July 17, 1951 J. B. MARTIN 2,560,972

HORIZONTAL AXIS BALL MILL WITH PERIPHERAL SCREENING AND LIFTING BAYS

Filed Dec. 9, 1947

3 Sheets-Sheet 1

Fig. 1.

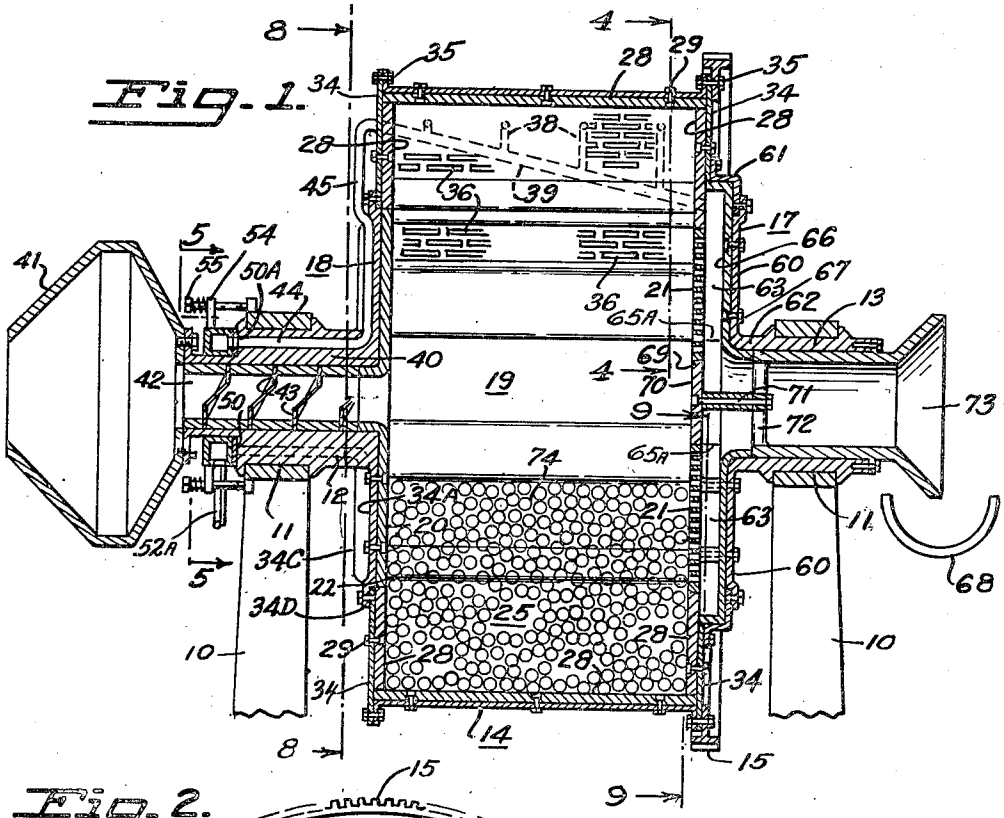


Fig. 2.

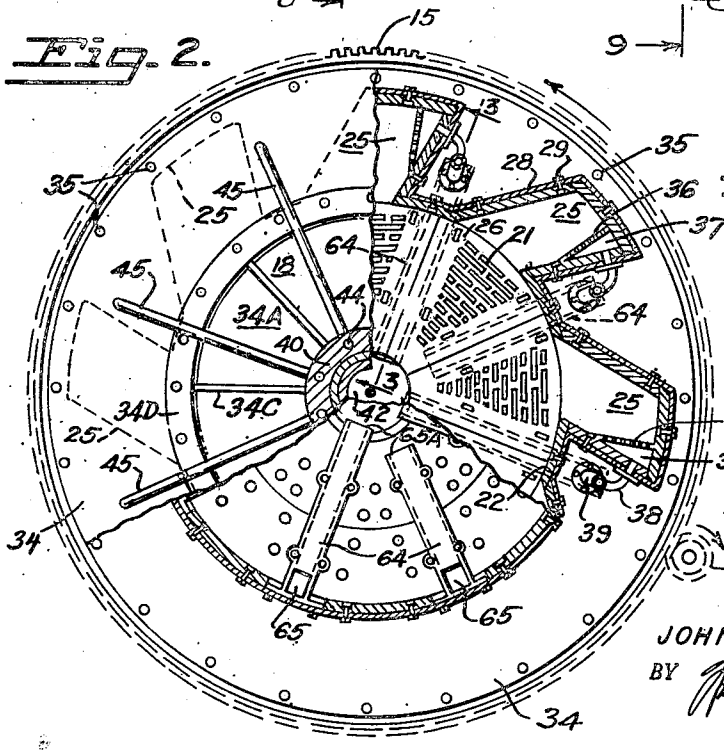
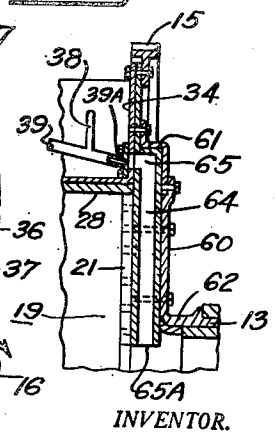


Fig. 3.



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Fig. 4.

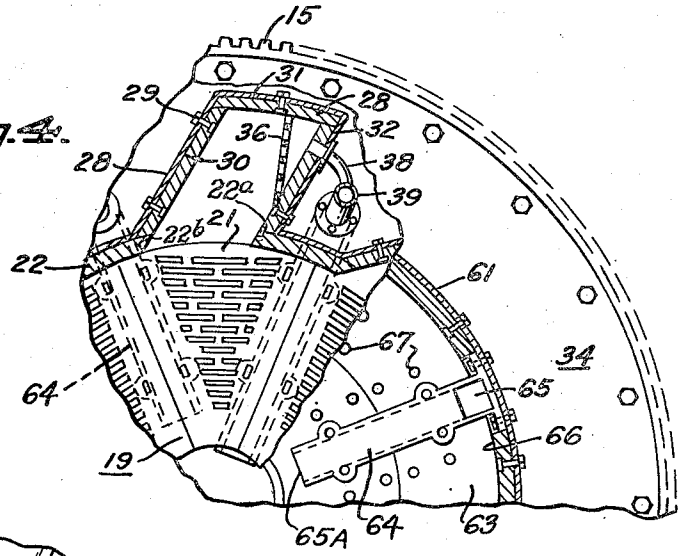


Fig. 5.

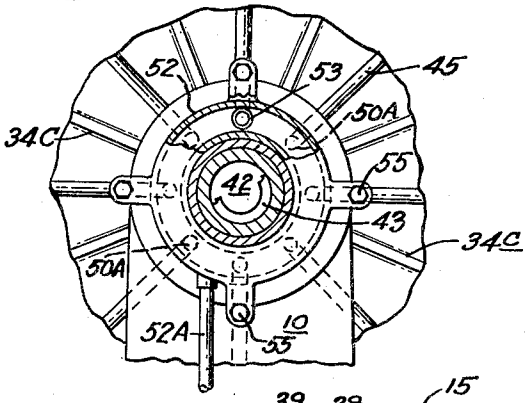


Fig. 7.

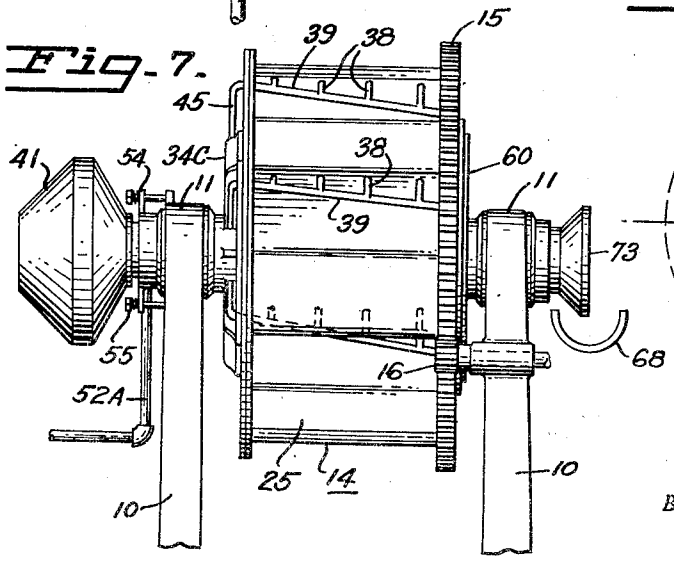
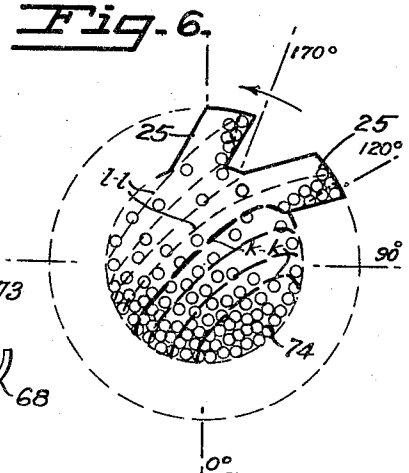


Fig. 6.



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Fig. 8.

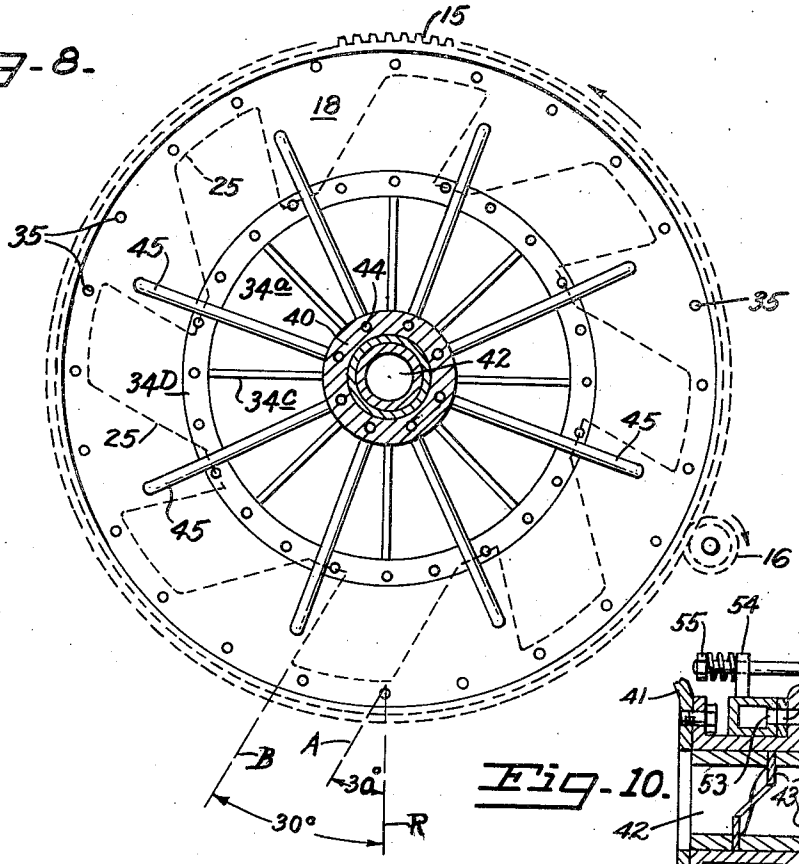


Fig. 10.

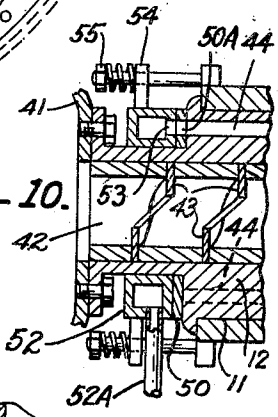
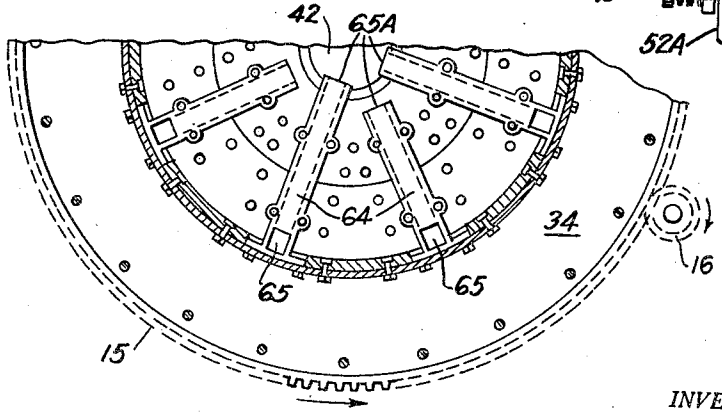


Fig. 9.



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HORIZONTAL AXIS BALL MILL WITH PERIPHERAL SCREENING AND LIFTING BAYS

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Application December 9, 1947, Serial No. 790,509

3 Claims. (Cl. 241—70)

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This invention relates to ball mills for grinding ores and the like and particularly relates to ball mills having buckets or bays disposed circumferentially of a cylinder, which latter has heretofore been known in such mills.

Ball mills in the known art for comminuting ores have depended on the cascading of balls or other heavy grinding members such as quartz rocks, within a rotating cylinder or drum, the axis of rotation usually being horizontal to the base or ground, feeding the ore aggregate in at one end, sifting the progressively comminuted ore through screens at the ends of the cylinder or at its circumference, or both.

Broadly, the present invention comprises an arrangement of structure whereby additional balls or grinding pellets may be accommodated in a ball mill, utilizing the cascading of the usual number and weight of the balls in the manner now known, and retarding the cascading of the additional balls or a portion thereof, to a deferred position of rotation of a rotor member within which the balls are contained.

An object of the invention is to provide a rotary ball mill in which cascading of a portion of grinding balls or members is delayed beyond the normal and standard angle of such cascading of the balls in a rotary ball mill drum, by provision of bays or pockets circumferentially spaced about, and opening into the drum, for receiving and carrying a portion of the grinding members to a position of greater elevation than the normal position of cascading of the balls, whereby the balls so elevated are flung across the hollow drum from such elevation to impact an aggregate mass of balls and ore in the bottom portion of the drum.

A still further object is to provide a rotary ball mill in which bodies of ore to be ground may be continually divided into relatively small batches and mulled in the mill, and thus the comminuted portions more readiy sifted in small batches from the aggregate.

Yet another object is to provide such a mill in which the pulverized portions of the ore are quickly and continuously cleared.

With the foregoing and other objects in view, as will more fully appear from this specification, one form in which the invention may be advantageously embodied is described herein and illustrated in the accompanying drawings.

In the drawings:

Fig. 1 is an axial transverse vertical section of the mill of the invention.

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Fig. 2 is an assembly view of parts shown in Figs. 4, 8 and 9.

Fig. 3 is a fragmentary sectional view on lines 3—3 of Fig. 2, showing details of tube construction.

Fig. 4 is an enlarged view partly broken, and partly in section on line 4—4 of Fig. 1.

Fig. 5 is a view of valve and valve ring assembly.

Fig. 6 is a diagrammatic view illustrative of one phase of operation, and Fig. 7 is a reduced generalized side elevation.

Fig. 8 is an end elevational view on line 8—8 of Fig. 1.

Fig. 9 is a fragmentary view, partly in section on line 9—9 of Fig. 1.

Fig. 10 is an enlargement of detail of valve ring structure shown in Fig. 1.

Referring to the drawings, in which like reference characters indicate corresponding parts in the several views, 10 indicates suitable supports for trunnion bearings 11 at opposite axial ends of the apparatus. Upon the trunnion bearings are mounted co-axial hollow trunnion structures which may be designated the feed trunnion 12 at one end and discharge trunnion 13 at the opposite end of a rotor generally indicated 14 which has at one of its sides a circumferential driven gear 15 meshing with a pinion gear 16, the latter being driven in direction of the arrow adjacent thereto in Fig. 2, by any suitable power source, such as an electric motor (not shown). The trunnions and rotor are connected for unison rotation.

The rotor 14 is irregularly generally cylindrical and has side end walls indicated generally 17 and 18 which have numerous detais of structure to be described.

Between the side end walls 17, 18, the rotor comprises a hollow cylindrical drum or chamber 19 which is centrally free of obstruction and of a diameter substantially defined at one end by a central inner wear plate 20, and the outer central face plate 34A of the side wall 18; and defined at the opposite end by an inner perforated screen 21, which preferably is segmental for purpose of replacement of its parts. The circumference of the central cylindrical drum portion 19 of the rotor is defined by circumferentially relatively spaced transverse plates 22 longitudinally extending in respect of the axis of rotation of the rotor, which separate bays or buckets to be further described. The outer central face plate 34A may be provided with suitable reinforcing ribs 34C and connecting flanges 34D,

Radiating out from, and communicating with, the central drum cylindrical chamber 19, and of a length extending between the opposite end inner walls of the rotor, are a plurality of hollow elongated circumferentially spaced buckets or bays 25 opening into the central cylinder as at 26. Each bay has three longitudinal walls in addition to its opening 26, the inner face of the walls being lined with replaceable wear plates 28 secured by bolts 29. The bay openings 26 are of a sufficient width so that grinding members and ore may readily enter and discharge from the bays. The radial depth of the bays is more or less arbitrary, though of sufficient depth to receive a substantial quantity of grinding members and ore. Since the principal purpose of the bays is to elevate and throw a quantity of grinding balls across the relatively large hollow drum, obviously the bays should not be too deep to readily discharge the balls. Therefore, the depth of the bays may be specified as substantially less than the maximum diameter of the central drum, or conversely, the maximum diameter of the drum is greater than the depth of the bays.

The longitudinal walls of the buckets or bays may be arbitrarily designated with relation to the direction of rotation as the forward wall 30, the circumferential outer wall 31, and the follower or lifting wall 32, the spaces between the bays at the circumference of the drum being closed by the wall 22 of the circumferential portion of the hollow central cylindrical drum chamber, thus preserving in the drum portion a cylinder into which the bays have their openings 26, the maintenance of the cylindrical form of drum centrally within the surrounding bays serving to support the loose mass of grinding members or balls which are not segregated and conveyed by the bays. The opposite ends of the bays are closed by disc plates 34 suitably connected by bolts 35 to the circumferential casing 27 and similarly lined with replaceable wear plates 28. The forward wall 30 and the follower lifting wall 32 of the bays are inclined angularly relative to a radius R of the rotor intersecting the center of the opening 26, the incline being rearwardly counter to the direction of rotation of the rotor, an angularity of approximately 25 to 35 degrees being satisfactory, as shown by 30 degree angle lines A and B. It is preferred that such angularity of the forward wall 30 and the follower or lifting wall 32 shall be substantially similar, so that they are substantially parallel, providing bays which in transverse section would be rhomboidal, though other geometric cross sections may be employed in which the opening 26 into the cylindrical drum portion is the maximum circumferential width of the bays whereby the incline of said forward wall will not impede the flight of the balls as they are impelled from the bays. The degree of angularity of the lifting wall 32 determines the quantity of grinding members received in the bays and the angle of slippage at which the balls will be discharged, and also provides an inclined shovel blade having an angular plow nose 22a lengthwise of the drum at an acute angle of junction of the lifting wall 32 and the circumferential plates 22 of the cylindrical portion of the drum, whereby the cylindrical form of drum is maintained to support the mass of loose grinding members or balls. Upon rotation of the rotor the bays or buckets become filled with a definitely segregated quantity of balls and ore while the bays are rotating at the bottom portion of the drum, and as the drum is rotated upward and the loose balls of the cylindrical portion cascade toward the bottom, the plow nose 22a shears a path or cleavage between the segregated balls in the bays and the mass of loose balls and ore which is in the cylindrical portion, and thus carries the segregated quantity of balls in the bays to a discharge position of rotation beyond the position of cascading of the loose balls in the cylinder of the drum portion. The angular inclination of the forward wall 30 counter to direction of rotation is of equal or greater importance than the angularity of the follower lifting wall 32 since such angularity provides an obtuse angle 22b at the joining of the forward wall to the cylindrical wall of the central drum portion, and thereby determines the size of the opening 26 into the bays, and also determines whether the elevated balls may be readily discharged by throwing from the bays without being obstructed by the forward wall when a bay has been rotated to an angle of discharge slippage of the contents.

Since it may be desirable to sift comminuted ore particles from the bays, means are provided for that purpose. A sifting screen 36 extends longitudinally of each bay, having one of its longitudinal edges secured intermediate the longitudinal side edges of the lifting walls and being angular thereto, and supported at its opposite longitudinal edge by the outer wall of the bays, thus providing a longitudinal pocket 37 in one of the outer corners of the bay. The pockets 37 of the bays each have connected thereinto through the lifting walls 32 a plurality of outlet pipes 38, the other end of which connects and communicates with a fluid conduit 39 extending laterally transversely at an incline across the exterior of the rotor, in the valleys between the relatively spaced bays, the discharge ends of the conduit pipes being indicated 39A.

The hollow trunnion 12 at the feed end comprises a strong trunnion block 40 for rotation in bearing 11 and it has mounted thereon at its outer end a feed bell or hopper 41 opening for feeding purposes into a feed tube 42 which extends longitudinally axially of the feed trunnions and has therein a helical rib drive 43. Also longitudinally through the feed trunnion block 40 there is provided a plurality of circumferentially arranged tubular bores 44, each of which communicates with a liquid supply radial pipe 45, which latter communicates with the inclined transverse pipe 39, there being one of these pipe assemblies for each bay, which, as stated, is positioned in the valley between the bays, and exterior thereof.

At its outer end portion the feed trunnion has a ring valve, comprising an annular ring valve plate 50 of suitable wear resistant material circumferentially of the hollow tube portion 42 and mounted for rotation with the trunnions. The ring valve plate 50 has relatively registering ports 50A therethrough, one port for each of the pipes 45 and the inclined pipes 39 in the bay valleys, which in the present example are eight in number. Also mounted fixedly on the feed trunnion bearing, but not rotating with the trunnion, is an annular tubular valve ring 52 having a single valve vent 53 therein, positioned at its top in register with the path of rotation of the tubular bores 44 through the ports of the valve ring plate. This annular tubular ring has spring tensioned mountings by flanges 54 and spring-loaded bolts 55 so that its superficial sliding contact with the

abutting assembly of valve ring 52 is slidingly tight against leakage.

It has heretofore been described that at the opposite or discharge ends the wall 17 comprises several features and that the central cylinder drum 19 of the rotor is penetrably closed by perforated screen 21, and that the side ends of the bays are closed by wear plates 28 and casing plates 34, the latter serving as a mounting support for the perimetral driven gear 15. In addition, this wall 17 has mounted thereon an end disc plate 60 supported in spaced relation to the screen 21 by angled flanges 61, said disc plate being perpendicularly formed centrally to provide the hollow tubular discharge block 62 which also serves as a trunnion for rotation in trunnion bearing 11. Thus a circular chamber 63 for comminuted ore is provided at the discharge end of the rotor, being relatively thin in an axial dimension in the nature of an upraised circular blister. The circular receiving chamber 63 has a diameter sufficiently in excess of the diameter of the central cylindrical portion of the rotor and the screen 21, to include within its periphery the inward discharge end 39A of the fluid conduit pipe 39.

The blister or chamber 63 comprises a housing within which is positioned a plurality of radiating relatively spaced tubes 64 each having an opening 65 at its radially outer end for communication with the terminal end 39 of the inclined pipes 39, the opposite or radially inner end 65A of the tubes being opened into the hub discharge portion of the blister chamber, and the inner ends of alternate tubes being relatively shorter to eliminate clogging at the hub and provide space for passage of pulverized material sifted into said chamber through the screens 21. The thickness of the tubes 64 is such that they serve also as supporting ribs to reinforce the screen 21.

A changeable wear plate 66 may be provided as an internal liner for the outer wall 60, it being understood that it is not of sufficient thickness to obstruct the passageway in the chamber, and it may be releasably secured to the outer wall by bolts 67.

A discharge funnel 73 is mounted in the opening of the trunnion block 62, provided with an outwardly flared end for depositing the pulverized products from the rotor into a suitable launder 68.

For the purpose of placing balls in the mill or removing them, or for replacing wear plates 28 or for any other purpose necessary for entry within the rotor, an opening 69 is provided centrally of the screen 21. This opening 69 may be closed by a plate 70 which is maintained in position by a sub-shaft 71, secured by a bolt to a spider crossbar 72 in the discharge funnel 73.

In operation, ore of any suitable kind, crushed as is customary to a ¾ inch mesh, is fed into the receiving feed bell 41. The ore may be fed wet or dry, and if desired that it be wet, water or cyanide solution or other suitable liquid may be added in the feed bell. As the ore is fed, it is picked up by the helical drive 43 in feed tube 42, and thus propelled into the central drum chamber 19 which has therein a supply of loosely tumbling grinding members such as hard steel balls 74, hard rock pellets or the like, of suitable size to provide the desired impact on the ores and also to enter into the bags and be discharged therefrom as the rotor is rotated. The quantity of balls or pellets employed and the weight thereof will vary with the character of ore being pulverized. Generally it is sufficient if the rotor of the ball mill is filled about ½ of its capacity with balls.

In the known ball mills, as the rotor is rotated, the balls and ore are carried up the incline of the inner wall of the rotor in the direction of rotations thereof, and as they reach an angle of slippage or cascading superinduced by rotation of the cylinder, they fall back to the bottom of the cylinder and by impact and mulling, pulverize the ore in the interstices therebetween, the fines or comminuted ore particles working out through screens of the cylinder such as end screens 21. There is a recognized and well known formula for the cascading of the balls in such operations. In the present invention all the advantages and action of the known ball mill are present in the central cylindrical drum portion 26, to support the usual mass of balls in the cylindrical drum portion. The buckets or bays 25 also fill with balls or grinding pellets and ore when they are at the bottom of the cylindrical chamber, and by reason of the angular incline of the follower, or lifting wall 32, they shear off segregated batches of balls and ore from the mass, and they do not discharge the balls until the balls therein have passed or overridden the angle of slippage or cascading of the balls and ore in the cylindrical portion. In the cylindrical drum portion 19 corresponding to the known ball mill, the balls and ore, as they are carried up the side wall of the cylinder, usually commence to slip or cascade when the cylinder makes somewhat more than a quarter revolution, or about 90 degrees, and they complete the cascading when the cylinder has rotated about 120 degrees from the bottom. The additional balls in the bays of this invention do not begin to cascade until the lifting wall of a bay arrives at a position representing an angle of slippage which, if the angle of the lifting wall is 30 degrees to the described radius, is substantially a rotation of approximately 120 degrees from the bottom and the balls in the bays continue to cascade therefrom until the bays have rotated approximately 170 degrees to 180 degrees. Thus the fall of the balls from the bays is deferred, or override the cascading of the balls in the cylindrical drum chamber. The fall of the balls from the bays being greater than those in the cylinder, and their velocity of rotation being in a greater circumference giving them greater force, they are thrown across the axis of the drum and pound the ore and the balls in the bottom of the cylinder with increased impact and in an area of the mill which is not reached by the cascading balls of the drum portion of the cylinder, thus greatly increasing the grinding efficiency of the mill.

In the ordinary cylindrical ball mill substantially all the crushing from cascading of the balls occurs in approximately a 45 degree segment of the drum cylinder between the lower end of the vertical diameter taken as zero, and minus 45 degrees contra to the direction of rotation, whereas in this invention, with the additional override of the discharge of balls from the bays, the thrust or cascade of the balls from the bays provides a pounding or impact area substantially an additional 45 degrees beyond the impact of balls from the cylindrical portion. This is shown in the diagrammatic view of Fig. 6 in which lines *k*—*k* indicate the accepted standard graph line of balls falling in the known cylindrical ball mills, and graph lines *l*—*l* indicate the

falling of the balls from the bays of the present invention.

The comminuted ore particles from the central cylinder chamber work out through the screens 21 and into the upraised blister chamber 63, and then work out through the discharge orifice 73. There is also a very considerable quantity of comminuted ore which is ground by impact of the falling of the balls to the bucket bays when they are at the bottom of the rotor. As the bays move upward by rotation of the rotor, the comminuted ore in the bays sifts through the bay screens 36 and is carried through the tubes 38 to the pipes 39 thence through opening 65 into the radial tubes 64 and thus discharges into the discharge opening 73, through the collecting chamber 63.

Again referring to the annular tube valve ring 52 at the feed end of the apparatus, it is provided with a feed conduit 52A for a supply of any desired type of fluid, for use in maintaining the conduit 39 cleared of comminuted ore which has emptied into conduit 39 from the bay outlets 38. As the trunnion and ring plate 50 rotate in unison the ports in the ring plate and tubular bores 44 successively pass the single opening of the tubular valve ring and thus an intermittent jet of the liquid, or air if desired, is forced through the liquid feed pipes 45 to and through the manifold discharge pipes 39, thus clearing each manifold discharge pipe 39 at each rotation of the rotor and facilitating carrying the ore particles therein to the discharge tubes 64 and to the discharge outlet. It is to be understood that alternatively compressed air may be fed through the ring valves instead of liquid.

It is also to be understood that the employment of the sifting screens 21 at one end of the cylindrical portion of the drum rotor, and screens 36 longitudinally transversely of the bays are the preferred form of structure since they serve to segregate the fines of the pulverized ore material as it is discharged from the mill. However, grinding ball mills, both with and without such screens at the end of a cylinder are well known in the art. The principal inventive feature of the present invention is in the employment of the bays spaced circumferentially of the central cylinder portion of the grinding rotor or drum.

Having described the invention, I claim:

1. In a ball mill, a rotatably mounted rotor adapted for receiving therein loose grinding members and material to be ground and having openings at its opposite ends providing an inlet and a discharge outlet, said rotor including a cylindrical central drum portion, axially longitudinal bays extending radially outwardly from the central drum portion and each bay having an opening into the central drum of sufficient size to permit the grinding members to enter into and discharge from the bays, the said bays having a forward wall and a follower lifting wall, said walls of the bays extending radially outwardly from the central drum portion substantially in relative parallelism at an angular incline rearwardly relative to rotor radii intersecting the center of the opening of the bays, said incline being counter to the direction of rotation of the rotor.

2. Ball mill apparatus of the class described having the elements of claim 1, and in which a sifting closure screen is mounted adjacently spaced relative to the discharge end of the rotor, and a collecting chamber for screened material is mounted between said sifting screen and the discharge outlet of the drum.

3. Ball mill apparatus of the class described having the elements of claim 1, and in which a screen means is mounted within the bays longitudinally of the follower lifting wall whereby ground material in the bays may be sifted therefrom during rotation of the rotor, and conduit means having communication at one end with the follower lifting walls of the bays and communicating at the opposite end with the discharge outlet of the rotor.

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