Jan. 1, 1952 N. L. HALL 2,580,541

ROTARY GRINDING OR DRYING MILL

Filed Dec. 29, 1947 3 Sheets-Sheet 1

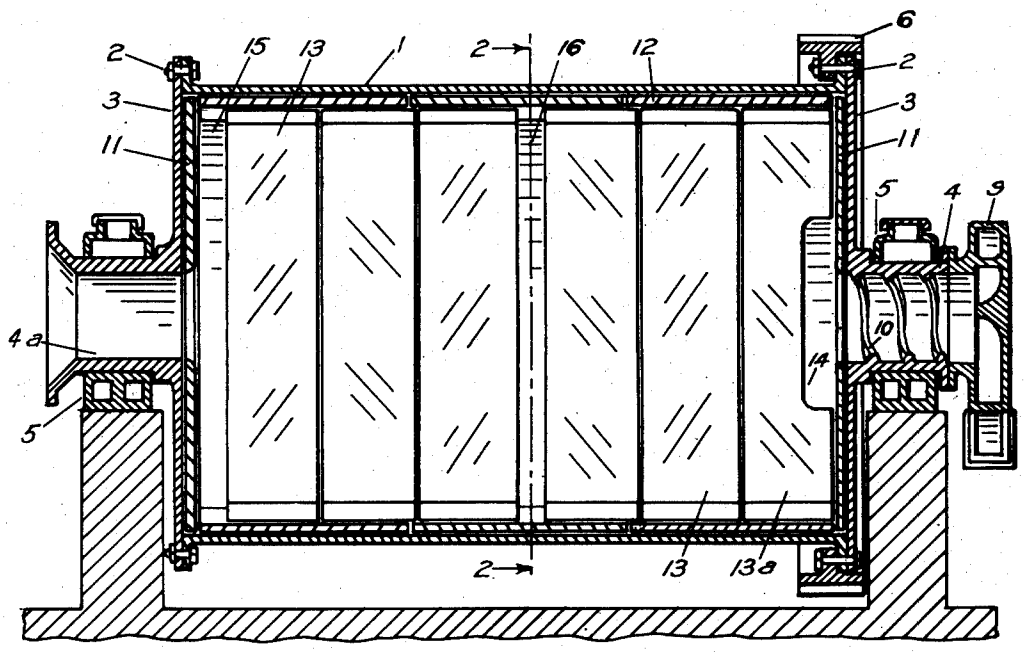


Fig. 1.

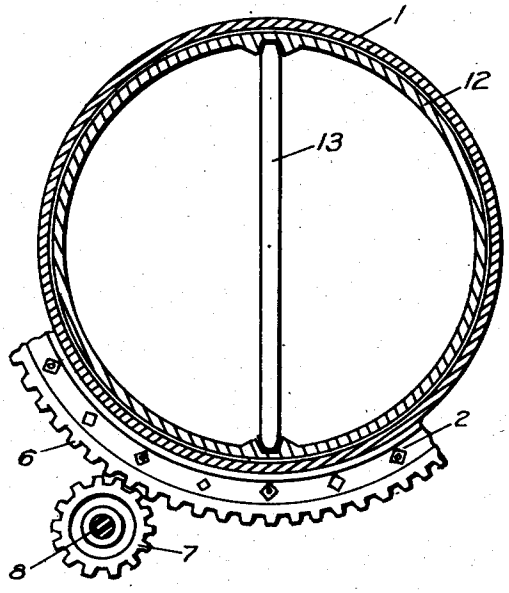


Fig. 2.

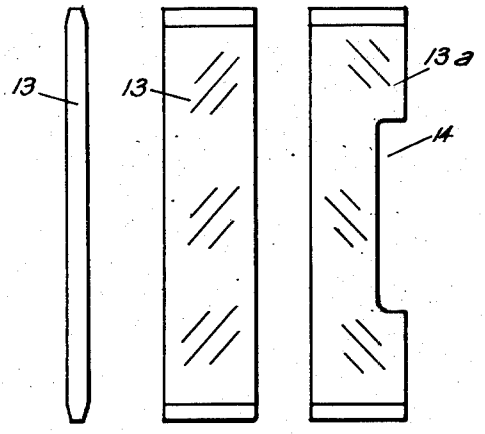


Fig. 3. Fig. 4. Fig. 5.

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ROTARY GRINDING OR DRYING MILL

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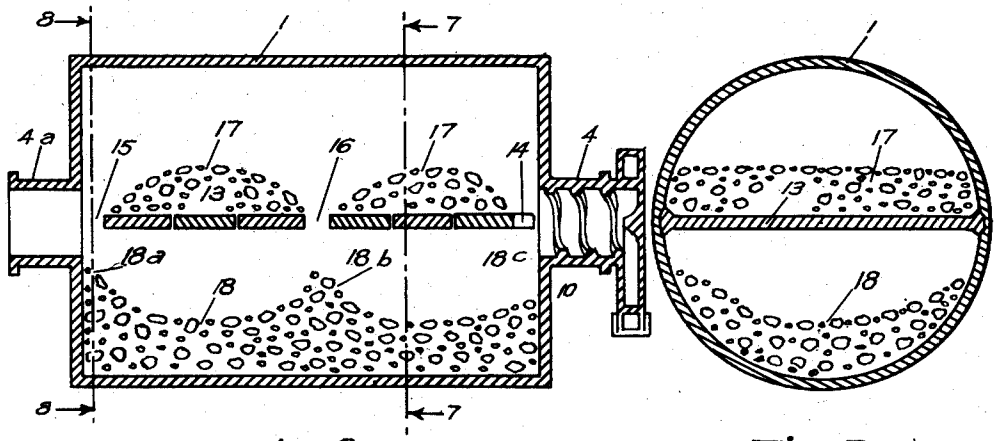


Fig. 6.

Fig. 7.

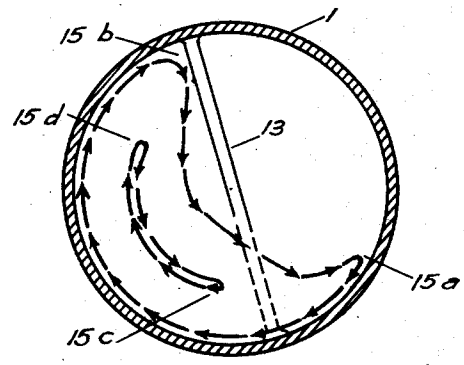


Fig. 8.

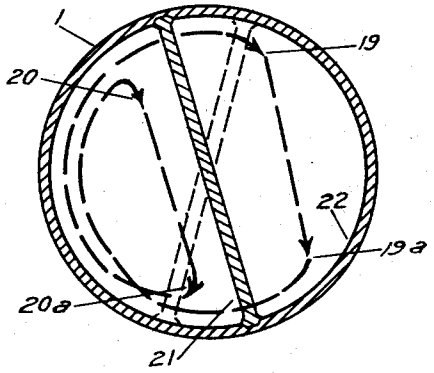


Fig. 9.

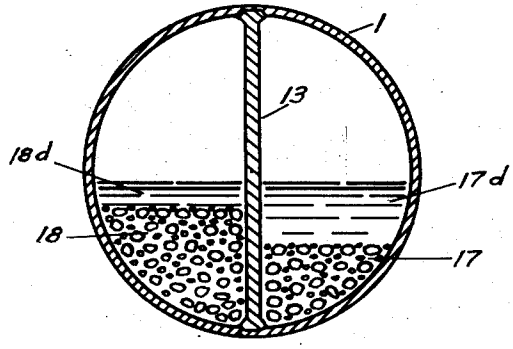


Fig. 10.

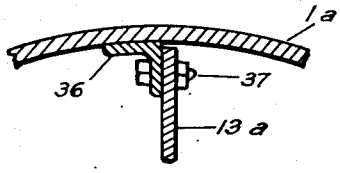


Fig. 11.

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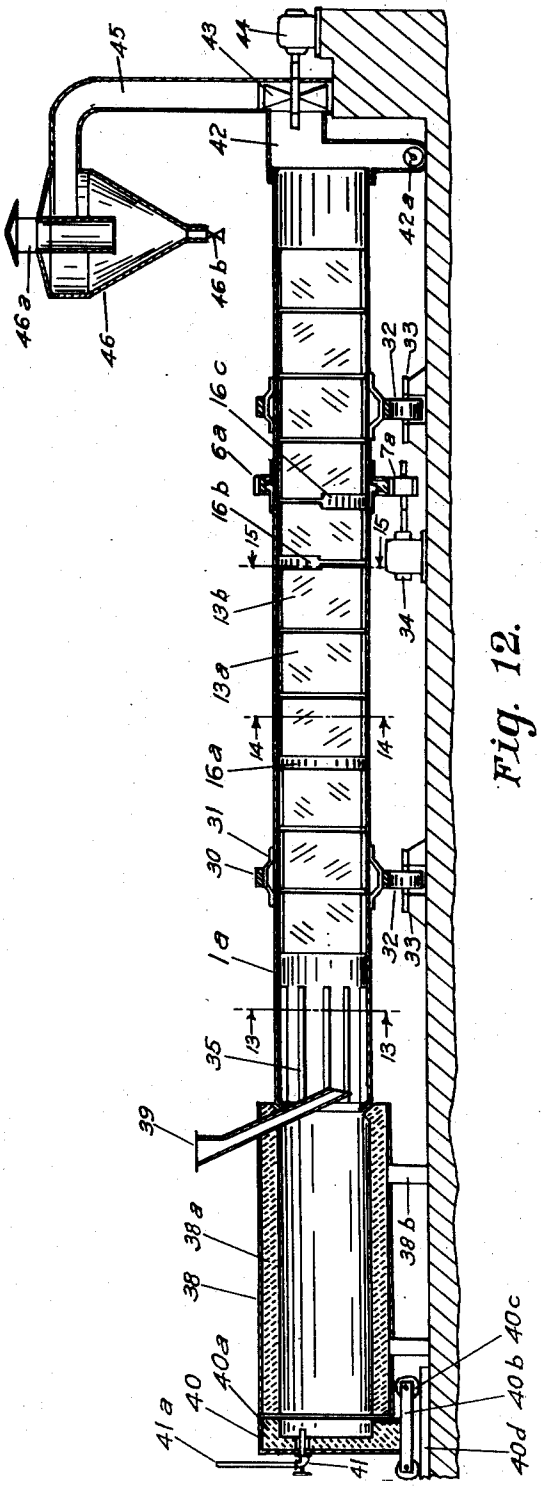


Fig. 12.

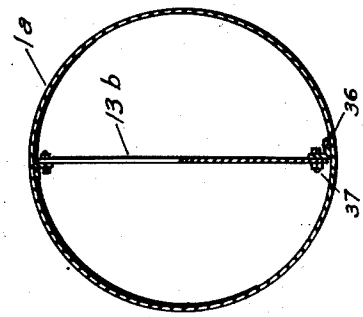


Fig. 15.

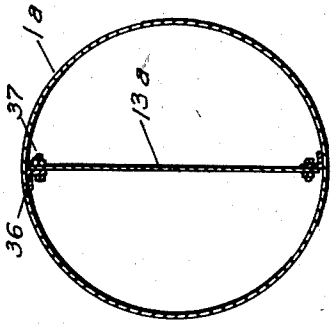


Fig. 14.

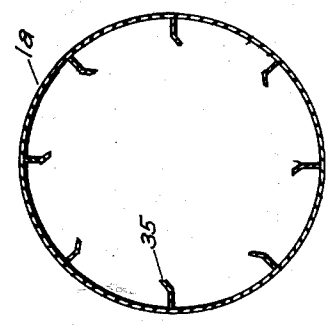


Fig. 13.

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UNITED STATES PATENT OFFICE

2,580,541

ROTARY GRINDING OR DRYING MILL

Newton L. Hall, Long Beach, Calif.

Application December 29, 1947, Serial No. 794,338

3 Claims. (Cl. 241—137)

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This invention relates to cylindrical revolving or tumbling mills and in its various applications can be used, as a horizontal rotary drier, as a rotary calcining or incinerating furnace, or as a ball or grinding mill.

Under the trade name of a ball or tube mill it is used for the grinding or comminuting of rocks, the dressing of ores, or the fine grinding of materials to a dry powder, or to a wet pulp, and wherein a load of primarily crushed rock or material is freely tumbled in a revolving cylinder to develop its secondary or finer grinding with a grinding medium such as steel balls or stone pebbles being inter-mixed within the mill load to assist in the comminuting operation.

In this class of mills, the load is subject to a tumbling action or falling in a drum or other rotating receptacle as distinguished from machines in which the material is broken up by the grinding action of stamps, jaws, rolls or similar crushing elements.

In the following outline the term "ball mill" is used to denote a revolving cylinder or other receptacle in which a freely tumbling contained load is under reduction from the grinding or crushing action of the tumbling mill load, such a term applying to a mill using balls or pebbles as a grinding medium, the internal action within the mill being fundamentally similar.

Ball mills have been developed under a variety of cross sectional shapes such as single cylinders of cylindrical or conical barrel shape, of multiple cylinders revolving around a common axis, or of a simple cylinder with a single longitudinal division wall placed diametrally within the mill to divide its interior into two semi-cylindrical compartments, as outlined in Letters Patent of the United States #1,315,770, reference being particularly made to the latter type of ball mill, hereinafter referred to as a "compartment mill."

Other applications of the compartment mill can be made for service such as a horizontal rotary drier, wherein a developed heated gas is passed through a revolving cylinder simultaneously with a transient load which is passing either parallel or countercurrent to the flow of gas so that in passing the load through the cylinder it is acted upon by the heated gases to develop a dewatering or drying, a calcination, or an incineration of the load. The various applications are treated in their order in the following descriptions.

Reference is made to the accompanying drawings which form a part of these specifications,

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the same numerals referring to similar parts in all the views, and wherein:

Figure 1 represents a longitudinal vertical section of a compartment ball mill with the compartment wall in a vertical position;

Figure 2 is a cross section taken on line 2—2 of Figure 1, showing a fragmentary portion of the mill driving gear, and pinion;

Figure 3 shows a side edge view of a sectional part for the compartment wall;

Figure 4 shows a side view of a sectional part of the compartment wall, as shown in Figure 3;

Figure 5 shows a sectional part of a compartment wall, modified to produce a slot for a portion of the diameter of the mill, or to be used adjacent to the feed trunnion;

Figure 6 is a diagrammatic view of a compartment mill taken in longitudinal section with the compartment wall in a horizontal position, and showing an approximate section of the half mill loads when the mill is in a standing position;

Figure 7 is a cross section taken on line 7—7 of Figure 6;

Figure 8 is a cross section taken on line 8—8 of Figure 6, the compartment wall in the background being shown in almost a vertical position and showing in broken arrow lines the course of action of that part of the mill load which is adjacent to the discharge head of the mill, the action being similar to a plain mill action, that is, one in which no diametral wall were provided;

Figure 9 is a cross section of a mill, similar to Figure 8, with the section being taken through the mill at the compartment wall and showing in dotted arrow line the orbit or path of movement of one of the mill half-loads;

Figure 10 is a cross section of a mill in a standing position with the compartment wall in a vertical position and with equal mill loads of unbalanced composition;

Figure 11 is a fragmentary cross section of a mill shell showing in detail a method of attachment for a compartment wall for use on a drier as shown in Figure 12;

Figure 12 is a longitudinal section of a compartment mill in application as a rotary drier, and showing in consecutive arrangement the accessory equipment involved in a drier circuit;

Figure 13 is a cross section of the rotary drier taken on line 13—13 of Figure 12;

Figure 14 is a cross section of the rotary drier taken on line 14—14 of Figure 12;

Figure 15 is a cross section of the rotary drier taken on line 15—15 of Figure 12.

Referring to the drawings: A cylindrical shell 1 is provided with heads 3 attached thereto by bolts 2, the heads being provided with hollow trunnions 4 which revolve in the bearings 5, the cylinder being driven by the attached gear 6, operated by the gear pinion 7 which in turn is driven by the drive shaft 8 and which can be operated by any suitable motive power.

Supported on the feed trunnion 4 at the feed end of the mill is the scoop 9 which in its revolution picks up and then delivers the feed to the mill through the hollow feed trunnion 4, the feed being advanced along the trunnion by the internal thread screw 10 which revolves as a part of the feed trunnion 4. After passing along the mill the load is freely discharged through the discharge trunnion 4*a*.

To withstand the abrading action received from the falling load within the mill, the heads 3 are provided with liners 11 and the mill shell is likewise protected from abrasion and load wear by the circular lining rings 12 which are placed within the cylinder by virtue of removing one head of the mill and collectively several rings line the entire inner circumference of the mill shell.

Diametrically across the liner 12 is placed the compartment wall 13 as illustrated in Figures 3 and 4 and as assembled in Figures 1 and 2. As shown in Figure 5, the compartment wall is left open on one side edge at 14 to allow for a free fall of the feed on entering the mill as it is being discharged from the feed trunnion 4. At the discharge end of the mill the compartment wall is discontinued before reaching the mill head at the space 15 and which allows the mill loads on each side of the compartment wall to join in common before being discharged from the mill through the hollow discharge trunnion 4*a*. Also, the compartment wall is interrupted in continuity along its length by providing space 16 between two sections of the wall 13, this space providing for a free fall through the wall of a portion of each compartment load as it advances along the mill and serves to develop a balancing and intermixing of the compartment loads in addition to the provision provided at spaces 14 and 15.

In Figures 6 and 7 the mill sections are shown with the compartment wall being in a horizontal position to illustrate an outline of the mill load when it has taken its repose in slope when either out of action, or, when starting to slowly revolve as the mill is being placed into operation. The mill load 17, which is shown above the compartment wall 13, falls over the end edge of the wall and joins the load 18 which is below the wall, thus placing the mill load in a larger proportion below the wall. It can also be noted in Figure 6 that the screw thread 10 on the interior of the feed trunnion 4 has a single point of delivery for the advancing feed and which would deliver the feed on one side of the wall 13 more than the other. As hereinafter further explained, unequal mill loads under momentum can not easily be corrected to a balanced position, and as shown in Figure 10, with the compartment wall in a vertical position, the mill half loads may reach the same hydrostatic level within the mill but one half load may have a greater ball load or a greater proportion of grinding media as shown at 18, and the other half load a lesser proportion as shown at 17. It is apparent that an easily flowing feed, such as a liquid pulp, would have a tendency to pass through the mill interior in the space of least resistance to its flow or through the compartment which had the small

complex load as at 17*d* rather than through 18*d*.

In all cross sectional figures the mill rotation is considered as turning clockwise.

Referring to Figure 8 showing an outline of the mill load while operating within the space 15; the speed of the mill is advanced to bring the load speed just under the centrifugal effect necessary to carry the load over the zenith of the mill interior, thus allowing the load to descend in a cascade until it again reaches the toe of the load against the opposite side of the mill shell where it joins the mill load and ascends as before.

The movement of the load in the space 15 is similar to the action which is developed in a plain mill, that is, one without a compartment wall. As noted by the broken arrow outlines of the load in Figure 8, the load is lifted with the revolving mill shell and in its momentum advances to a position which is almost the zenith of the mill interior whereupon it opens as a crest and descends as a cascade where it again meets the mill shell at the toe of the load and then reenters the load and continues as before. That portion of the load which is away from the mill center and near the shell is ascending, 15*a* to 15*b*, whereas the cascading portion of the load above it, 15*b* to 15*a*, is descending and develops what could be termed a shear zone, 15*c* to 15*d*, between the ascending and descending portions of the load as noted at the interior broken arrow lines.

A mill load which is in action and under momentum has the gyratorial characteristic of travelling in one plane and until its momentum becomes inert it will continue to do so without change of direction. To change that gyratory path requires an extraneous force and an element of time is involved for the development of that change. The advancing movement of the mill precludes such an element of time.

The practical perimetrical speed of a mill load in a large ball mill is about 384 feet per minute. Such a speed will allow the centrifugal effect of the load to break at the crest, after which the effect of gravity will develop and the load will descend in the desired cascade. A speed of 410 feet per minute will develop a centrifugal effect which will carry the load over the zenith of the mill interior, cause the load to open without the desired cascade and scatter as a rain in falling. The desired operation is, to keep the mill load with a definite cascade of the falling portion resting upon the ascending portion of the load, thus developing a definite shear zone within the load.

By the use of a compartment wall placed diametrically through the mill there is a decided change of conditions governing the tumbling mill load.

When the mill revolves and the wall meets the load, that is to say, one half of the total load of the mill, it starts to lift the load towards the zenith of the mill interior and when the zenith is approached it drops the half load in a substantial body and through practically the maximum cross sectional space within the mill. As this load falls it drops in its entirety, substantially as one mass, the mixture of the mill load being uniformly distributed. The half load falls with a general impact, of a general mixture, and through substantially the maximum space within the mill, and as this load falls, the air within the space below the load passes through the load in displaced position. The fallen half load is then at the nadir of the mill interior and in

its continued revolution within the mill, it follows the advancing side of the compartment wall and rises but just before again reaching the zenith of the mill interior it again falls behind the wall—for it has no supporting wall as in the previous fall—to a position which is principally against the rising side and opposite end of the wall, accordingly, each half load acquires two falls for each revolution of the mill, the main fall being of the load in its position above or before the wall, and the secondary fall being in a position below or following the wall. Referring to Figure 9, the dash line approximates the travel or orbit of each half load in one revolution of the mill, the primary fall being of the load when it is above the compartment wall, as noted by the arrow points 19 to 19*a*, and the secondary fall in its position below the wall, as noted by the arrow points 20 to 20*a*.

In its revolution with the mill the momentum of the mill load and the time required for overcoming the inertia of that load when acquiring a gravity fall determines the position of the mill and compartment wall when the load falls will take place. Under the required speed, the time of maximum fall of the load which is above the wall, will take place during the passing of the compartment wall within 20° either way of the vertical mill center line, and in ascending, the load which is below the compartment wall will descend and fall as at 20 and 20*a*, principally against the ascending side of the wall as at 21.

When the load is circumferentially advancing under a momentum any change in its direction of movement involves an element of time for the acceleration of such change. The advancing movement of the mill load overcomes a time required for a change of directional movement of the load parts. The load does not slide over the wall in reaching its lower positions and the points of wear of the mill interior are principally on the mill lining at a position about 30° from the advancing end of the wall, as at 22 and, secondarily, on the side of the wall near to the shell as it rises as at 21, a similar action taking place on the opposite side of the shell and wall during the next half revolution of the mill.

The mill half loads do not fall simultaneously but the load opens and closes in falling and as each half load falls it intermixes and changes position with the air of the mill interior. The loads fall with a squash rather than a definite impact and have a general change of position of its components with each fall.

The forces involved in a mill load under action are, centrifugal, centripetal, and gravitational. The revolving movement of the mill receptacle develops a centrifugal force within the load which is reacted upon by its centripetal force governed through the receptacle structure and which opposes the centrifugal action. Ball mill speeds are maintained to develop a centrifugal action which is below that required to carry the mill load to the full zenith of the mill interior and in a mill of plain receptacle without a compartment wall, a wave crest is formed and before reaching the zenith of the mill interior the load tops and then cascades over the surface of the load to its lower position where it reaches the toe of the load, combines, and ascends as before and as illustrated in Figure 8. In a compartment mill the load is under a similar centrifugal action but due to its support from the compartment wall it is carried past the zenith of the mill interior, likewise, an element of time

is required for the gravity force to overcome the centrifugal action and this element of time mitigates against any extraneous longitudinal movement of the load parts.

Centrifugal action on the load parts is at a maximum towards the mill load perimeter and at a minimum at the mill center, and due to the fact that the centrifugal force near the mill center is negligible, no time is required for overcoming it and the load parts start a gravity movement downward without a loss of time and under a full freedom of acceleration in falling, accordingly, that part of the load which is towards the mill center starts its unrestricted gravitational downward movement first and develops an opening movement through the load successively towards its perimeter near the zenith of the mill interior. The load does not fall as a solid mass but opens and closes in its falling actions, intermixing with the air of the half mill chamber.

Mill loads within the mill are masses of considerable weight and its parts are not easily displaced, and when under momentum, the resistance to displacements of the load parts becomes more stubborn, each part being held in its circumferential and gravitational path by a similarly acting body closely adjoining, and when for any reason the loads on either side of the compartment wall become unbalanced and of different size, the longitudinal mobility of the mill load parts is not always sufficient to pass the unequal parts of the mill load around the ends of the compartment wall to effect an equalization of the half loads, and the heavier parts of the mill load, such as the ball load, will remain in unbalanced proportion on either side of the compartment wall, and when this condition exists, particularly with a load undergoing wet grinding, the liquid portions having a less resistance in their flow through the mill will pass through on the side of the mill where there is a smaller ball load and a greater proportion of liquid pulp, accordingly, the mill pulp will pass through the mill without securing as full a crushing action as if both compartments were filled with similar ball loads. A provision for the constant balancing of the mill half loads is required. Such a provision is provided by placing openings or space 16 in the compartment wall so that as the half loads are acting with the mill revolution, a portion of the load on each side of the compartment wall can pass through to the other side and enter the adjoining half load, thereby maintaining a circulation between the mill half loads in addition to the end wall provisions, at 14 and 15.

The cross section of the load body been revolved in a plain mill action, as shown in Figure 8 well blankets the half load adjoining which is behind the compartment wall and obviates a free passing of half load parts around the wall for a balancing effect. As shown in Figure 6, the part of the load 17 which passed through the slot 15 to form the load part below, 18*a*, was revolved as a plain mill action due to the frictional influence of the adjoining discharge head of the mill, whereas, that part of the load 17 which passed through the space 16 had a free and unobstructed fall through the wall 13 to join the part of the half load at 18*b*, for the conditions influencing the load adjoining the slot 16 were uniform both radially and longitudinally on each side of the opening.

When a plain mill is placed in operation there

is a constant and steady peak load placed upon the operating motor due to the fact that the center of gravity of the mill load is under a constant leverage and there is a load lift on the motor almost without variation.

When a compartment mill is placed in operation there is a high peak load during the first revolution of the mill and until the time when the load slides to its lower position whereupon the loading on the motor is relieved and the motor picks up a speed which is transmitted into the mill loads so as to give them a momentum which carries them to the zenith of their actions, whereupon the loads again fall to their lower position, relieving the motor again and during the second revolution of the mill it practically reaches the full speed required for continued operation. The loading placed upon the motor by the falling half loads is intermittent and the inequalities developed by the varying load lifts is compensated and balanced by the mill weight and mass so that the operation of a compartment mill is easier on the motor than is the operation of a plain mill with its constant leverage of load lift.

The conditions governing the passing of the load parts through the space **15** at the end of the wall and the intermediate space **16** are decidedly different. The moving load within the space **15** virtually blankets the adjoining load which is in the compartment sections so that a larger half load on one side of the wall can not pass around the end of the wall to equalize and balance a smaller half load on the other side. At the intermediate space **16** the compartment wall lifts a half load a portion of which can pass through the space or slot to the section or compartment below, and do so in a free and unrestricted fall, for the space below the wall is temporarily vacant. There is thus provided a constant intermixing means for adjusting and balancing the two half loads both as to size and composition.

Small tramp balls discharged from a plain mill show a well rounded and worn shape but similar balls discharged from a compartment mill are broken sharp and are cracked in a wedge, pie-cut shape.

Ball mills carry a heavy load and have lengths which are seldom more than twice their diameters. Tube mills have similar loads and are of longer length up to four and five times the diameter, whereas, rotary driers carry light weight loads and have lengths which are generally ten times their diameters. The proportions of the two are extreme to each other but their internal action is fundamentally similar although the mills are used for different purposes.

In adapting the compartment mill for use as a rotary drier the first consideration to be made is with regard to the mill speed of revolution. A ball mill of six feet diameter would have a speed of about 24 revolutions per minute, whereas a plain rotary drier of the same diameter would have a speed of from 6 to 8 revolutions per minute. The ball mill speed is maintained to develop a proper cascading of the load but the drier speed is regulated so that the internal lifters of the drier will carry over and spill the load through the heated gases passing through the chamber. Modifying the drier to the compartment feature places a different construction upon the mill action.

Referring to Figure 12 wherein is illustrated a longitudinal section through a rotary drier combination of equipments: A fuel supply pipe **41***a*, delivers fuel such as oil or gas to the burner **41**, which is attached to the firing hood **40** with fire brick lining **40***a*, resting on a base **40***b*, set on rollers **40***c*, which travel on the track **40***d*, so that the firing hood can be moved away from the furnace for entrance to the interiors for repairs or other purposes, or, for regulating during operation the amount of air passing into the stationary furnace **38** with its fire brick lining **38***a*, setting on fixed foundations **38***b*. The ignited flame developed at the burner **41** is designed to develop a complete combustion within the furnace before the heated gases enter the rotary drier, otherwise the gases of the fuel would improperly mix with the fumes developed in the drying operation, and the length of the furnace is designed to meet such conditions of combustion. A feed chute **39** penetrates the furnace **38** so that a delivery of feed can be made to the revolving rotary drier **1***a*, such a drier being composed of an elongated hollow cylinder, with or without heat insulation lining, open at both ends and riding on riding rings **30** attached to the shell by spreaders **31**, all revolving on movable rollers **32** supported at stationary bearings **33**. A driving gear **6***a*, is attached to the mill shell and is operated by the pinion **7***a*, which is directly driven by the motor **34**. The first section of the drier is supplied with load lifters **35** to receive feed from the feed chute **39** and operate to break up the feed and carry it over in its approach to the compartment wall **13***a*, which is developed in sections being attached to lugs **36** arranged as a part of and opposite sides of the mill cylinder, the compartment wall or plate being attached thereto by the bolts **37**. The discharge end of the drier delivers the feed to a stationary discharge hood **42**, the feed product dropping to the screw conveyor **42***a*, for suitable delivery. The discharge hood is further supplied with a suction fan **43** operated by the motor **44**, the draft from which draws the heated gases through the drier, carries the light weight feed forward and delivers the dusting particles in the gases through the discharge conduit **45** and delivers them to the cyclone dust collector **46** where the exhaust from the system reaches the atmosphere at the outlet **46***a*, the finer dust settling for collection at the cyclone gate **46***b*.

The suction fan **43** affords the chief motive for the migration of the load through the revolving mill and for the removal of the vapors being passed off by the drying load. The revolving cylinder can also be given a slope approximating one half inch per foot of length of the mill to assist the fan in the migration of the load through the mill, also for clearing the cylinder of its load when the fan is out of service.

The rotary drier ordinarily does not have an insulating lining for the feed load is non-abrasive, is light in weight, and the heat developed by the furnace is designed to be closely compensated by the vaporization of the moisture so that its heat value is perfectly absorbed in the drying operation. A furnace gas with an entering temperature close to cherry heat would be reduced or absorbed so that the discharging feed would have a temperature well under the boiling point.

Similar to ball mill operation and design, the compartment wall in a drier requires a compensation and balancing feature for the mill loads and for this effect the wall space **16***a*, is provided and in addition half length spaces **16***b*, and **16***c*, the wall being shown in section **13***a* in Figure 14, and **13***b*, in Figure 15.

The compartment wall feature eliminates the

need for lifters, such as 35, and under the same principles as outlined for the ball mill, the compartment drier utilizes the falling half loads to pass through the gases of the mill interior so as to develope an intimate contact between the feed and the transient gases. The compartment drier places a greater load upon the suction fan for the additional draft required and for the fact that the contained vaporized moisture within the cylinder is under a greater density and compression and its more rugged control is required to pass its expansion to the atmosphere at the cyclone discharge.

The agitated contact caused between the feed passing through the drier gases develops a more rapid drying and results in a rotary drier of increased capacity.

In a plain mill drier, the load occupies one portion of the cross sectional area of the cylinder and the gases another, the upper portion. An increase of mill diameter to secure a greater capacity of product is limited by the gravity effect of the spilling load and there is a definite relation and limit between the diameter of the mill and efficient drying reactions. The compartment drier is not limited to such conditions, for the actions of the falling half loads as they are being passed through the gases at each fall makes the drying contact between the load and gases intimate and positive, for the load constantly contacts the gases at each fall regardless of the diameter of the drier cylinder. Also, the falling load receives an impact which develops a uniform drying effect upon the small particles of the mill load, such an impact being violent in comparison to the limpid spill of the load of a plain mill as it passes over and falls from the lifters.

An opening in the compartment wall for purposes of equalization of loads should preferably extend from one perimeter directly across the mill to the opposite side, or, from the mill center to either perimeter. An opening in the wall such as an aperture has a variable effect in passing feed through the wall from one side to the other according to the amount of load in the mill, whereas, a slot opening extending from the mill center towards the perimeter is effective under all proportionate loadings.

The compartment mill feature can be applied to several operations, such as for ball, pebble, or tube mills used for the fine grinding of ores or cements; for rotary kiln used for the calcination of ores; for rotary driers used for the dehydration or drying of pulps or meals to develop stock foods; and, for the rotary waste incinerator wherein the mill actions develop opening contacts to assist in the combustion of material with a minimum of smoke and smog. The compartment mill actions in all of these operations are fundamentally similar.

I claim:

1. A horizontal rotary mill comprising: a cylindrical casing having openings at both ends for receiving and discharging material; and a wall within the casing lying substantially in a diametral plane and extending across the full diametral width of the casing and longitudinally for the major portion of the length of the casing to divide the interior thereof into two compartments; said wall being provided with an opening intermediate its ends extending across the full diametral width of the casing to provide for free passage of material by gravity through said opening from each compartment to the other during rotation of the mill.

2. A horizontal rotary mill comprising: a cylindrical casing having openings at both ends for receiving and discharging material; and a plurality of longitudinally aligned wall sections within the casing lying substantially in a common diametral plane and extending across the full diametral width of the casing and longitudinally for the major portion of the length of the casing to divide the interior thereof into two compartments; said wall sections being spaced apart longitudinally to define an opening between each pair of adjacent sections extending across the full diametral width of the casing for free passage of material by gravity through said opening from each compartment to the other during rotation of the mill.

3. A horizontal rotary mill comprising: a cylindrical casing having openings at both ends for receiving and discharging material; and a wall within the casing lying substantially in a diametral plane and extending across the full diametral width of the casing and longitudinally for the major portion of the length of the casing to divide the interior thereof into two compartments; said wall being provided with an opening intermediate its ends extending radially the full distance from the axis of the casing to the perimeter thereof to provide for free passage of material by gravity through said opening from one compartment to the other during rotation of the mill.

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