April 5, 1960 D. H. FAIRCHILD 2,931,584

BALL MILL

Filed April 9, 1956 3 Sheets-Sheet 1

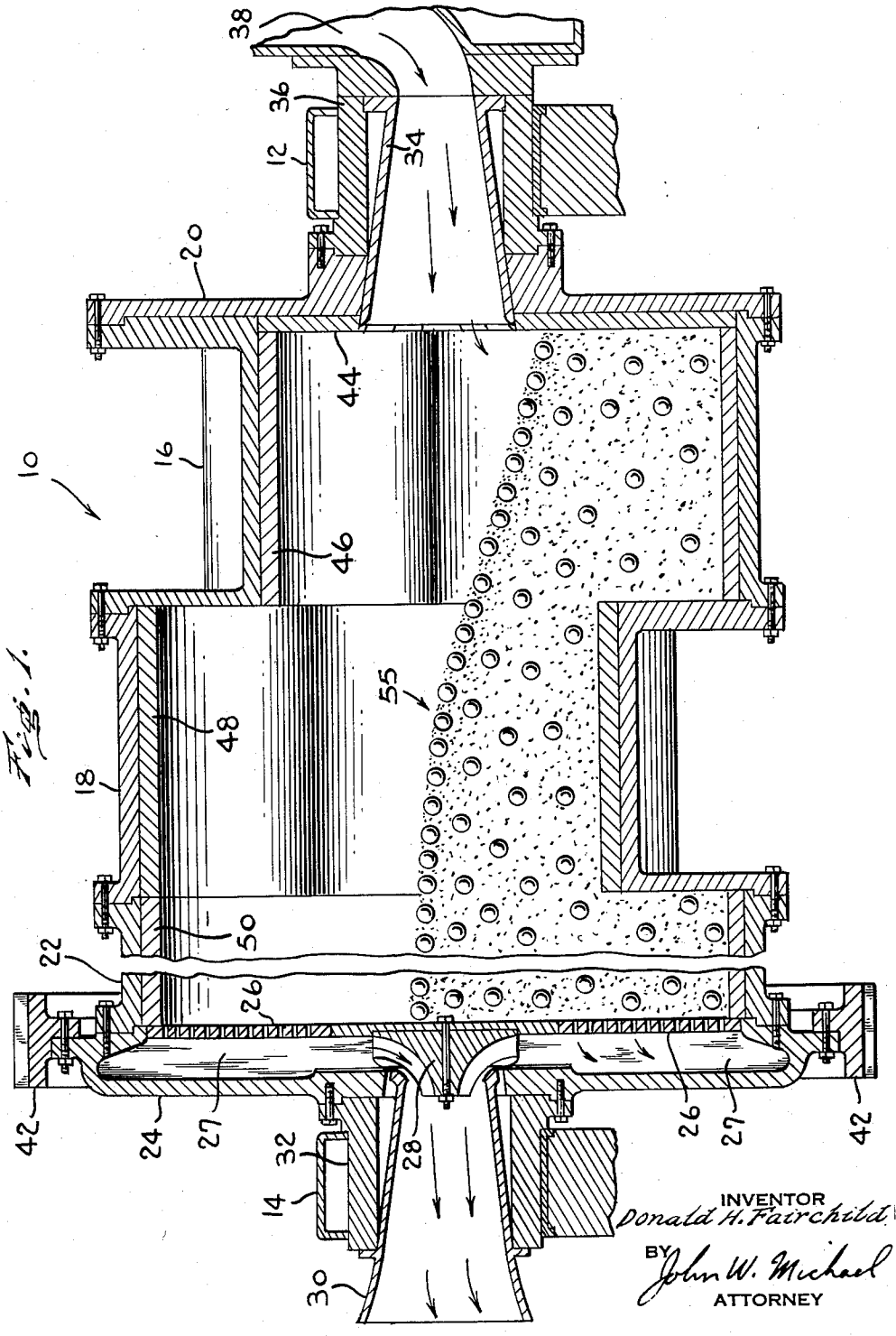



Fig. 1.

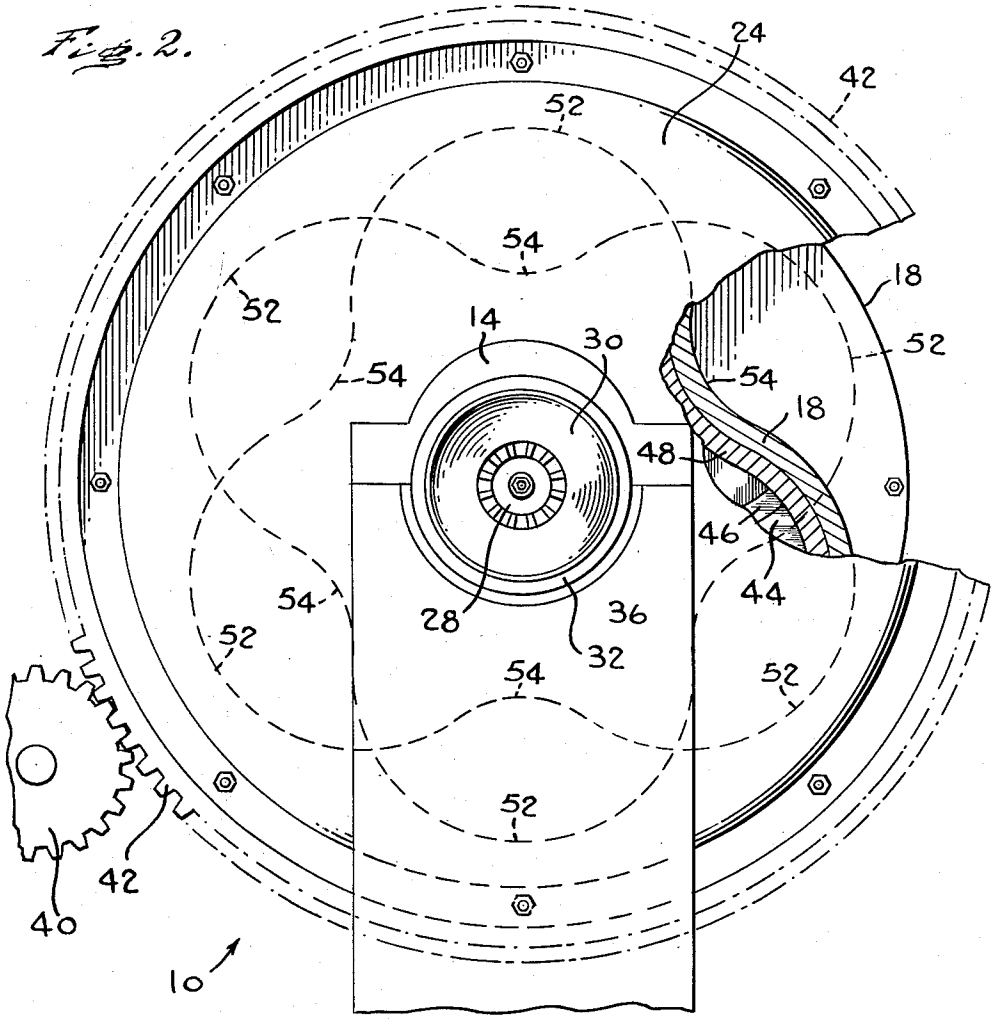
INVENTOR
Donald H. Fairchild
BY
John W. Michael
ATTORNEY

April 5, 1960 D. H. FAIRCHILD 2,931,584

BALL MILL

Filed April 9, 1956 3 Sheets-Sheet 2

Fig. 2.




INVENTOR
Donald H. Fairchild
BY
John W. Michael
ATTORNEY

April 5, 1960 D. H. FAIRCHILD 2,931,584

BALL MILL

Filed April 9, 1956 3 Sheets-Sheet 3

Fig. 3.

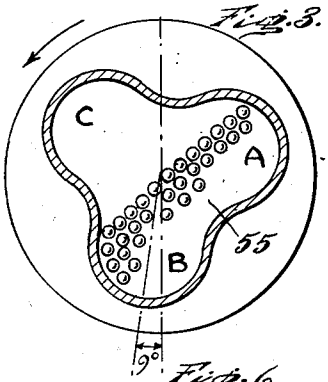



Fig. 4.

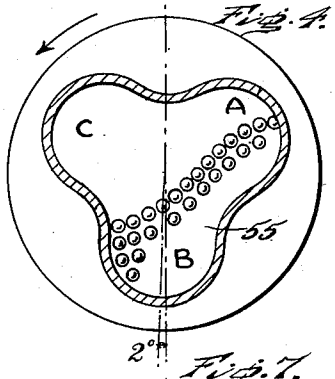



Fig. 5.

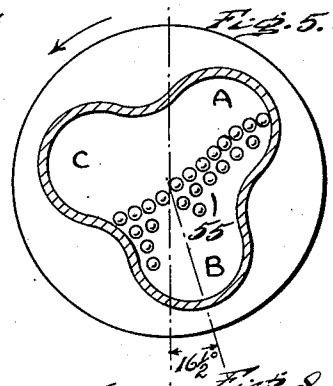



Fig. 6.

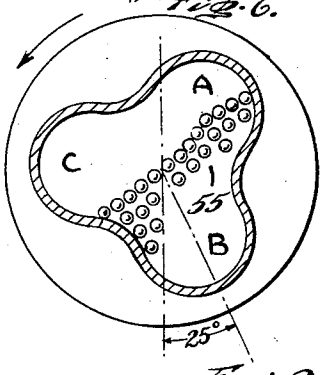



Fig. 7.

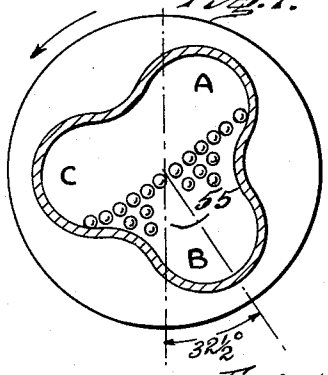



Fig. 8.

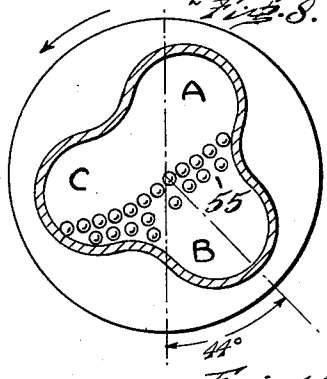



Fig. 9.

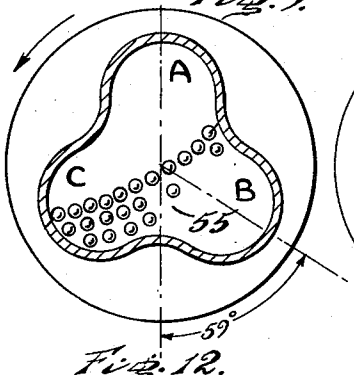



Fig. 10.

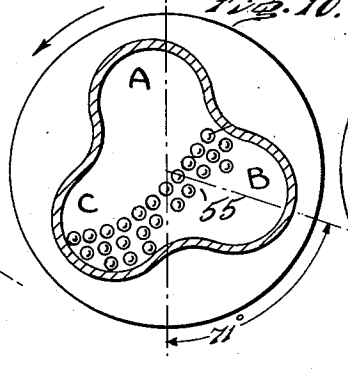



Fig. 11.

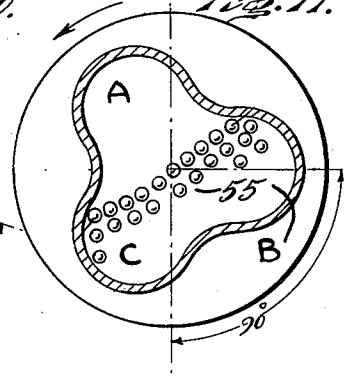
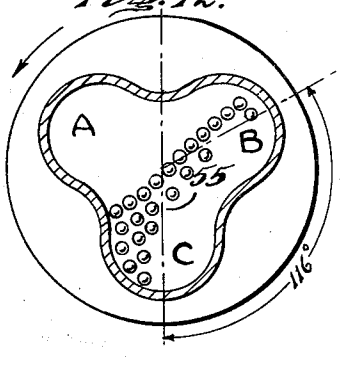



Fig. 12.




INVENTOR
Donald H. Fairchild
BY
John W. Michael
ATTORNEY

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2,931,584

# BALL MILL

Donald H. Fairchild, Tucson, Ariz.

Application April 9, 1956, Serial No. 577,072

8 Claims. (Cl. 241—153)

This invention relates to ball mills and is a continuation in part of my application Serial No. 289,924, filed May 24, 1952 (now abandoned in favor of the present application).

The principal object of this invention is to provide a ball mill having superior performance.

Another object of this invention is to increase the activity of the ball charge in a ball mill to thus increase the grinding action.

Another object is to provide a ball mill in which the sizes of the discharge are more closely grouped.

Another object is to provide a more efficient ball mill without sacrificing capacity or grinding ability.

Still another object is to provide a ball mill in which the power demand is more uniform than on present mills.

The above objects are carried out by a ball mill having a unique interior configuration which approximately doubles the activity of the ball charge while additionally providing a totally new type of grinding action in one zone of the mill. This mill has two or more communicating sections or stages each of which has an interior shaped to provide three equally spaced curved lobes separated by curved bulges. This results in each lobe being opposed by a bulge. Each lobe acts somewhat like a pocket in that it picks up a portion of the ball charge and carries it upwardly until the point is reached where the charge cascades downwardly. This is accomplished in ⅓ of a revolution of the mill and thus the charge is cascaded about three times for each revolution as opposed to the 1½ time action found in the usual cylinder type mill. While Figs. 3 to 12 will be explained in detail later, reference thereto now will illustrate the action in ⅓ of a revolution of one stage of this mill. These figures, derived from stroboscopic photographs, additionally illustrate the rather unique constancy of the load (that is, the charge being elevated) on the power source. Considering one stage only there is still an undesirable fluctuation in the power demand but when a second stage offset by 60° is added the power demand is levelled off to an extent that the power demand of the present mill is more uniform than any conventional mill. The side-by-side stages bring in a unique attritional grinding action between the stages. As the charge in one stage is cascading the charge in the other stage is quiescent and there is a definite attritional action between the charges in the two stages.

Other objects and advantages will be pointed out in, or be apparent from, the specification and claims, as will obvious modifications of the single embodiment shown in the drawings in which:

Fig. 1 is a vertical longitudinal section through the present ball mill;

Fig. 2 is an end view of the discharge end of the mill with part of the discharge head and grate broken away to show some of the interior configuration in detail; and

Figs. 3 to 12 are derived from stroboscopic photographs taken during approximately ⅓ of a revolution of the mill. Each figure has the number of degrees before or after bottom center marked on the figure.



Referring to the drawings in detail, the ball mill includes a housing 10 rotatably mounted on hollow bearings 12, 14 which permit central feed and discharge, respectively. The housing includes two communicating shell sections or stages 16, 18 bolted together with a feed head 20 secured to the first section 16 and a discharge stage 22 and discharge head 24 secured to the second stage 18. A suitable grate 26 is employed to permit discharge of the ground material while retaining the balls and unground material in the mill. On the left (Fig. 1) or discharge side of the grate conventional radial ribs 27 may be provided to direct the discharge toward the fluted guide 28 secured to the grate to direct the pulp through the liner 30 in discharge trunnion 32 carried by head 24. The axial length of discharge stage 22 and the details of the discharge apparatus form no part of the present invention and may take any desired form. Ore or other material is fed into the first stage 16 through replaceable liner 34 in feed trunnion 36 rotatably mounted in bearing 12. Any suitable feed mechanism, denoted by numeral 38, may be employed to feed into the trunnion liner 34.

The mill is driven by pinion gear 40 engaging ring gear 42 and the mass of balls 55 is cascaded within the mill to grind the ore. As will be pointed out hereinafter, the balls have a hammering action on the interior. This action wears the mill interior so, as customary in other mills, the mill is lined. The feed head has lining 44 and the grinding stages 16, 18 have linings 46, 48 respectively. The discharge stage 22 is provided with lining 50. Incidentally, there will be some grinding action in the discharge stage since it is much like a conventional cylinder mill but the grinding in this stage is not important and the stage serves mainly to develop a larger discharge area at the grate.

Each stage or section is provided with three equally spaced curved lobes or bucket portions 52 with curved bulges 54 between the lobes so each lobe is opposed by a bulge. The curve of the bulges and lobes is similar for reasons which will be pointed out hereinafter. Now referring to Figs. 3 to 12 the action of the ball charge 55 will be considered. In Fig. 3 the balls are starting to cascade from lobe A while lobe B is 9° before bottom center. As the sequence continues as the mill rotates counterclockwise the balls cascade into lobe C and those in lobe B are elevated to the position in Fig. 10 at which time the balls in lobe B start cascading. Between Fig. 3 and Fig. 12 approximately ⅓ revolution of the mill has occurred and the entire charge has been cascaded once. Thus in a complete revolution the charge cascades three times.

It is interesting to note the action of the charge with respect to the vertical centerline. In Fig. 3 the mass to the left of the centerline is close in due to the presence of the bulge but as rotation continues the left side of the charge passes over the bulge and advances into lobe C like a wave while the charge cascades out of or recedes from lobe A like a wave. The result is to keep the center of gravity of the mass fairly uniform although not so uniform that the power demand for one stage would be as uniform as desirable. For this reason two stages are employed with the stages offset by 60° to balance out fluctuations in power demand. This results in a quite uniform demand, far better than in cylinder mills. This, of course, leads to better life of the drive mechanism.

Having the two stages 60° offset results in a unique attritional grinding at the interface between stages. Thus the balls in one stage are relatively quiescent while the charge in the other stage is cascading, giving attritional grinding at the interface.

With the above factors in mind it becomes clear that three lobes are critical. One lobe is not possible. Two or four lobes fail to utilize the lobe-bulge action and the unbalance in power demand rules out such a form. Five or more lobes results in such small lobes as to be merely a glorified ribbed liner such as generally employed in the art with fifteen or more ribs. Therefore, three lobes are critical. For satisfactory performance the two stages are essential. More stages can be employed but in such cases most likely would be to use four, six or eight, etc. to maintain the best balance. The bulges serve to cooperate in keeping the working diameter somewhat uniform while additionally serving to assist in lifting the balls and forcing the balls to cascade a greater distance. Another advantage of the bulge is that the balls tend to pound it rather than slide on the mill lining. This pounding, if a manganese steel liner is used, conditions the liner and actually prolongs the liner life.

Normally the ball charge in a ball mill runs about 45% of the volume. Comparative tests indicate the present ball mill grinds better than a cylinder mill where the charge is the same. Thus a cylinder mill and the present mill selected to give the best comparison were operated on a batch basis as follows. Each mill charged with 720 pound ball charge, each with an ore charge of 67 pounds of ore —½"+¼" (accurately prepared and split), and operated for forty minutes at the best speed for the particular mill (35.6 r.p.m. for cylinder, 34.5 for the lobe-type). In both instances the ore was 45% solids by weight with water added as necessary to provide the stated percentage of solids by weight. The results are as follows:

*Table #1*

| | −½"+3 mesh | −3 mesh +8 mesh | Cum +8 mesh | −65 mesh | −200 mesh | −325 mesh |
|---|---|---|---|---|---|---|
| | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* |
| Cyl | 2.3 | 1.4 | 3.7 | 95.5 | 88.1 | 76.6 |
| Lobe | 0.9 | .2 | 1.1 | 98.3 | 93.2 | 80.1 |

From this it can be seen the grinding in the lobe mill is superior with more uniform and finer grinding and far less large material than left in the cylinder. In the test the cylinder mill used 1.460 kilowatt hours while the lobe mill used 1.540 kilowatt hours. Power comparison on a per ton basis is as follows:

*Table #2*

| | K.w.h. Per Ton | |
|---|---|---|
| | −65 mesh | −200 mesh |
| Cyl | 45.7 | 49.5 |
| Lobe | 46.9 | 49.4 |

From this it can be seen there is little difference in power consumption. One final figure is of significance and that is as follows:

*Table #3*

| | Pounds Ground Per Minute | |
|---|---|---|
| | −65 mesh | −200 mesh |
| Cyl | 1.60 | 1.47 |
| Lobe | 1.65 | 1.56 |

Here the figures favor the lobe mill slightly. The lobe mill is certainly superior when it is realized that the grinding action is so definitely superior.

Another test was made in which the lobe mill had only half the ball charge of the cylinder mill and here a very marked advantage was shown by the lobe mill. The charge and feed data follow:



*Table #4*

| | Ball Charge, lbs. | Ore Charge, lbs. | Percent Solids by Weight | Mill, r.p.m. | Grinding Periods, Minutes | K.w.h. Used |
|---|---|---|---|---|---|---|
| Cyl | 720 | 67 | 60 | 35.6 | 40 | 1.590 |
| Lobe | 360 | 67 | 60 | 34.5 | 40 | 1.407 |

The grinding data is as follows:

*Table #5*

| | −½"+3 mesh | −3 mesh +8 mesh | Cum +8 mesh | −65 mesh | −200 mesh |
|---|---|---|---|---|---|
| | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* |
| Cyl | 2.5 | 1.6 | 4.1 | 95.3 | 92 |
| Lobe | 0.6 | 0.6 | 1.2 | 98.5 | 95 |

Here the grinding action of the lobe mill is still superior to the cylinder mill even though the ball charge is cut in half. The reduction in ball charge reduces the power requirement which shows in Table #4 and in the following table:

*Table #6*

| | K.w.h. Per Ton | |
|---|---|---|
| | −65 mesh | −200 mesh |
| Cyl | 49.8 | 51.8 |
| Lobe | 42.0 | 44.2 |

These figures definitely favor the lobe mill since the superior grinding is obtained with reduced power consumption. These advantages are obtained with an added benefit of faster grinding as follows:

*Table #7*

| | Pounds Ground Per Minute | |
|---|---|---|
| | −65 mesh | −200 mesh |
| Cyl | 1.60 | 1.54 |
| Lobe | 1.65 | 1.59 |

The test data appearing in the above tables indicates the definite superiority of the present lobe mill over the usual cylinder mill. This mill grinds better and faster and with less power than the cylinder mill. This is accomplished while additionally having a more uniform power demand which should prolong the life of the drive.

Although but one embodiment of the present invention has been illustrated and described, it will be apparent to those skilled in the art that various changes and modifications may be made therein without departing from the spirit of the invention or from the scope of the appended claims.

I claim:

1. A ball mill including a grinding section rotatable about a generally horizontal axis, the interior of the grinding section having only three lobes equally spaced about the axis and separated by inwardly projecting bulges so each lobe is opposed by a bulge, a second grinding section similar to the first section but angularly offset approximately 60° about said axis with respect to the first section, the interiors of said sections being in communication.

2. A ball mill according to claim 1 including means for feeding ore to be ground into one stage and for discharging ground ore from the other stage.

3. A ball mill including a plurality of communicating grinding sections rotatable about a common horizontal axis, each section having three equally spaced concave lobes separated by inwardly projecting curved bulges, the

mill containing a ball charge to grind ore by the cascading balls as the mill is rotated, the sections being secured together in an angularly offset relationship to render the power demand more constant.

4. A ball mill according to claim 3 in which there are two sections and the sections are offset angularly by about 60° so the lobes in one section line up axially with the bulges in the other section.

5. A ball mill according to claim 4 in which the curvature of the bulges is substantially the same as the curvature of the lobes.

6. A ball mill including a horizontally disposed rotatable elongate drum adapted to carry a normal operating load of balls and material to be worked upon thereby, the drum having a plurality of like sections forming a chamber extending lengthwise thereof and having a continuous wall made up of an annular series of circumferentially spaced longitudinally disposed inwardly opening bucket portions with each bucket portion being sized so as to hold a multiplicity of the balls in the ball load and inwardly faced ridges between and connecting bucket portions, the adjoining section being related so that the bucket portions of one section are in axial alignment with the ridges of the other section.

7. A ball mill including a horizontally disposed rotatable elongate drum adapted to carry a normal operating load of balls and material to be worked upon thereby, the drum having a plurality of like sections forming a chamber extending lengthwise thereof and having a continuous wall made up of an annular series of circumferentially spaced longitudinally disposed inwardly opening bucket portions with each bucket portion being sized so as to hold a multiplicity of the balls in the ball load and inwardly faced ridges between and connecting the bucket portions, the adjoining sections being related so that the bucket portions of one section are in axial alignment with the ridges of the other section, the ridges having convex



faces disposed toward the rotational axis of the drum and the bucket portions having concave bottoms disposed away from said axis and having sides extending between and joining the ridges and bottoms.

8. A ball mill including a horizontally disposed rotatable elongate drum adapted to carry a normal operating load of balls and material to be worked upon thereby, the drums having a plurality of like sections forming a chamber extending lengthwise thereof and having a continuous wall made up of an annular series of circumferentially spaced longitudinally disposed inwardly opening bucket portions with each bucket portion being sized so as to hold a multiplicity of the balls in the ball load and inwardly faced ridges between and connecting the bucket portions, the adjoining sections being in open communication with each other defining said chamber and related so that the bucket portions of one section are in axial alignment with the ridges of the other section, the ridges having convex faces disposed toward the rotational axis of the drum and the bucket portions having concave bottoms disposed away from said axis and having sides extending between and joining the ridges and bottoms.


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