

Nov. 14, 1944.

L. A. FITZGERALD

2,362,811

BALL MILL LINER

Filed Jan. 29, 1942

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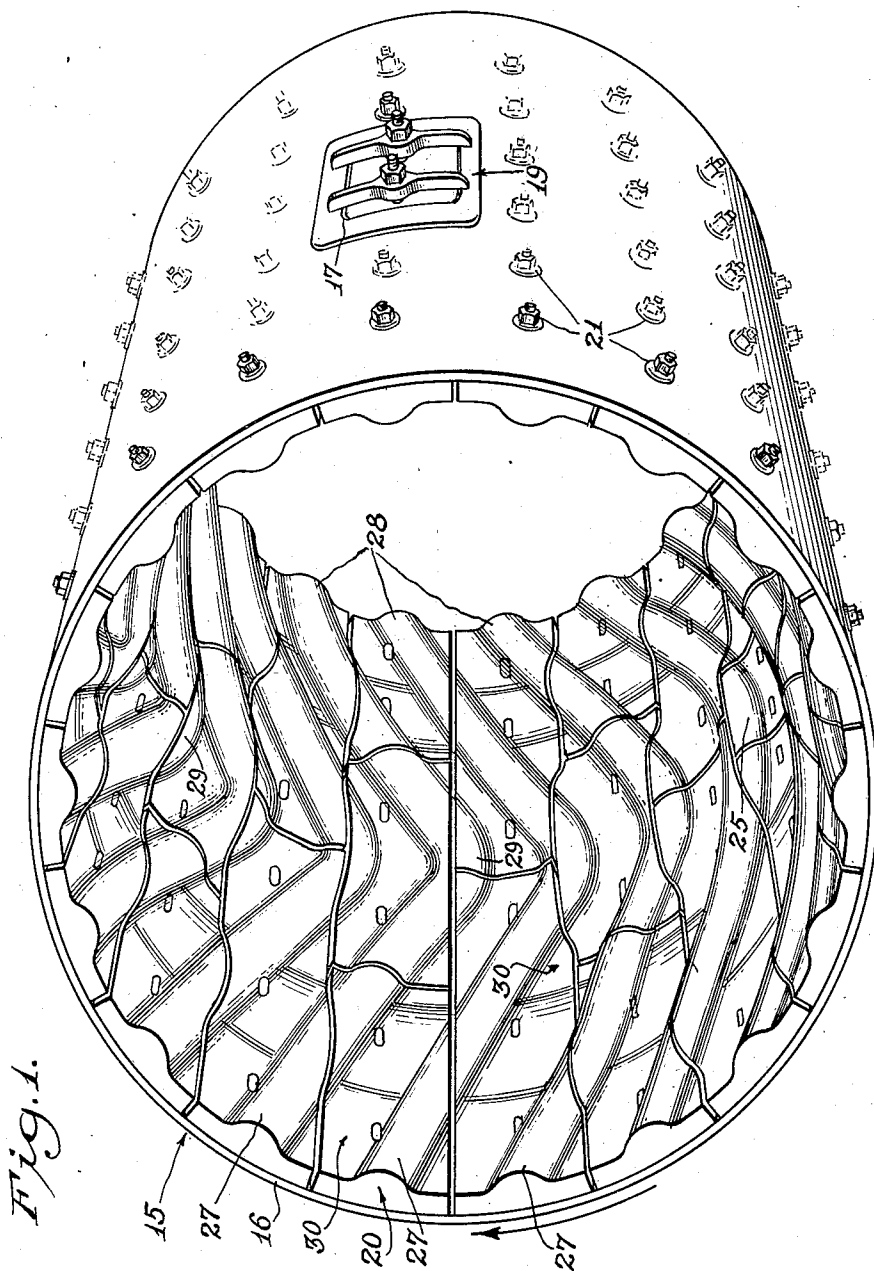


Fig. 1.

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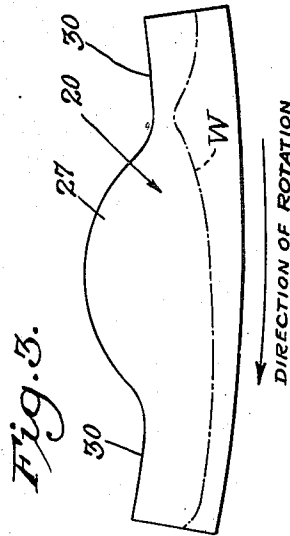
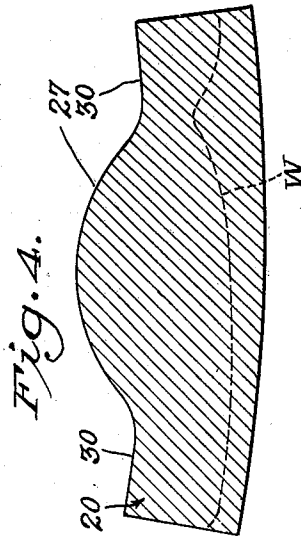
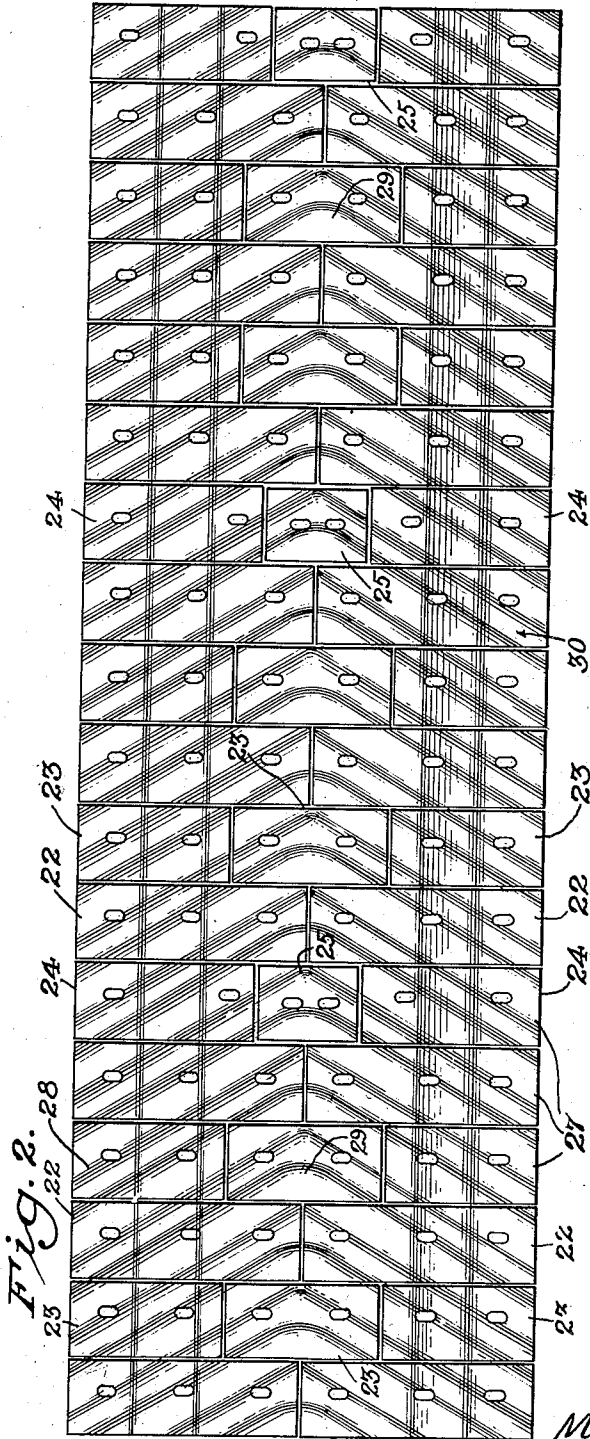
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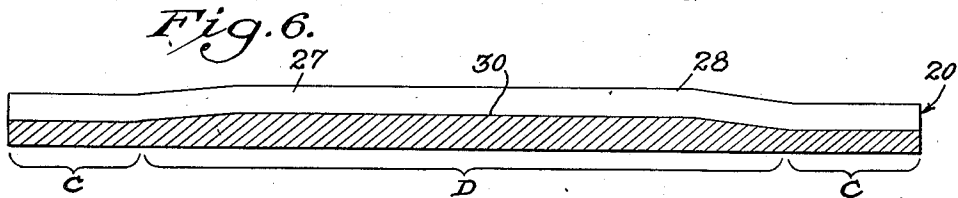
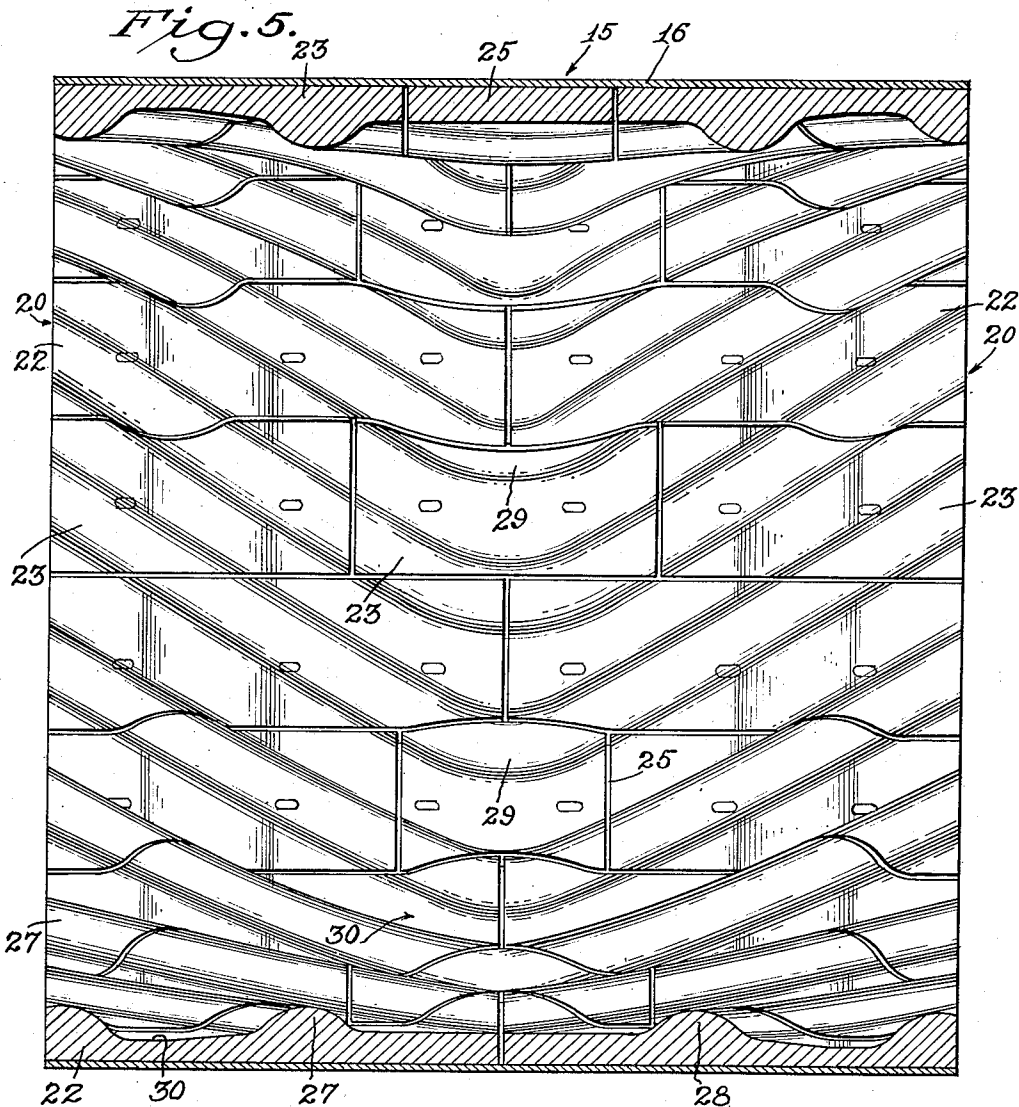
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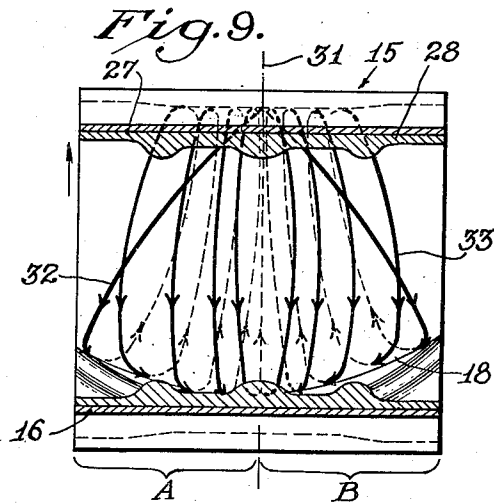
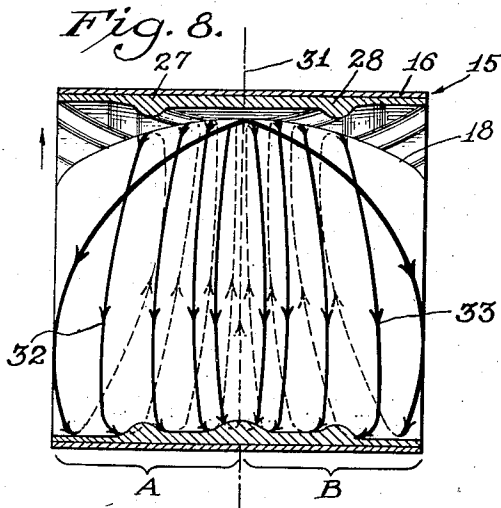
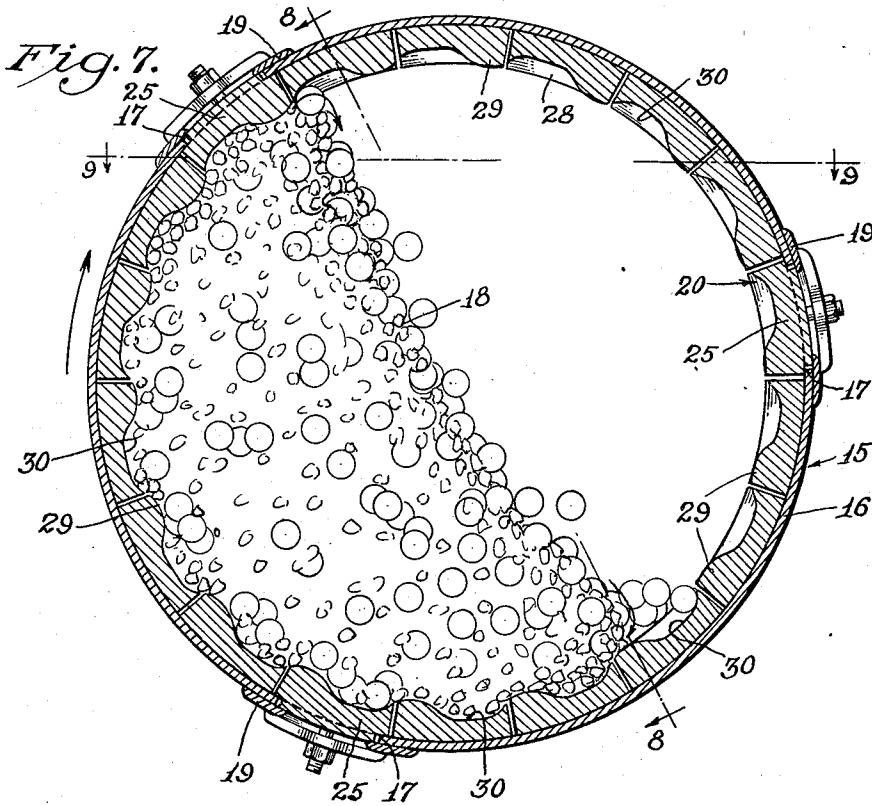
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BALL MILL LINER

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UNITED STATES PATENT OFFICE

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BALL MILL LINER

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14 Claims. (Cl. 83—9)

This invention relates to liners for ball-type grinding mills and more particularly concerns improvements in replaceable breast liners for such mills.

In a mill of this type the grinding action results from the crushing and abrading of the material such as ore by and between tumbling grinding bodies, and between the grinding bodies and the liners of the grinding chamber within the rotating cylinder of the mill. The grinding bodies may be in the form of steel balls or slugs, pebbles, or the like, depending upon the material to be ground, but for convenience will be referred to generally as balls.

In the conventional arrangement, the balls are spread in a more or less uniform grinding column throughout the length of the horizontally mounted mill, and a large proportion of the grinding takes place between the tumbling balls and the liner, the principal movement and thus grinding force of the balls being in vertical planes at normals to the mill axis, that is, up and down and to only a very limited extent axially, that is, horizontally.

A principal aim of the present invention is to increase beyond the usual extent the grinding action of ball against ball, by causing the balls to strike and grind against one another positively and continuously in considerable horizontal components of motion concurrently with—but in addition to—the usual vertical tumbling movement resulting from rotation of the grinding cylinder of the mill.

Another object is to provide the breast liner with novel means active in the operation of the mill to concentrate the grinding ball load and material in a grinding column of increased depth toward a medial plane of the ball chamber to the relief of wear on the end liner structure of the mill.

A further object is to provide a ball mill breast liner which can be manufactured at a cost comparable to conventional liners but which increases output through diverting grinding wear to the lower cost grinding bodies and thus prolongs the life of the higher cost liner, and results in substantial operating economies.

Another advantage of my improved liner which I find from tests is that when spherical balls are used as the grinding bodies, they tend to stay round for a longer time than with conventional liners. This seems to result from the action of my liner in promoting a more continuous and varied movement and rotation of the balls so that no ball is scoured, like a boulder embedded in a

glacier, against the liner surface long enough at a time in any one given position to develop substantial flats on the balls.

Another advantage of my liner is that the slab sections of which they are composed may be of the same rectangular size and pattern as that of the more or less standard ordinary slab sections, with the result that the standard retaining bolts can be employed without changing either the bolts or their locations in the mill or drilling any new bolt holes in the mill.

Another object is to provide an improved arrangement for effecting a continuous circulation of the grinding balls longitudinally of the mill and thus prevent channeling or "racing" of the breast liner. Once such a channel or race is started, the balls tend to stay in it to an increasing extent, with the result that there is continuously accelerated wear causing the liners to wear through rather quickly at the channel or race.

If, as in the present instance, it is desired to promote longitudinal movement of the balls and material, any such channeling acts something like a trench seriously impeding longitudinal movement.

In ordinary breast liners with plain surfaces or parallel horizontal corrugations, the rolling and sliding of the balls in the rotation of the mill seem to cause the balls to find starting depressions which artificially locate and temporarily hold successive balls in a fixed transverse plane. As the successive balls roll and slide from these starting depressions, they tend to elongated the starting depressions arcuately until finally they become circumferential channels or races in the inside surfaces of the liner. Such starting depressions may be the end gaps between liner slab sections, or bolt head holes, or flaws, waviness, or weak spots.

This phenomenon of channeling or racing will better be understood when it is explained that the movement of the mixture of balls and ore, or other material, is something of a combination of a simple rolling of the balls and liquid-like flow of the material, with a glacier-like scouring of the liner, considering the balls to be embedded boulder-like in the mass of material and to a large extent held against rotation by the pressure of the weight of the balls and material above the balls and material which come in scouring contact with the liner. This is why the action of the balls, must be described in terms of both rolling and sliding or scouring.

In the past the ribs or corrugations of breast

liners have sometimes been arranged obliquely or as parallel partial convolutions of helices. To a certain extent the longitudinal or horizontal components of movement of the charge due to the obliquing of the corrugations has tended to minimize channeling. But this tendency toward freedom from channeling has been at the penalty of other and more serious objections. If, as usual with the obliqued corrugations, the spiraling is so arranged in reference to the direction of rotation as to promote flow toward the discharge end, the results are: An excessive wear on the head liner at the discharge end of the mill; an excessive crowding of the material against the discharge ports such as to impede discharge; an insufficiency of the time the material remains in the mill, because of the urge toward the discharge end; and a faster wearing of one end half of the breast liner than of the other end half. Or, if the spiraling is arranged the other way in reference to the direction of rotation so that the spirals tend to promote flow toward the feed end, then the results are: An excessive increase in the time which the material remains in the mill; a crowding toward the feed ports which impedes feed; and a faster wearing of one end half of the breast liner than of the other end half.

In the past the obliquely arranged ribs or corrugations have sometimes been staggered or provided with interruptions or gaps. In such case, far from remedying the tendency to channeling, the tendency is greatly increased. This is because the gaps, or the ends of staggered ribs, as the case may be, provide very definite starting positions for the passage of successive balls which quickly develop channels or races in the breast liner.

By my invention the obliqued arrangement of the corrugations of the breast liner is such that the tendency to channeling is minimized—in fact, substantially eliminated—without promoting an increased flow toward either end, without excessive wear upon the head liner at either end, without crowding the material against the feed inlet or the discharge ports to impede their functions, and without causing one end half of the breast liner to wear faster than the other half.

As a corrugated liner wears, the greater erosion on the leading slopes of the ridges than on their trailing slopes causes a gradual backward shift of the ridges. One of the important practical advantages of my liner is that despite this extensive shifting—even to the extent that the ridge finally shifts backwardly to a position entirely beyond the position of the original ridge—the pattern of the corrugations is maintained without tendency to develop channeling, and as a result the characteristic action of my liner, together with the benefits flowing from it, are maintained throughout the life of the liner and throughout the entire extreme range of backward ridge shift.

Other objects and advantages will become apparent from the following detailed description and from the accompanying drawings, in which:

Fig. 1 is a perspective view of a ball mill cylinder with the ends omitted, showing my improved liner therein;

Fig. 2 is a projected plan view of the liner;

Fig. 3 is an enlarged end view of one of the liner slabs;

Fig. 4 is a transverse vertical sectional view through the liner slab;

Fig. 5 is a vertical longitudinal sectional view taken on the diameter of the ball mill cylinder;

Fig. 6 is a schematic longitudinal sectional view

taken along the center line of one of the grooves or valleys in the liner;

Fig. 7 is a transverse vertical sectional view through approximately the longitudinal center of the mill cylinder;

Fig. 8 is a schematic longitudinal sectional view, on a reduced scale, taken substantially along the line 8—8 of Fig. 7; and

Fig. 9 is a reduced schematic longitudinal sectional view, taken substantially along the line 9—9 of Fig. 7.

In carrying out my invention, the grinding balls are caused to have an improved ball-against-ball action in the operation of the mill. This I accomplish by imparting to the balls, in addition to the usual tumbling action, an impact action longitudinally of the mill axis. That is, while tumbling, the balls are urged constantly from opposite sides toward a common transverse plane of the grinding chamber to set up what may be likened to a riptide action.

The mass of balls may, for convenience, be considered as roughly divided into two opposing sections respectively urged toward a common transverse medial meeting plane where the opposing balls of the sections impinge against one another with considerable grinding pressure and also place the balls in the respective sections under similar, but, of course, gradually diminishing pressure as the distance increases from the meeting plane. I have found that as a result of this action the balls pile up in the region of the meeting plane in a substantially greater grinding column than in the case of simple conventional tumbling, and the heavier balls in particular tend to seek the meeting plane region throughout the grinding action. Thus, there is imparted to the balls a definite, purposeful grinding action which is in addition to and supplements the normal grinding action resulting from the usual tumbling of the balls by rotation of the mill.

These advantageous results are effected by a novel construction of the grinding surface of the breast liner with which the cylinder of the mill is equipped.

Referring now to the drawings, the mill identified generally as 15 (Figs. 1, 5 and 7) may be of standard or other suitable design including a horizontal cylinder 16 suitably mounted for power driven rotation about its longitudinal axis. In actual practice the cylinder 16 is equipped at its respective opposite ends with material inlet and discharge structures and end liners, which are not shown because they involve no feature of this invention but may be of any well known type.

Access into the grinding chamber within the cylinder 16 may be had through one or more suitably located manholes 17 for charging the mill with or dumping therefrom a discrete mass of grinding balls 18. The manhole 17 has a conventional closure structure 19.

The manhole 17 is also of service for entry to equip the cylinder 16 with a replaceable breast liner 20. The latter is preferably in the form of relatively small size, easily handled, narrow segmental plates or slabs extending lengthwise of the cylinder and shaped to conform to its inside wall. Removable attachment of the liner slabs is effected in any suitable manner by means such as bolts 21.

Each of the slabs of the liner 20 is preferably subdivided for convenience in handling into a plurality of sections, and the joints between the sections of alternate slabs are staggered to prevent the channeling by the grinding bodies 18.

Thus, certain rows of slabs may comprise two equal sections 22 (Fig. 2) while alternate rows comprise three proportionately smaller equal sections 23. At the manhole 17, there may be a slight alteration in size of the liner section to conform to the manhole size, thus providing equal size end sections 24 and an intermediate manhole section 25 which is removably secured in place by the associated manhole closure structure 19. A slight spacing is left between all adjacent edges of the various liner sections to facilitate speedy mounting of the sections. However, the spacing about the manhole section 25 may be slightly greater to assure at all times adequate clearance for ready removal from the manhole 17, even though there may be a certain amount of peening over or flow of the metal of the section 25 or of the immediately adjacent sections under the impact of the grinding bodies 18.

According to the present invention, the grinding surface of the liner 20 is formed over all with two uniform and equally pitched (in this instance approximately 30°), though oppositely extending, series of oblique corrugations or ribs 27 and 28, respectively, which in this instance extend equal distances inwardly from the respective opposite ends of the liner 20 and meet substantially chevron fashion at the transverse center plane of the grinding chamber. The meeting ends of ribs 27 and 28 join in a continuous curvingly peaked sweep, as indicated at 29. The over-all result is a herringbone pattern.

In the illustrated practical embodiment, there are as many of the ribs in each series as there are slabs in the liner 20. The outer ends of the ribs have their center radius on the longitudinal center lines of the associated slabs. The slopes of the ribs—both leading and trailing slopes—are of easy ogee transverse contour. The ribs project about two inches from the intervening valleys, that is, from the adjacent cylindrical plane of the liner, and the liner slabs, when new, are from three to three and one-half inches thick, exclusive of the ribs.

The pitch of the ribs 27 and 28 may be so related to the width of the liner slabs as to run off of the slabs on which they start and diagonally across the respectively adjoining slabs toward the center, with the peaks 29 largely, if not altogether, on the second adjacent slab. As shown, each of the liner slabs has the outer starting end section of one of the ribs 27 at one end and that of one of the ribs 28 at the other end. Inwardly spaced from the rib end sections are rib extensions aligned with, and service as continuations of, the rib sections of the slab adjoining at the advancing side. The peaks 29 are in the form of convergences located on the slab adjoining on the trailing side and co-operating with the inner ends of the rib extensions. As a result, each of the chevron-shaped rib units 27, 28 is nested between the adjacent rib units at both sides in a herringbone pattern. The several plate sections 22, 23 and 24 of the liner are, of course, made with appropriately aligned sections of the various ribs conforming to the preconceived herringbone pattern.

The spacing between the bases of the adjacent ribs 27 and 28 may be about the same as the width of the ribs and is designed to receive the balls 18 and provide flat bottom grooves 30 within which the balls are guided by the ribs inwardly away from the ends of the cylinder 16 toward the meeting points 29, as the cylinder is rotated in the direction shown by the arrows in Figs. 1 and

7, whereby the peaks 29 trail on the upswing side of the grinding chamber. At the peaks 29, the grooves 30 may widen out slightly to afford greater clearance.

As observed in operation, there is superimposed upon the usual tumbling action of the balls 18 within the mill a movement of the balls away from opposite ends and toward a meeting plane, indicated generally by the line 31 in Figs. 8 and 9, coinciding with the center line of the peaks 29. This effect is apparently produced by deflection of the liner-contacting balls 18 toward the meeting plane 31 by the ribs 27 and 28 as the cylinder 16 rotates to tumble the ball mass.

Thus, referring to Figs. 7, 8 and 9, frictional contact between the liner 20 and the contacting balls 18 carries such balls in the direction of rotation of the cylinder, but gravity and the inertia and friction of superimposed balls cause the contacting balls to seek the low point in the grinding chamber by sliding and rolling down the up-traveling surface of the liner. As the sliding, rolling balls 18 encounter the respective ribs 27 and 28, they seek to follow the advancing sides of the ribs down the channels 30 and crowd toward the meeting plane 31. Because of opposition from surrounding balls, this lateral deflection of the balls by any given one of the ribs 27, 28 is only more or less momentary and of limited extent, but the accumulative effect after engagement with several successive ribs is appreciable.

In addition, as the balls ride over the unbroken rib humps, they jostle the superimposed balls and agitate the mass which appears to give enough relief from the weight of the mass so that as the balls move down the trailing sides of the ribs, they more or less follow the inclination of such sides in the direction of deflection. This is strikingly evident from an examination of the liner after it is worn away to the point of necessitating replacement, which reveals the rib ridges still prominent and retaining their identity in the pattern though worn down from the original arcuate form to relatively sharp peaks and shifted, by the brunt of wear on the advancing sides of the ribs, over adjacent to where the trailing side had been. (See the dot-dash line W in Figs. 3 and 4 which is representative of the ultimate wear surface found in the slabs of a replaced liner.) Further support for this conclusion is in the worn condition of the grooves 30 which are now revealed as valleys of substantially smooth, arcuate form.

Noteworthy, also, is the fact that the worn liner exhibits a remarkable freedom from circumferential channelling. The worm ribs are of substantially uniform prominence and the intervening valleys are hollowed out smoothly parallel with the ribs.

The speed at which the cylinder 16 is rotated is designedly rapid enough to exceed substantially the sliding, rolling, rib retarded movement of the balls 18 down along the liner 20, so as to carry such balls up as nearly as practicable to the top of the grinding chamber before they have traveled to any great extent toward the meeting plane 31. At the top the balls fall away from the liner by force of gravity and tumble down the sloping top of the ball mass. As a result the balls 18 travel continuously in a cyclical path which takes them recurrently under the ball mass up to the top and then down again.

Because of the inward deflection of the engaged balls 18 by the herringbone rib structure, there is a general movement or gradual working

over of the balls progressively from the ends of the mill so that the cyclical path traveled proceeds in substantially helical fashion toward the meeting plane 31. As shown diagrammatically in Figs. 8 and 9, the balls in the two sections of the mass, designated A and B, at opposite sides of the meeting plane 31, work gradually inwardly in respective generally deformed-helical paths 32 and 33, the helices of which gradually flatten out and describe progressively larger arcs adjacent the plane 31 as the pressure increases and the grinding column deepens from the crowding together of the balls of the two sections A and B of the mass. At the plane 31, the balls reach the peak of the grinding column and fall back, as indicated, to the starting points of the respective helical paths 32 and 33 for repetition of the cycle.

It is to be understood, of course, that the preceding description of the ball action is directed simply to the total effect which has been observed and that due to the vigorous agitation and hard crowding of the balls effected by movement over the ribs 27, 28 added to the turbulence incident to tumbling there is much erratic travel of individual balls. All of this results in substantial improvement in the grinding effectiveness of the balls one against the other and an increase in the total productive capacity of the mill between necessary breast liner replacements.

Since the ball-against-ball grinding is increased and the breast liner is to that extent relieved from the burden of the grinding, a resilient material such as rubber may be used for the liner instead of the usual manganese or other alloy steel. Such resilient material must be capable of resisting the cutting action of broken balls, tramp iron or the like. Its advantage over metal lies in the freedom from wear, but at the same time the rate of production is reduced to the extent that results from action of the balls against the metal liners.

If desired, the liner 20 may be reinforced, for increased wear at its inner or central region where grinding is concentrated by the action of the converging ribs 27, 28. Thus, as seen in Fig. 6, the liner 20 is uniformly thickened from points at the inner ends of relatively short opposite end portions C of the liner slabs throughout the central region indicated at D and inclusive throughout of the ribs 27, 28 as well as the grooves 30. This difference in thickness is also shown comparatively in Figs. 3 and 4.

This central thickening need not be as great as might at first be supposed. Despite the central concentration of load, the wear is not so excessive therebeneath in my liner because the overlying weight of the concentrated load tends to restrain ball-on-liner impact. Also, the end regions of the breast liner are subject to more forceful ball impact, although by fewer balls, and this tends to result in end region wear more closely approximating the central region wear of the breast liner. Another limitation on the central thickening of the liner is that the outward slope of the liner face away from the central thickening tends to urge the load toward the ends of the mill, and this tendency should not be permitted materially to defeat the function of my herringbone corrugation pattern in urging the load toward the central meeting plane.

In the specific illustrative embodiment here shown, the mill diameter is about 6½ feet, its length about 8½ feet, the balls, where new, are

about 3½ inches in diameter, and the mill is rotated at a speed of about 20 R. P. M.

While I have illustrated and described a preferred embodiment of my invention, modifications may be made without departing from the spirit of the invention, and I do not wish to be limited to the precise details of construction as set forth, but desire to avail myself of all changes within the scope of the appended claims.

Having thus described my invention, what I claim as new and desire to secure by Letters Patent of the United States is:

1. In a breast liner providing a protective grinding surface for the inner wall of a ball mill cylinder, a uniform series of continuous ribs extending spirally inwardly from the opposite ends of the inner surface of the liner and meeting chevron-fashion to form a herringbone pattern, the ribs being adapted, when the cylinder is rotated with the meeting ends of the ribs trailing, to deflect the grinding balls of the mill toward a meeting zone substantially coinciding with said meeting ends, whereby to impart a component of positive longitudinal ball-against-ball grinding motion to the balls in addition to the tumbling motion effected by rotation of the cylinder.

2. A breast liner as defined in claim 1, which is replaceably secured to the grinding cylinder and is constructed of a set of co-operating slabs carrying predetermined aligned sections of the rib pattern.

3. A liner as defined in claim 1, in which the entire central area of the liner is appreciably thickened to withstand greater wear.

4. A ball mill breast liner comprising a grinding surface formed with a continuous series of alternate continuous ribs and grooves extending inwardly from the liner ends in a herringbone pattern, the convergences of the ribs being at substantially the longitudinal center of the liner, said ribs and grooves being adapted for guiding the grinding balls of the mill toward said center as an incident to rotation of the liner with said convergences trailing.

5. A ball mill breast liner comprising a surface adapted to cooperate grindingly with a mass of balls, and a continuous series of spaced substantially chevron-shaped continuous rib units in inter-nested relation on the grinding surface, the peaks of the rib units being aligned circumferentially of the grinding surface, and the spaces between adjacent rib units providing grooves within which the balls are received and urged by the rib units toward the peaks as an incident to operation of the mill.

6. A liner as specified in claim 5 in which the rib units are of rounded transverse surface so that the balls may roll and slide thereover relatively smoothly.

7. A breast liner for ball mills comprising a surface adapted to cooperate grindingly with a tumbling mass of grinding balls in the operation of the mill, and a series of continuous ribs extending spirally from opposite sides toward a common plane and designed to deflect the balls toward such plane when the liner rotates in the direction in which the inner ends of the ribs trail in movement, the trailing sides of the ribs extending in the same spiral direction as the advancing sides of the ribs so as to cooperate in the ball-deflecting action with the opposed advancing sides of the immediately adjacent ribs.

8. A ball mill breast liner comprising a grinding surface supporting the mass of balls in the

mill, and continuous ribs on said surface extending inwardly from opposite ends of the surface at approximately 30° pitch into convergence for deflecting the balls toward the convergences during rotation of the mill.

9. A replaceable cylindrical ball mill breast liner comprising a set of cooperating longitudinally extending slabs subdivided into shorter more readily manipulable sections, and integrally formed portions of ribs on the slab sections arranged to cooperate with the rib portions of contiguous slab sections to form continuous ribs units respectively extending inwardly from both of the respective opposite ends of the liner and biased in opposition to the direction of grinding rotation of the liner for deflecting the grinding balls into a zone of maximum grinding concentration spaced inwardly from said ends.

10. A replaceable cylindrical ball mill breast liner comprising a set of relatively narrow cooperating longitudinally extending slabs; and integral ball-deflecting continuous ribs formed on the grinding surfaces of the slabs; said ribs commencing at, and extending diagonally inwardly from, the opposite ends of the slabs and being of such length as to extend across a plurality of contiguous slabs into substantially chevron-shape convergence.

11. A cylindrical ball mill breast liner comprising a set of relatively narrow longitudinally extending slabs, the slabs being subdivided into more readily manipulable shorter sections with the sections of alternate slabs staggered to avoid channeling the end joints between sections by the grinding balls riding thereover in the rotation of the mill, and chevron-shaped continuous ball-deflecting ribs on said slabs, said ribs having their convergences trailing with respect to the direction of rotation of the mill and being formed to extend across a plurality of contiguous slabs, the convergences of the ribs being located at the joints between adjoining slab sections on alternate slabs and on the staggered slab sections of the remaining slabs extending across the latter joints.

12. In a ball mill, the combination of a substantially cylindrical supporting and enclosing housing, having an inlet and outlet and having means for its support for rotation on the axis of said housing, with a liner for the wall of said housing, said liner being of resilient, non-metallic material, and a multiplicity of substantially spherical grinding balls of predetermined size, in said mill, engaging said liner, said liner being formed with a multiplicity of substantially parallel and continuous ridges and grooves, each ridge and groove having two end portions extending longitudinally and inwardly from the ends of said housing and in a rotary direction inside said housing, and the end portions of each ridge and groove converging at an apex located between the ends of the mill, said mill being constructed and arranged for rotation in such direction that the apices of the ridges trail after the end portions of the ridges, the balls being caused to rotate and being lifted by the ridges and impelled inwardly

from both ends of the mill, to effect an improved grinding action of the balls against each other, while maintaining their shape substantially spherical and driving the balls and the charge inwardly from both ends of the mill to prevent clogging at the inlet or outlet.

13. In a ball mill, the combination of a substantially cylindrical supporting and enclosing housing, having an inlet and outlet and having means for its support for rotation on the axis of said housing, with a liner for the wall of said housing, said liner being of resilient non-metallic material, and a multiplicity of substantially spherical grinding balls of predetermined size, in said mill, engaging said liner, said liner being formed with a multiplicity of substantially parallel and continuous ridges and grooves, each ridge and groove having two end portions extending longitudinally and inwardly from the ends of said housing and in a rotary direction inside said housing, and the end portions of each ridge and groove converging at an apex located between the ends of the mill, said mill being constructed and arranged for rotation in such direction that the apices of the ridges trail after the end portions of the ridges, the balls being caused to rotate and being lifted by the ridges and impelled inwardly from both ends of the mill, to effect an improved grinding action of the balls against each other, while maintaining their shape substantially spherical and driving the balls and the charge inwardly from both ends of the mill to prevent clogging at the inlet or outlet, the said ribs being of substantially uniform cross sectional shape.

14. In a ball mill, the combination of a substantially cylindrical supporting and enclosing housing, having an inlet and outlet and having means for its support for rotation on the axis of said housing, with a liner for the wall of said housing, said liner being of resilient, non-metallic material, and a multiplicity of substantially spherical grinding balls of predetermined size, in said mill, engaging said liner, said liner being formed with a multiplicity of substantially parallel and continuous ridges and grooves, each ridge and groove having two end portions extending longitudinally and inwardly from the ends of said housing and in a rotary direction inside said housing, and the end portions of each ridge and groove converging at an apex located between the ends of the mill, said mill being constructed and arranged for rotation in such direction that the apices of the ridges trail after the end portions of the ridges, the balls being caused to rotate and being lifted by the ridges and impelled inwardly from both ends of the mill, to effect an improved grinding action of the balls against each other, while maintaining their shape substantially spherical and driving the balls and the charge inwardly from both ends of the mill to prevent clogging at the inlet or outlet, the said ribs being of substantially uniform cross sectional shape, and the ribs and grooves being formed with transversely curved surfaces of gradual curvature.

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