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METHOD AND APPARATUS FOR SEPARATING AND CLASSIFYING SUBSTANTIALLY SPHERICAL BODIES INTO DIFFERENT SIZE GROUPS

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Fig. 1

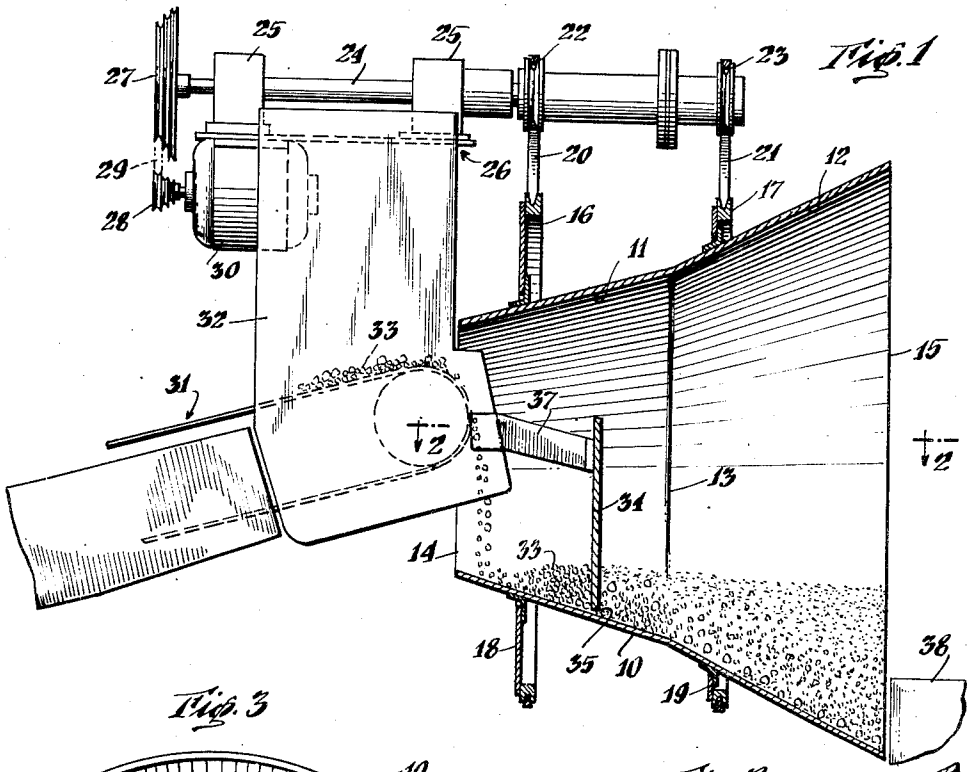


Fig. 3

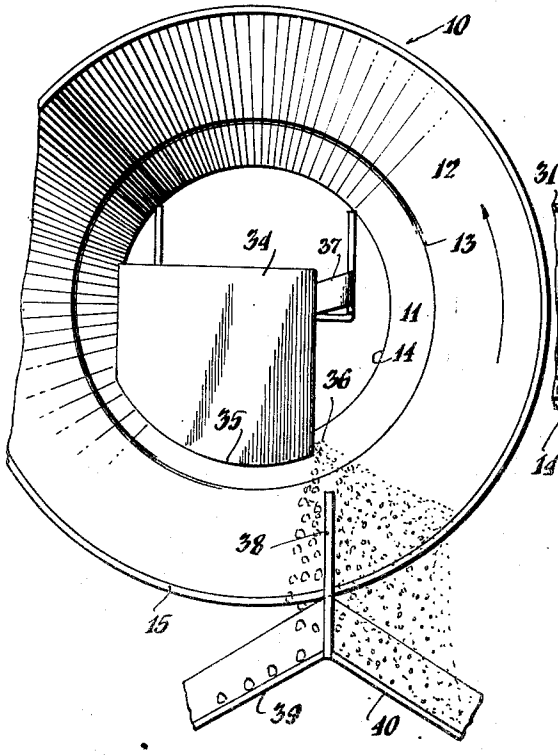
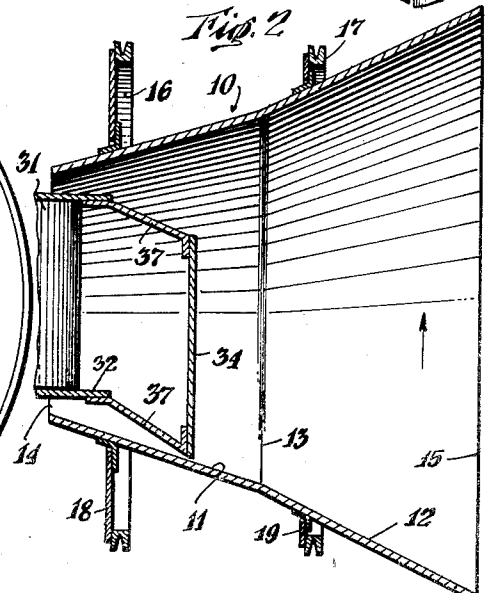


Fig. 2



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METHOD AND APPARATUS FOR SEPARATING AND CLASSIFYING SUBSTANTIALLY SPHERICAL BODIES INTO DIFFERENT SIZE GROUPS

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6 Claims. (Cl. 209—113)

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The present invention relates to a method of separating and classifying substantially spherical bodies into different size groups, and more particularly for separating a mixture of substantially spherical bodies of different sizes into two or more groups, each including bodies having diameters in a predetermined size range. The invention also relates to apparatus for carrying out this method.

It has been the conventional method of separating material into different sizes to pass it through gratings, or screens, having openings of different sizes. This has been quite adequate in some instances in making a size separation of various materials, but is uneconomical on a large scale commercial basis in separating material of different sizes wherein the bodies of materials to be separated are made up of fine, relatively hard particles loosely agglomerated together, and wherein this material, if put through a conventional screen, could be disintegrated to some extent and could leave portions of the material adhering to the screen. This causes several practical difficulties: first, it builds up soft adherent material on the screen, which tends in practice to vary the effective size of the screen openings, so that a screen or grating which should pass bodies up to a predetermined size will pass only smaller sized bodies. Secondly, it tends to cause the breaking up of some of the relatively soft bodies into bodies of smaller size, which is undesired from certain points of view at least, and particularly from the point of view of a particular use for which the present invention is adapted.

The apparatus of the present invention may be used in accordance with the method thereof in the separation and classification of substantially spherical bodies. Among the compositions of such bodies which it may be desired to separate and classify as to size are bodies of iron ore concentrates, for example, concentrates of some taconite and magnetite ores. In some metallurgical processes these ores may, if desired, be formed into nodules or pellets with or without a small amount of combustible material and it may be desired to separate and classify such nodules or pellets as to size. The present method is adaptable for the purpose of separating and classifying any bodies of substantially spherical form which are different in their physical properties substantially solely as to size and all of which have substantially the same density and surface-frictional characteristics.

The method of the present invention is particularly adapted to separating and classifying substantially spherical bodies of moist pyrite into different size groups. These bodies are made up of pyrite fines moistened with water. They are so soft that they may be crushed by pressure between the fingers. The pyrite particles themselves are extremely small, such as flotation concentrate, while individually having the hardness and other properties of pyrite. The bodies to be separated and classified may be of a large variety of sizes, for example, a preferred size range for a particular commercial purpose in the case of nodules formed of pyrite fines being from about $\frac{3}{16}$" to about $\frac{1}{4}$" in diameter. The pyrite itself is quite hard and non-compressable in character, so that when such bodies are put through a conventional screen, the hard and abrasive character of the pyrite material tends to wear out the screen in a relatively short time, in addition to the difficulties above noted, all of which have been experienced in practice. The substantially spherical bodies, or "nodules" as they may be called, may thereafter be used, among other uses, in recovering values from pyrite in accordance with the teachings of the U. S. patent to Renken, No. 2,530,630, issued November 21, 1950.

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It has been found that substantially spherical bodies of this kind can be formed by supplying the pyrite fines, moistened with a certain amount of water, to the interior of a rotating drum. In this drum the material rolls over upon itself, so that the nodules, or substantially spherical bodies, may be formed as a snow ball may be rolled up. In order to separate the nodules, or substantially spherical bodies of a desired size range for use, for example, in the Renken process, from smaller and/or larger sizes, resort was had for a time to a succession of screens in a manner conventional in the prior art. It was found, however, that all the various difficulties referred to hereinabove were experienced.

The apparatus used in carrying out the method of the present invention may be briefly summarized as a rotating member having at least one inside surface which is substantially frusto-conical in shape and wherein the member is rotated about the axis of symmetry of this surface. The member is so supported and disposed during its rotation that this axis is approximately horizontal, or at least is in such a position that the smaller diameter supply end of the surface has its lowermost portion located somewhat above the level of the lowermost portion of the larger diameter discharge end thereof. The smaller diameter end of this surface may be either open

or closed. The mixture of different sizes of substantially spherical bodies or nodules to be separated as to size is supplied in a suitable manner onto this rotating surface adjacent to the smaller diameter end thereof. Preferably there is arranged near the supply point a shield, the bottom portion of which is shaped substantially to conform to and is located adjacent to the lower portion of the rotating surface, so that substantially spherical bodies supplied in rear of this shield will be deflected thereby in the direction of rotation of the surface. The mixed sizes of these bodies pass thence generally toward the larger diameter discharge end of this rotating surface. In so doing, the rotation of the surface tends to move the substantially spherical bodies from the lowermost portion thereof to a higher level, so that these bodies roll by gravity in a direction opposite the direction of rotation of the rotating member, particularly the frusto-conical interior surface thereof. It has been found that the larger diameter bodies will roll further and faster than the smaller diameter bodies, as they are not required to come up to such a high spin velocity. When, therefore, there are provided means adjacent to the open larger diameter end of the rotating conical surface for selectively diverting to different delivery points the substantially spherical bodies rolling off the open larger diameter end of this surface at different angular zones respectively around the axis of rotation thereof, a practical and effective separation, adequate for many commercial purposes is effected. The arrangements for diverting different size bodies to different delivery points may be adjusted as to position to select different divisions of sizes and may be arranged to distinguish between two or more different size groups.

Other features and advantages of the present invention will be apparent from the following description of one embodiment thereof, specifically described in the following specification. Various equivalents of some of the constructions particularly illustrated will be described as the description proceeds.

In the accompanying drawings:

Figure 1 is a somewhat diagrammatic view, principally in elevation, but with the rotating member in vertical section, illustrating one embodiment of the present invention;

Fig. 2 is a detailed view substantially in horizontal section on the line **2—2** of Fig. 1; and

Fig. 3 is a view of the rotating member and the deflecting shield as seen from the right in Fig. 1.

The device particularly illustrated in the accompanying drawings and hereinafter described in detail is one which has been successfully used in the separation of nodulized pyrite fines to separate the pyrite nodules into different size groups or ranges for subsequent treatment in accordance with the process disclosed in the Renken patent aforesaid.

As particularly shown in the accompanying drawings, there is a rotatable member generally indicated at **10** which is formed in a manner to provide an imperforate, substantially frusto-conical interior surface. While it is contemplated, in accordance with the present invention, that the interior surface of the member **10** could be formed as a single frusto-conical surface, or conical surface, there is particularly illustrated a device in which this interior surface is formed by two conical portions **11** and **12**, each of which is frusto-conical and which are arranged concentrically about a common axis in end to end relation, so

that the larger end of the surface **11** is contiguous with the smaller end of the surface **12** at a circular line **13**.

The member **10** may be formed, as shown, of relatively thin sheet material, such as metal, and in any suitable manner, the outside configurations of this member being immaterial.

This member **10** is mounted for rotation about the common axis of symmetry of the single surface or of the surfaces **11** and **12**. This interior surface, or these surfaces, as the case may be, are so arranged and disposed that the smaller diameter or supply end thereof indicated at **14** is at a higher level or elevation than the larger diameter or discharge end **15**, as to the lowermost portion of each such end. In other words, the portions of these surfaces which will support the material being handled is so arranged that the material will tend to move by gravity from the smaller diameter or feed end **14** to the larger diameter or discharge end **15**.

Means are provided for mounting the member **10** in such a way that the lowermost portion of the end **14** will be above that of the end **15** and also for rotating the member **10** during the normal operation thereof. It is contemplated that there could be provided some special and separate means for mounting the member **10** for rotation as by circular running flanges on the member **10** concentric with the axis thereof and running on suitable rollers in a way similar to that in which rotary kilns are supported. There is chosen for illustration in the accompanying drawings, however, an arrangement by which the member **10** is both supported or suspended and rotated by driving belts. For this purpose, therefore, the member **10** is provided with a pair of circular pulleys **16** and **17**, which are preferably of the same pitch diameter and which are suitably secured to the member **10** by intermediate structural means, as generally indicated at **18** and **19**, so as to be concentric with the axis of symmetry of the conical surfaces **11** and **12**. These pulleys are arranged to be supported and rotated by suitable endless belts, here shown as V-belts **20** and **21**, which pass around driving pulleys **22** and **23** respectively. The pulleys **22** and **23** are both fixedly mounted on a common drive shaft **24**, which is journalled in any suitable bearings **25** in a supporting structure generally indicated at **26**. Any suitable means may be provided for driving the shaft **24** at a desired and preferably adjustable speed, the means here shown being a conical group of pulleys **27**, any one of which is arranged to be driven by a respective one of a complementary group of pulleys **28** through a driving belt **29**. The group of pulleys **28** may be driven from a prime mover such as an electric motor **30**.

In the embodiment of the invention here shown, the common axis of the surfaces **11** and **12** is arranged substantially horizontal. This arrangement is not, however, absolutely essential, as it is required merely that the conical surfaces of the member **10** be rotated about their common axis of symmetry, and that this axis be so disposed that the discharge end shall be lower than the feed end, so that the material being classified as to size will move by gravity progressively from the feed end to the discharge end.

Any suitable means may be provided for supplying the material, which is to be classified as to the size, preferably substantially continuously to the interior of the rotating surface, or sur-

faces, such as the surfaces 11 and 12, and to a point or place adjacent to the smaller diameter end 14 thereof. As shown in the accompanying drawings, there is provided a conveyor means generally indicated at 31, which is driven in any suitable manner (not shown) and which is supported as shown at its end near the member 10 by a depending supporting structure 32 carried by the main supporting structure 26. As shown, this conveyor means supplies the material indicated at 33 on the conveyor means 31 onto the interior of the surface 11 adjacent to the smaller diameter end 14 thereof.

If desired, however, the material 33 could be supplied to this portion of the surface 11 by any other means available and from either end of the member 10. Thus, for example, the device would operate in exactly the same manner if a suitable chute or conveyor means were provided entering into the interior of the member 10 through the larger diameter end portion 15 thereof. Under such circumstances, it would be possible to close the smaller diameter end of the member 10, either by continuing the surface 11 to a point at the apex of this conical surface, or by a transverse plate or closure. The conveyor means 31 is, therefore, but one example of a means for supplying the material 33, consisting of the substantially spherical bodies in mixed sizes, to the interior of the member 10 during the rotation thereof and at a point or place adjacent to the smaller diameter end of this member or more specifically of the conical interior surface thereof.

It is preferable, in most commercial embodiments of the invention, to provide a shield 34 located between the supply point, that is, the point at which the material 33 is supplied to the interior of the member 10, and the discharge end thereof. This shield 34 has its bottom portion 35 shaped substantially to conform to and is located adjacent to the lower portion of the rotating surface 11, as shown in Figs. 1 and 3. In this way, the rotation of the member 10 is relied upon to move the material 33 laterally of the shield as shown at 36, Fig. 3, and thus to feed this material gradually and progressively past the shield 34. The shield 34 may be supported in a stationary position as shown by any suitable supporting means; for example, brackets 37 may be provided, securing this shield to a stationary part of the conveyor means 31 or to any other stationary support which may be available.

While the use of a shield as shown at 34 is not absolutely essential for the operativeness of the apparatus of the present invention, it has been found that under usual commercial operating conditions, superior results are obtained when such shield is used, as the material is fed more uniformly through the member 10 and the selectivity of the separation of the material into different sizes is improved.

As will be evident from the foregoing, as the member 10 rotates, the rotation thereof will tend to move all the material 33 in the lowermost portion thereof upwardly in respect to such lowermost portion. This material, which consists of substantially spherical bodies of different sizes, will then tend to roll downwardly in a direction generally opposite the direction of rotation of the member 10, so as to regain its position in the lowermost portion thereof. This is so because the member 10 is rotated at a speed such that the centrifugal force effective on the material 33 will not be sufficient to overcome the force of gravity tending to move the material down to the lowermost portion of the interior surface supporting this material. During this movement of the substantially spherical bodies of the material opposite the direction of rotation of the member 10 and its surfaces 11 and 12, the individual bodies will be caused to roll. It has been found that this rolling develops a spin velocity for each of the substantially spherical bodies which must, of course, be higher for smaller diameter bodies than for larger diameter bodies moving the same distance along the surfaces 11 or 12. It has been found that the larger diameter bodies will move further due to the fact that their spin velocity need not be so high, so that by the time the bodies have moved axially of the member 10 to the larger diameter end 15 of the conical surface 12, the larger diameter bodies will be closer to a point vertically below the axis of symmetry of the conical surfaces 11 and 12 than the smaller diameter bodies. This action is generaly proportional to the diameters of the individual bodies. If, then, a means be provided for selectively diverting to different delivery points, the substantialy spherical bodies rolling off respectively different angular sectors of the large diameter end 15 of the surface 12, there will be an effective separation between different sized bodies.

Such a selective diverting means is shown, for example, at 38, this means as shown comprising a plate arranged in a stationary position in a vertical plane substantially parallel to the axis of rotation of the member 10 and with one edge closely adjacent to the larger periphery of the surface 12 at 15. The means 38 acts in conjunction with a pair of chutes 39 and 40 to direct different size range bodies to different delivery points. The means 38 may take other forms than that particularly shown, but is essentially a means for mechanically separating substantially spherical bodies falling off different angular zones of the discharge end of the surface 12, the angular dimensions of these zones being measured in a plane perpendicular to the axis of rotation of the member 10.

It will be understood that the selective diverting means 38 may be mounted in any suitable way (not shown) and is preferably adjustable in any conventional manner (not shown), so as to effect a division at a selected point between bodies rolling off the larger diameter end 15 of the surface 12 at different angular zones thereabout. There may be two or more of the selective diverting means as shown at 38 to give three or more different size groups of the substantially spherical bodies, only one means 38 providing two such groups being shown in the accompanying drawings.

As shown, for example, in Fig. 3, the larger diameter bodies will roll further toward the center and will be diverted to the left by the chute 39; while the smaller bodies will not roll as far and will be diverted to the right by the means 38 and the chute 40. These two size groups of material (or more groups if there be provision for more than two), will then be diverted by suitable means to different points. The details of the chute or other delivery means for delivering these bodies to different delivery points form per se no part of the present invention and are not further described herein.

As a first example of a device constructed in accordance with the present invention and

which has been used in carrying out the method thereof for separating relatively soft spherical bodies of nodulized pyrite as herein taught, a device was constructed substantially as shown in the accompanying drawings and operated as herein taught. This device had an inside diameter at the feed end of 24 inches; a diameter at the discharge end of 48 inches; a total length along the common axis of the member 10 of 48 inches; a slope for the first 24 inches (the surface 11) of 17°; a slope for the last 24 inches (the surface 12 of 27°; the device was operated at a speed of 18 R. P. M. and served to classify moist pyrite pellets at the rate of 6 tons per hour.

The following is a table showing the size distribution of the substantially spherical pellets or nodules in the group selected for use in accordance with the Renken patent aforesaid resulting from classification by the method of this first example and in accordance with the present invention:

Size of bodies, Tyler Mesh	Percent Wt.
+3	8.8
+4	78.5
+6	9.4
+8	2.0
+10	0.3
−10	1.0
Total	100.0

As a second example of an apparatus embodying the present invention and for carrying out the method thereof for larger scale operation, the device may be made with a smaller end diameter of 72 inches; a diameter at the larger end of 104 inches; an axial length of 48 inches; a slope of the smaller diameter end portion (the surface 11) 14° 32′ (this portion extending 27 inches along the common axis of rotation of the member 10); a slope of the last 21 inches along the axis of rotation (the surface 12) 23° 10′; a rotation speed of 10 R. P. M.; and having a capacity of about 20 to 25 tons per hour. In general, it has been found that a peripheral speed for the discharge end periphery of about 250 ft. per minute results in satisfactory operation when classifying pyrite pellets or nodules of the type herein contemplated for use.

Other types of material having a different bulk specific gravity may require different angles of slope for the single frusto-conical surface used, or for each such surface, such as 11 or 12. The speed of rotation may also or alternatively be varied to compensate for the different average specific gravity of the material being handled. Such desired characteristics may be determined by experiment to get best results for any particular material.

It is further contemplated that there may be more than two surfaces, each frusto-conical in shape as 11 and 12; or that the interior surface of the member 10 may merely approximate a frusto-conical shape and actually be of progressively increasing slope or bell shape, with the slope at a maximum at the discharge end and at a minimum at or adjacent to the feed end. From another viewpoint, it may be said that the apex angle of the frusto-conical surfaces increases from that of the surface 11 at the supply end to that of the surface 12 at the discharge end of the apparatus. It is further contemplated that a device constructed substantially in accordance with the present invention and for carrying out the method thereof, may be formed as a rigid part of a drum in which pellets may be formed by rolling up the moist material forming the pellets as a snow ball is rolled up.

While there is herein shown and described but one particular apparatus embodiment of the invention, various equivalents have been pointed out as the description proceeded and some particular dimensional examples have been given of different embodiments of the invention. Further, it has been pointed out what features are essential and what are not essential. Other equivalents as to both method and apparatus will occur to those skilled in the art from the foregoing description and are to be considered within the purview of the appended claims, which are to be construed validly as broadly as the state of the prior art permits.

What is claimed is:

1. Apparatus for effecting a separation of different sizes of substantially spherical bodies, comprising a member having an imperforate, substantially frusto-conical interior surface, which surface has an axis of symmetry and an open larger diameter end and a smaller diameter end, means mounting said member for rotation about said axis, with said axis positioned so that the larger diameter end of said surface has its lowermost part at a lower level than the lowermost part of said smaller end, so that rotation of said member will move said bodies in the lowermost portion thereof to a higher level and so that said bodies will roll by gravity in a direction opposite the direction of rotation of said member during such rotation, means for rotating said member about said axis, means for supplying substantially spherical bodies to the interior of said member adjacent to said smaller diameter end, a stationary baffle disposed inside the smaller diameter end portion of said member and having a lower edge portion conforming substantially to the curvature of the adjacent part of said member and positioned closely adjacent thereto for deflecting the bodies supplied to the interior of said member in the direction of rotation thereof, and means for selectively diverting to different delivery points the bodies rolling off the open larger diameter end of said surface of said member at different angular zones respectively about said axis.

2. Apparatus for effecting a separation of different sizes of substantially spherical bodies, comprising a hollow member having an interior surface formed of at least two imperforate, contiguous, coaxial, substantially frusto-conical surfaces, the hollow interior of said member having a smaller diameter supply end and an open larger diameter discharge end, said member being arranged so that said surfaces, which collectively make up said interior surface have the common axis of symmetry and are disposed in such position that the larger diameter end of said interior surface has its lowermost part at a lower level than the lowermost part of said smaller diameter end, the apex angle of the one of said surfaces at the discharge end of said apparatus being greater than the apex angle of the one of said surfaces at the supply end of said apparatus, so that rotation of said member will move said bodies in the lowermost portion thereof to a higher level and so that said bodies will roll by gravity in a direction opposite the direction of rotation of said member during such rotation, means for rotating said member about said axis, means for supplying substantially spheri-

cal bodies to the interior of said member adjacent to said smaller diameter end, means for selectively diverting to different delivery points the bodies rolling off the open larger diameter end of the interior surface of said member at different angular zones respectively about said axis, and a stationary baffle disposed inside the smaller diameter end of said member and having a lower edge portion conforming substantially to the curvature of the adjacent part of the interior surface of said member and located closely adjacent thereto for deflecting the substantially spherical bodies supplied to the interior of said member in the direction of rotation thereof during such rotation.

3. The method of separating into different size groups substantially spherical bodies of material which are different in their physical properties substantially solely as to size and all of which have substantially the same density and surface frictional characteristics, which comprises the steps of supplying such bodies of material in mixed sizes to a member having a substantially frusto-conical interior surface and adjacent to the smaller diameter end of said surface, said member being mounted for rotation about a substantially horizontally disposed axis of symmetry of said surface, rotating said member about said axis to move said bodies upwardly in respect to the lowest portion of said surface so as to cause said bodies to roll by gravity toward said lowest portion, whereby bodies having larger diameters will roll further toward said lowest portion than smaller diameter bodies when both have the same spin velocity, and selectively diverting to different delivery points said bodies which roll off respectively different angular zones of the larger end of said member.

4. The method in accordance with claim 3, wherein said bodies of material in mixed sizes

are introduced into the smaller diameter end portion of said member substantially continuously as a stream of controlled volume.

5. The method in accordance with claim 3, wherein said spherical bodies of material are composed of pyrite fines, which are agglomerated with water, wherein said method is operated to separate bodies of about ¼'' diameter from smaller bodies, and wherein the speed of rotation of said member about its axis is such that the peripheral speed of the larger diameter end of said surface is about 250 feet per minute.

6. The method in accordance with claim 3, comprising the step of increasing the spin velocity of said spherical bodies during their course through said member not only due to their travel toward a larger end of the frusto-conical surface as aforesaid, but also by providing in said member at least two contiguous frusto-conical surfaces from the smaller inlet end of said member to the larger outlet end thereof, wherein the frusto-conical surface adjacent to said outlet end is formed as a surface of rotation of a line disposed at a greater angle with respect to said axis than the angle formed by a similar line in the frusto-conical surface adjacent to said inlet end.

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