per minute.

The optimum degree of eccentricity depends on the same factors mentioned above with respect to optimum diameter. With increasing degree of fineness I find it advantageous to reduce the eccentricity of the helicoid and increase the revolutons per minute. This reduction in eccentricity reduces the possible throughput and these three factors, together with the degree of separation aimed for, are each adjusted according to their relative importance in the specific operation.

The eccentricity at the lower end of the helicoid is less than the eccentricity at the top of the helicoid, and this maintenance of a difference in the eccentricities between the lower end and the upper end is the crux of this invention. For much work, an eccentricity producing a horizontal motion at the upper end of the helicoid of 0.15 inch is highly satisfactory in combination with an eccentricity at the lower end producing a horizontal motion at that point of 0.02 inch. For most ordinary uses the extent of horizontal motion provided at the top of the helicoid may be anywhere up to about 0.15 or 0.20 inch, and the extent of horizontal motion at the bottom of the helicoid will advantageously be from approximately one-twentieth to one-half the extent of the horizontal motion at the top of the helicoid. A low degree of eccentricity at the bottom in proportion to the degree of eccentricity at the top will give better separation but lower throughput. The larger the particles to be separated, the greater the eccentricity.

It is highly desirable that the helicoid be constructed so that all radii thereof are at an angle of 90° to the axis of cylindric sleeve **1**. The axis of the cylindric sleeve will be the same as the axis of the eccentric section **8** of the drive shaft. Any substantial variation from this construction will greatly reduce the effectiveness of the device. It is of course necessary that the helicoid be in axial alignment with cylindric sleeve **1**. Also it is essential that the drive shaft **7** be maintained in truly vertical position.

The pitch of the helicoid can be varied. High degrees of pitch increase the capacity of the separator but decrease the thoroughness of separation. This latter can be offset by increasing the number of full turns of the helicoid. For most work on particles having a size passing through a 100 mesh per inch standard sieve and not passing through a 300 mesh sieve, I have found that a pitch of two to three inches per turn on a two-foot diameter helicoid is quite satisfactory. While the pitch may be increased substantially above this figure, it must not be increased to the point at which it causes turbulent flow of the material undergoing separation.

The helicoid is advantageously made of fiberglass, resin bonded. A rubber surface also is satisfactory, or a metal surface. It is important however that the surface be smooth and uniform throughout its length. As indicated by numeral **5** on the drawing the helicoid is furnished with a peripheral flange about an inch high, and it would be quite feasible to enclose the helicoid with a cylindrical wall which would act both as a flange and to give structural strength.

A shaft speed of from five hundred to twelve hundred revolutions per minute is the ordinary range for operation, the exact speed being selected according to the various factors present in a specific instance. Lower rates of shaft speed, down to 300 revolutions per minute will be effective in many cases but needlessly reduce the capacity of the device. Rates as high as 2000 revolutions per minute have proven effective and satisfactory in the case of low-throughput operation with very fine material.

Chutes **19** and **21** or equivalent receiving means will be used to receive the separated material from the lips of the helicoid, and these chutes will be positioned below the lips in such numbers, of such widths, and at such precise locations as may be required to obtain the cuts desired.

What I claim is:

1. A non-rotatory nutating helicoidal separating device comprising: a vertical drive shaft, and intermediate the two ends thereof a section eccentric to the axis passing through the two ends of said shaft and having a greater degree of eccentricity at the upper end of the ecccentric section than at the lower end thereof; a cylindric sleeve fitting snugly around the eccentric section of the shaft; a helicoidal surface constructed about the said cylindric sleeve, in axial alignment therewith and rigidly fastened thereto; means for preventing rotation of the helicoidal surface; a rigid frame supporting the vertical shaft at points above and below the eccentric section; and a means for rotating the shaft.

2. A non-rotatory nutating helicoidal separating device comprising: a vertical drive shaft, and intermediate the two ends thereof a section eccentric to the axis passing through the two ends of said shaft and having a greater degree of eccentricity at the upper end of the eccentric section than at the lower end thereof; a cylindric sleeve fitting snugly around the eccentric section of the shaft; a helicoidal surface constructed about the said cylindric sleeve, in axial alignment therewith and rigidly fastened thereto, fitted with an upturned rim throughout the length of its outer edge but having no rim along its terminal lips; means for preventing rotation of the helicoidal surface; a rigid frame supporting the vertical shaft at points above and below the eccentric section; and a means for rotating the shaft.

3. A non-rotatory nutating helicoidal separating device comprising: a vertical drive shaft, and intermediate the two ends thereof a section eccentric to the axis passing through the two ends of said shaft and having a greater degree of eccentricity at the upper end of the eccentric section than at the lower end thereof; a cylindric sleeve fitting snugly around the eccentric section of the shaft; a helicoidal surface of not less than one full turn constructed about the said cylindric sleeve, in axial alignment therewith and rigidly fastened thereto, fitted with an upturned rim throughout the length of its outer edge but having no rim along its terminal lips; means for preventing rotation of the helicoidal surface; a rigid frame supporting the vertical shaft at points above and below the eccentric section; and a means for rotating the shaft.

4. A non-rotatory nutating helicoidal separating device comprising: a vertical drive shaft, and intermediate the two ends thereof a section eccentric to the axis passing through the two ends of said shaft and having a greater degree of eccentricity at the upper end of the eccentric section than at the lower end thereof; a cylindric sleeve fitting snugly around the eccentric section of the shaft; a helicoidal surface constructed about the said cylindric sleeve, in axial alignment therewith and rigidly fastened thereto; means for preventing rotation of the helicoidal surface; a rigid frame supporting the vertical shaft at

points above and below the eccentric section; a means for rotating the shaft; and receiving means positioned below the terminal lips of the helicoid and adapted to isolate one from another various portions of the material separated.

5. A non-rotatory nutating helicoidal separating device comprising: a vertical drive shaft, and intermediate the two ends thereof a section eccentric to the axis passing through the two ends of said shaft and having a degree of eccentricity at the upper end of the eccentric section between two times and twenty times the degree of eccentricity at the lower end thereof; a cylindric sleeve fitting snugly around the eccentric section of the shaft; a helicoidal surface constructed about the said cylindric sleeve, in axial alignment therewith and rigidly fastened thereto; means for preventing rotation of the helicoidal surface; a rigid frame supporting the vertical shaft at points above and below the eccentric section; and a means for rotating the shaft.

6. A non-rotatory nutating helicoidal separating device comprising: a vertical drive shaft, and intermediate the two ends thereof a section eccentric to the axis passing through the two ends of said shaft and having a greater degree of eccentricity at the upper end of the eccentric section than at the lower end thereof; a cylindric sleeve fitting snugly around the eccentric section of the shaft;

a helicoidal surface constructed about the said cylindric sleeve, in axial alignment therewith and rigidly fastened thereto and having all its radii at an angle of 90° to the axis of the said hollow cylindric sleeve; means for preventing rotation of the helicoidal surface; a rigid frame supporting the vertical shaft at points above and below the eccentric section; and a means for rotating the shaft.

7. A non-rotatory nutating helicoidal separating device comprising: a vertical drive shaft, and intermediate the two ends thereof a section eccentric to the axis passing through the two ends of said shaft and having a greater degree of eccentricity at the upper end of the eccentric section than at the lower end thereof; a cylindric sleeve fitting snugly around the eccentric section of the shaft; a helicoidal surface constructed about the said cylindric sleeve, in axial alignment therewith and rigidly fastened thereto; means for preventing rotation of the helicoidal surface; a rigid frame supporting the shaft in vertical position; and a means for rotating the shaft.

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