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GRINDING CHARGE FOR BALL MILLS

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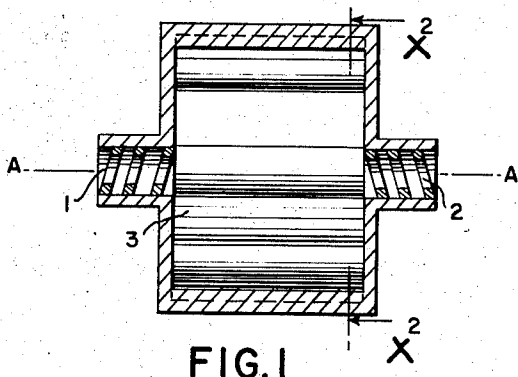


FIG. 1

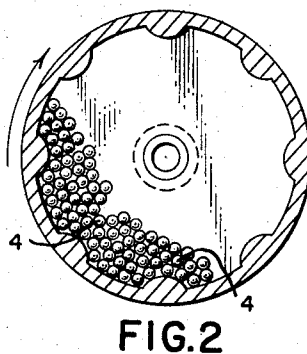


FIG. 2

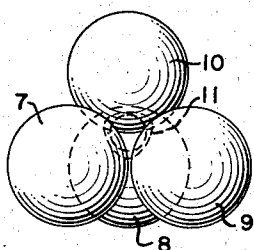


FIG. 3

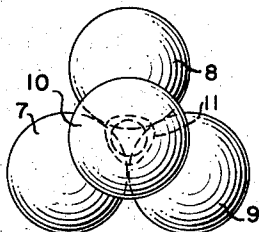


FIG. 4

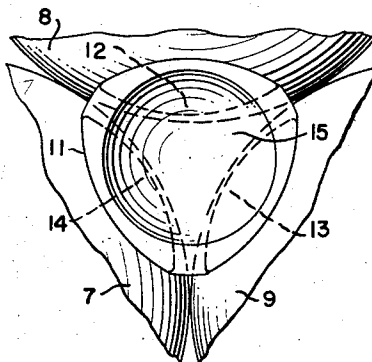


FIG. 5

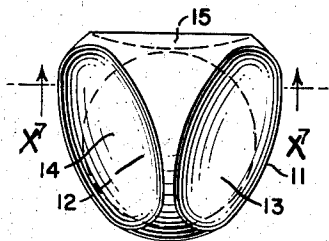


FIG. 6

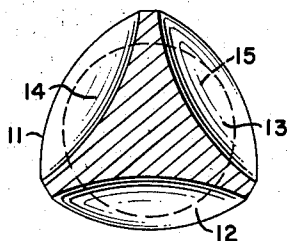


FIG. 7

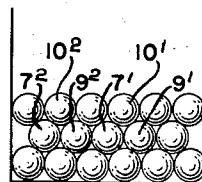


FIG. 8



FIG. 9

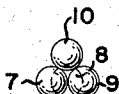


FIG. 10



FIG. 11



FIG. 12

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2,847,169

## GRINDING CHARGE FOR BALL MILLS

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2 Claims. (Cl. 241—184)

This invention relates to an improved grinding charge comprising a new combination of grinding elements for use in tubular horizontal revolving mills of the kind commonly called ball mills, used to pulverize ores, rocks, cement and other materials.

At present it is common practice in these mills to use a grinding charge consisting of only heavy balls, usually steel or iron, and the ore or other material to be pulverized is fed into one end of the mill in relatively coarse condition and is discharged from the other end in relatively fine condition, the pulverizing or grinding of the ore occurring in the mill under the action of the heavy balls as they fall, cascade, roll or slide around on each other, and on the ore, as the mill revolves.

Because the grinding charge consists of balls only, the ore is ground surprisingly slowly considering the great cost, large size, weight and power consumption of these mills, and this inefficient grinding is largely due to the fact that the balls make with each other only point contact for grinding purposes, or at best only over very small areas where the balls touch each other. That is, because the ores are pulverized and ground only at these small points or areas of ball contact, it is natural that the grinding rate in these ball mills is slow and quite inefficient.

Also, when balls only are used, there are many comparatively large interstices between the balls, and the ore collects and hides away in these interstices, thereby escaping the pounding and grinding action of the balls, and this hiding away of the ores in these interstices further contributes to the inefficient grinding results obtained.

An object of my invention is to provide an improved grinding charge whereby the ore can be more rapidly ground to the desired fineness with less power consumed per ton of ore than has been heretofore possible in ball mills of the type described.

In general, my improved grinding charge consists of a new combination of grinding elements, this new combination comprising balls of the kind heretofore used, or new types of balls if these may be developed, as a first element, and a newly devised element of a form hereinafter described, as the second element of the combination, and by the action of these two elements, one with the other, much larger contact areas are made available for grinding purposes than the contact areas or points heretofore available when balls only were used. Consequently, as a result of these greatly increased grinding areas between the elements, more ore will be ground per ton with my improved grinding charge, and with less power consumption, than has been heretofore possible when the same mill was equipped with a grinding charge consisting of balls only as was the common practice prior to my invention. In other words, the grinding efficiency of the entire mill is substantially increased by the use therein of my new improved grinding charge.

Other objects of my invention, and other advantages, may become clear from the following detailed descrip-

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tion, also from the drawings, and from the appended claims.

In the drawings, Fig. 1 is a diagrammatic longitudinal section of a revolving ball mill of the kind herein referred to, the balls, supporting bearings and other details being omitted in this view for purposes of clearness;

Fig. 2 is a diagrammatic transverse section through the mill taken on line X<sup>2</sup>—X<sup>2</sup> of Fig. 1, looking in the direction of the arrows, the grinding charge consisting of balls only, which has heretofore been the general practice, being shown in this figure;

Fig. 3 is a magnified front view of a group of four symmetrically stacked balls with my new grinding element indicated in the interstice between these four balls;

Fig. 4 is a plan view of the stack of balls with my grinding element in the interstice, as shown in Fig. 3;

Fig. 5 is a greatly magnified but fragmentary plan view of the three lower balls, and my grinding element, shown in Fig. 3, or in short, the top ball of Fig. 3 has been removed in this Fig. 5, to show the plan view of my new grinding element more clearly;

Fig. 6 is a front view of my grinding element alone, as it would be viewed in Fig. 5 if the balls were absent;

Fig. 7 shows a section through my new grinding element taken on line X<sup>7</sup>—X<sup>7</sup> of Fig. 6, looking in the direction of the arrows;

Fig. 8 is a diagrammatic view of a large number of balls in a container, showing the natural positions which these balls usually take with respect to each other;

Fig. 9 is a diagrammatic view showing a stack of balls that occasionally, but not often, occurs during the rotation of the ball mill;

Fig. 10 is a diagrammatic view showing a stack of balls that most commonly, and most frequently, occurs during the rotation of the ball mill;

Fig. 11 is a front view of the imaginary geometric figure that would be formed by joining the centers of the balls in Fig. 3 by straight lines;

Fig. 12 is a plan view of the imaginary figure described in Fig. 11.

In this art, when the mill is revolving on its horizontal axis A—A, Fig. 1, the rock, ore or other material to be ground is fed into the mill in relatively coarse condition through the inlet opening 1, and is discharged from the mill in relatively fine condition through the discharge opening 2, Fig. 1, and those skilled in the art will understand that during this grinding operation the horizontal chamber 3 of the mill is continually supplied with water to a suitable level to flush or wash the fine grindings out through the discharge opening 2 as these are produced.

Neither the ore nor the grinding charge is shown in Fig. 1, but Fig. 2 shows the conventional grinding charge 4 as heretofore used, consisting of balls only.

It is apparent from Fig. 2 that as the mill revolves in the direction of the arrow, the balls rise on one side as shown and then fall or cascade back onto those below, and in general the balls may be said continuously to rise, fall, roll and slide around on each other, and on the ore, as the mill revolves, and this action accounts for the grinding of the ore as referred to.

But, as previously mentioned, these mills do not grind the ore as rapidly as desired, the reason being that the pulverizing and grinding of the ore occurs only at the places where the balls contact each other, and the balls being spherical, they make only point contact with one another, or at best they make contact over only very tiny areas where they touch. Therefore, because of the smallness of the total grinding areas through the entire grinding charge 4, it is only natural that rate of grinding of the ores is relatively slow, or conversely, the grinding efficiency of the mill is small considering the large amount of power consumed, and also other factors.

Also, these mills, when using balls only, often produce excessive amounts of grinding that are much finer than the precise fineness desired, the reason being that particles of ore already ground to the desired fineness seem to be ground again and again by the balls, and thereby become too fine, while waiting for coarser particles not yet ground, to come out from the interstices between the balls to receive the proper share of the grinding. This surplus production of excessively fine powdery grindings is often objectionable because it slimes the liquor and interferes with subsequent treatment of the ores, and this is a further objection to a grinding charge consisting of balls only, along with the slowness of the grinding and the overall low efficiency of the mill already described.

Consequently, since all these defects are due principally to the small and insufficient total grinding area throughout said grinding charge consisting of balls only, I have endeavored to improve the character of this charge in such manner as will substantially increase the total grinding areas available therein, thereby to eliminate the above described defects and substantially to increase the efficiency of the mill.

To this end, I have observed that balls, whether trundled or shaken in a revolving mill, or in some suitably large receptacle as in Fig. 8, most frequently take a position relative to each other approximately as shown in Fig. 8. On due consideration this is but natural, because the upper balls always tend, even during the trundling or shaking motion, to settle under gravity into the valleys formed by the upper curved surfaces of the lower balls, and this results in maintaining a ball configuration continually approximately or resembling that diagrammatically illustrated in Fig. 8, even while the balls are in motion in the revolving mill, during operation.

In its most elementary sense, the characteristic of this configuration illustrated in Fig. 8, is shown in Figs. 3, 4 and 10, wherein the stacking of the balls 7, 8, 9 and 10 in Figs. 3 and 4, obviously corresponds with the stacking of the balls 7<sup>1</sup>, 9<sup>1</sup>, and 10<sup>1</sup> of Fig. 8, or with balls 7<sup>2</sup>, 9<sup>2</sup> and 10<sup>2</sup> of Fig. 8, and a little consideration will show that most of the balls in Fig. 8 stack themselves in a relative manner which corresponds approximately with the elementary stacking illustrated in Figs. 3, 4 and 10. In short, what I am saying is that this elemental stacking of the balls as shown in the last named figures is the most usual and most frequent configuration and stacking of the balls that continually occurs during the trundling of the balls in an operating mill, and this is confirmed by the close resemblance between the positions of the balls in Figs. 2 and 8, and therefore in Figs. 3 and 4, as the latter have been shown to be the elemental arrangement of Fig. 8.

I do not maintain that the balls always lie in or take this relative position with respect to each other, because on rare or special occasion I have observed that they sometimes arrange or stack themselves as in Fig. 9, but this and other miscellaneous stackings are comparatively infrequent, whereas the natural elementary stacking shown in Figs. 3, 4, 8 and 10, and in fact in Fig. 2, is far the more frequent, and in the aggregate greatly exceeds the sum total of all other kinds of miscellaneous stackings, such as Fig. 9 for instance.

Having thus observed that the great preponderance of ball relationships in an operating revolving ball mill, is that shown in Figs. 3, 4 and 10, I now proceed with the solution of the main problem, namely, to procure a substantial increase in the total grinding area within the grinding charge 4 of the mill, Fig. 2, over the small total area obtained when using balls only.

This I achieve by inserting into the interstice formed between the four balls shown in Figs. 3 and 4, a new specially formed grinding member or element indicated by reference numeral 11 in Figs. 3 and 4, the form and character of this element being better shown in the magnified view of Figs. 5, 6 and 7. The shape of this new

grinding element conforms approximately, but not necessarily exactly, with the shape of the interstice between these four symmetrically stacked balls, and in the surface of said grinding element I provide four concave grinding depressions 12, 13, 14 and 15, see Figs. 5, 6 and 7, these grinding depressions registering approximately with the adjacent portions of the convex surfaces of the balls, that is the portions which are at or adjacent the interstice, in the stack of balls shown in Figs. 3 and 4.

With the addition to the grinding charge, consisting of the conventional balls as one element, of an appropriate number of these new grinding members 11 acting as a second element of the grinding charge, it is noticed that the total grinding area now available within the charge will be substantially increased because there will be available not only all the point contact between the balls previously present, but in addition the much greater grinding areas between the convex surfaces of the balls and the concave depressions in the new elements 11; and obviously in view of this substantial increase in total grinding area within the grinding charge, there is a noticeable and substantial increase in the speed of grinding by the mill, also an appropriate reduction of power, and greater uniformity in the fineness of the grinding, so that the excessive and undesired amounts of extremely fine powdery grindings are now substantially reduced.

I am of course aware that the combination of the four balls and the grinding element 11 in the precise manner illustrated in Figs. 3 and 4 will not always occur, but because this symmetrical stacking of the balls is predominantly the most usual and frequent stacking, or configuration, as heretofore explained, it is obvious that the precise stacking of the four balls and the new element as shown in Fig. 4, or something quite like it, will occur with sufficient frequency during operation of the mill, as to bring about the desired improvements mentioned, namely the greater speed in the grinding, the reduction in the power consumed, and the greater uniformity in the fineness of the grinding.

I am also aware that heretofore it has been proposed to add to the conventional grinding charge, six-sided cubes, and other special elements, with and without grinding depressions, for the purpose of improving the action of the grinding charge as just stated, but all these prior attempts, at least so far as my knowledge and experience goes, have been of no avail whatsoever, the reason being that these proposed grinding elements did not suit or conform with the elemental stacking of the balls shown in Figs. 3 and 4, which as previously explained is the stacking that most frequently, in fact predominantly, occurs during the operation of these mills; and conversely, because my new element herein disclosed, including the concave depressions, is formed to suit this predominantly occurring stacking of the balls shown in Figs. 3 and 4, my invention has succeeded in bringing about the above mentioned improvements, even though previous attempts in the same direction have heretofore failed.

In endeavoring to define the elemental stacking of the balls shown in Figs. 3 and 4, which stacking dominates this invention as heretofore explained, I have described this configuration as a "a symmetrical stack of four balls," the term "stack" indicating that in some manner the balls are piled or placed one above the other in a stable relationship, and when four balls are considered it is clear that the only manner in which they can be so "symmetrically stacked," is in conformity with said Figs. 3 and 4.

As just stated, while I believe the term "a symmetrical stack of four balls," or some other phrase of like import, adequately describes the ball configuration shown in Figs. 3 and 4, nevertheless, I wish also to define or relate said ball configuration to the geometrical figures shown in Figs. 11 and 12 of the drawings, wherein the points *a*, *b*, *c*, and *d* respectively represent the centers of balls 10, 7, 8 and 9 of Figs. 3 and 4, and in Figs. 11 and 12 I have joined these points *a*, *b*, *c* and *d*, by the straight lines

shown. Even though these figures do not conform with the following statement, because of the angles and planes from which the balls of Figs. 3 and 4 are viewed, nevertheless a moment's consideration will show that each of the four triangles of Figs. 11 and 12, namely triangles *abc*, *acd*, *abd*, and *cbd* (for the latter see particularly Fig. 12), are all identical equilateral triangles, each corresponding with the triangle *bcd* of Fig. 12. In short, the particular stacking of the balls shown in Figs. 3 and 4 can be defined as one in which the four triangles formed by joining the centers of any three of these balls by straight lines are all identical equilateral triangles, as this phrase is used in the claims.

Also, in saying that my new element 11 shall "approximately conform with the interstice between such four symmetrically stacked balls," or like phrases, I mean to suggest that a fair degree of liberality is reserved to my invention, as to how far the corners of my element protrude out into this interstice; also whether the precise size of my new element in the interstice will permit the balls exactly to touch one another, or will hold them slightly apart from each other, and also as to whether the radius of the concave depressions 12, 13, 14 and 15 in my new element 11, shall precisely conform with the radius of the convex surfaces of the balls or not, better grinding being sometimes obtained with one relationship between these convex and concave faces, and sometimes better grinding being obtained with a slightly different relationship, depending upon the materials to be ground, and on other factors. In fact, a degree of liberality as to the details just expressed, and also other details and features of my invention, must be accorded to the scope of my invention, for the reason that the balls themselves, and also my new elements 11, wear and become smaller as the grinding of tons upon tons of ore proceeds.

From the foregoing description, I believe the operation of my new grinding charge will be clear, the basis thereof being that the greatly increased grinding surfaces produced between the conventional balls as one element, and my new members 11 as a second element, will cooperate in such manner as greatly to improve, or at least substan-

tially improve, the results procured by the grinding charge, above the results obtained when balls only are used.

I claim:

1. In a ball mill, an improved grinding charge comprising the combination of grinding balls and grinding elements, the shape of said grinding elements conforming approximately with the interstice within a group of four of said balls symmetrically stacked so that the centers of each three of said four balls lie approximately at the vertices of four substantially identical equilateral triangles formed by straight lines joining the centers of each three of said four stacked balls, and the surface of said grinding element having four concave grinding depressions registering approximately with the adjacent portion of the convex surfaces of said four symmetrically stacked balls.

2. For use in a ball mill, a new and improved grinding element the shape of which conforms approximately with the interstice within a group of four balls symmetrically stacked so that the centers of each three of said four balls lie approximately at the vertices of four substantially identical equilateral triangles formed by straight lines joining the centers of each three of said four stacked balls, and the surface of said grinding element having four concave grinding depressions registering approximately with the adjacent portion of the convex surfaces of said four symmetrically stacked balls.

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