May 11, 1954 E. D. PHILLIPS 2,678,168

FLUID SWEPT BALL MILL WITH BALL MOVING ROTOR AND STATIONARY DRUM

Filed Feb. 4, 1952 2 Sheets-Sheet 1

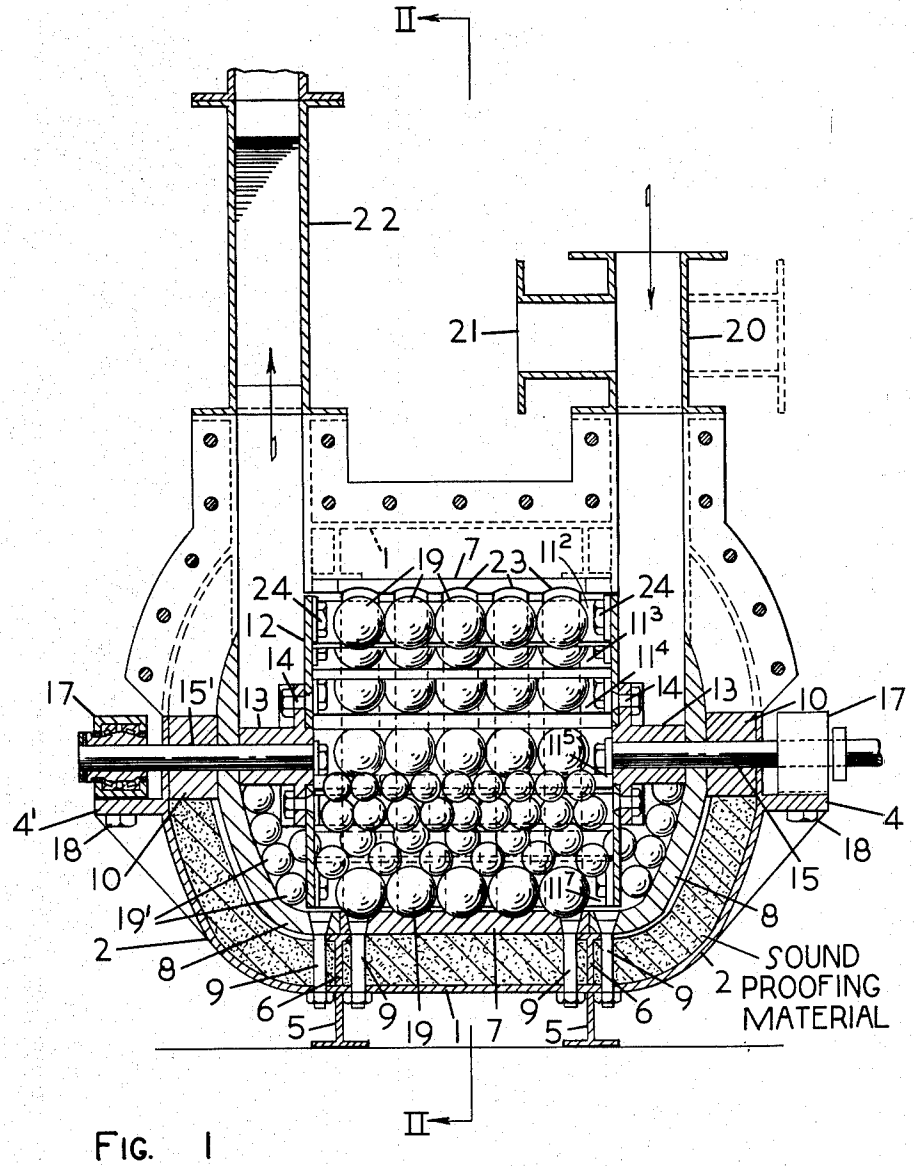


FIG. 1

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FLUID SWEPT BALL MILL WITH BALL MOVING ROTOR AND STATIONARY DRUM

Filed Feb. 4, 1952 2 Sheets-Sheet 2

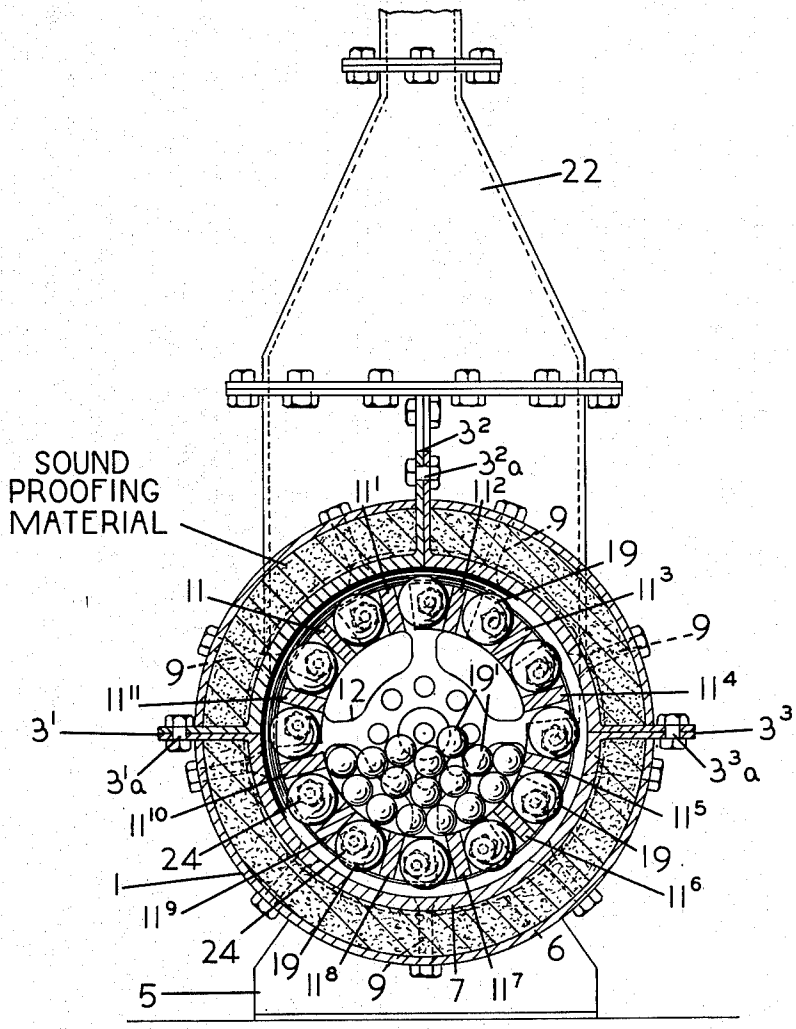


FIG. 2

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UNITED STATES PATENT OFFICE

2,678,168

FLUID SWEPT BALL MILL WITH BALL MOVING ROTOR AND STATIONARY DRUM

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Application February 4, 1952, Serial No. 269,820

6 Claims. (Cl. 241—47)

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My present invention broadly relates to means, primarily mechanical, for reducing, even to superfine form, certain fragmentary materials such as coals (including extremely difficult to reduce anthracite), cement clinkers, iron pyrites, coke breezes, petroleum cokes, pigments, grains and many other vegetable matters. This application is a continuation-in-part of my co-pending application entitled Fluid Swept Ball Mill With Ball Moving Rotor and Stationary Drum, Serial No. 123,245, filed October 24, 1949, now Patent 2,621,859 of December 16, 1952, which application, in turn, is a continuation-in-part of my abandoned application entitled Ball Mill, Serial No. 531,951, filed April 20, 1944.

An important object of my invention is to so design the particular arrangement of mechanical means that it is readily adaptable to having associated therewith an active fluid medium by which the reduced material can be most effectively collected and continuously removed from the region of the reducing means.

I am fully aware of the fact that numerous efforts have been made to create and design means having the same objectives as my invention. These designs have produced only moderate degrees of success. The general objective of my invention is to materially expand the success obtainable over anything heretofore accomplished in the particular field. In this connection, I cite in particular a number of fairly well-known so-called "drum and ball" or "ball mill" commercial products, also commonly termed "pulverizer." Each of these products, I know from first hand experience, have been criticized by commercial users and condemned by competition because of their relatively large power and space requirements. There are several major deficiencies contributing to the present inefficiency of the "drum and ball" type pulverizers.

First, and perhaps the greatest deficiency is the inability of these mills to separate the finely ground materials from the almost solid mass of material and balls rotating in the revolving drum before the reduction of these materials to a superfine product. This lack of separating capacity partially explains the relatively large power requirements of such mills. This excessive power requirement makes it difficult for this type of mill to successfully compete against high speed impact or hammer mill pulverizers, ball race type pulverizers, roller bearing mill type pulverizers and others whose power requirements are relatively lower but producing a coarsely ground product.

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Second, an excessive amount of energy is expended in rotating the "drum" or its equivalent element beyond that which is actually expended in reducing the material.

Third, all of these methods and machines employ excessive weights of machinery and occupy excessive mounting spaces with consequential high initial costs and inconveniences. Also, they require a large amount of plant space for dismantling and repairing.

All of the various types of pulverizers, both separately and as a group, because of the lack of control of the quality of their product, complicated operation, high power costs and over-all inefficiency are being displaced commercially by spreader stokers, particularly in the small and medium size installations. Until my invention, nothing was being done to eliminate these deficiencies of the "drum and ball" type mill, despite both the possibility and necessity for such improvement.

In the conventional "drum and ball" mill pulverizer, movement of the balls is dependent solely upon the balls being dragged into and maintained in action by the slight frictional and point contact existing between the balls and the wall of the rotating drum. This frictional contact is limited to those few of the balls that manage to make individual respective contact with the inner surface of the rotating drums. The total area of frictional contact is but a minute fraction of either the balls or the inner surface area of the drum. Thus, these conventional ball mills must be operated over a longer period of time to effect the same amount of reduction as will occur in a mill in which the movement of the balls is effected by positive engagement between the balls and their agitating means. Such increased operating time reduces efficiency and increases wear. This major handicap to effective reduction is one of the objectionable aspects of the said prior practices overcome by the instant invention. The greater quantity of power required to turn the rotor of my ball mill, due to the positive engagement with the balls, is offset by the elimination of the necessity for moving the mass and weight of the drum or grinding chamber shell. Thus, although the power consumption, per revolution, of my invention and of ball mills of conventional design are approximately equal, appreciable efficiency is obtained by my invention since the total reducing action obtained by each revolution of my invention is several times that of conventional ball mills. Further, since the balls in my invention are positively pushed and lifted into cascad-

ing position rather than raised into cascading position by a combination of frictional and centrifugal forces, my mill may be efficiently operated at less revolutions per minute. This speed reduction permits a power source of lesser horsepower to apply the same torque to the shaft driving the mill. These are but two of the ways in which my mill obtains a substantial increase in efficiency over ball mills of conventional design.

Another excessively expensive, operational handicap in these prior products arises out of the weight distribution opposing rotation. The weight is normally concentrated at an unnecessarily excessive radial distance from the center of rotation without provision of any counterbalance means, thereby creating an excessive, counter to rotation, torque plus a decidedly lop-sided wear and tear on the supporting journals and bearings. These objectionable factors are also overcome by the instant invention. By rotating only the rotor within the drum rather than the drum itself, the moment arm of the operating load is reduced, thus, reducing the torque necessary to operate the mill.

Another object of the instant invention is that of materially facilitating the making of repairs and the replacement of parts.

A further object of my invention is the elimination of certain of the operational hazards common to ball mills of conventional design. These hazards and their elimination are specifically brought out in connection with the description of the structure relating to them.

Other important objects of the instant invention will become readily apparent to those skilled in the particular art as its description in connection with the figures of the accompanying drawings is hereinafter carried out, which figures may be briefly identified as follows:

Figure 1 is a mid portion, cross-sectional side view elevation of the instant invention.

Figure 2 is a cross-sectional view along the line II—II of Figure 1.

Like reference symbols in the same figure and in the various figures of the drawings represent like elements and parts in the same. Referring first to Figure 1, numeral 1 indicates a horizontally mounted, preferably metallic, cylinder, partially closed at each end by preferably metallic, ellipsoidal heads 2, bolted, as indicated, or welded to cylinder 1. The heads 2 are illustrated as ellipsoidal but may vary somewhat in shape without departing from the principle of my invention. The numerals 5 indicate suitable, stationary mounting supports for the cylinder 1 and the elements associated therewith. The cylinder 1, as mounted on the supports 5, is stationary and cannot rotate.

The numeral 7 indicates a second cylinder or liner internally of, and more or less uniformly spaced from, cylinder 1 by spacing elements 6 and 10 and bolting elements 9. The liner 7 is partially closed at each end by ellipsoidal heads 8 bolted or welded to cylindrical liner 7. Like the heads 2, the heads 8 may vary in shape somewhat from that of an ellipsoid without departing from the principle of my invention. The second cylinder 7 together with the heads 8 define the grinding chamber which is also stationary and cannot rotate. The elements 15 and 15' indicate cylindrical stub shafts extending from outside internally of the said cylinders through close fitting openings centrally located in the respective heads 2 and 8. Each of the stub shafts 15 and 15' is supported in and by one of the roller bearing elements 17 mounted upon the brackets 4 and 4'. The brackets 4 and 4' are fixedly attached to the head elements 2. On the inner end of each of the stub shafts 15 and 15' a spider leg element 13 is securely mounted to rotate with its associated stub shaft. In some installations it may be preferable to make elements 13 and 15 and 13 and 15' as one piece. The spider leg elements are spaced apart the length of the second cylinder 7. The use of the stub shafts 15 and 15' leaves the major part of the internal, horizontal housing space unobstructed. The purpose of leaving the area between the spider leg elements 13 unobstructed will appear more fully hereinafter.

To each of the spider legs 13 (four being shown in Figure 2) is affixed, by bolts 14, a radially extending plate element 12. Extending between the plate elements 12 of one spider element 13 are pusher bars or partitions 11. The ends of each of the partitions 11 are bent at a right angle to the main body of the partition by which affixation to the respective plates 12 may be accomplished by installation of the bolts 24. Although Figure 1 indicates bolted construction, they may be welded. Thus, when shafts 15 and 15,' or either, are rotated, the elements 13 being affixed thereto, transmit the rotary motion to the hereinafter described balls 19 through the plates 12 and partitions 11. The plane of each of the partitions 11 is parallel to the axis of the stub shafts 15 and 15'. The plate elements, spider leg elements 13, and partitions 11 together form a cage or rotor occupying a major portion of the internal area of the second cylinder 7. The ends of the rotor may each be made as a single part, but such part should have openings or apertures to permit material to pass into the rotor. The rotor operates as an agitator for actuating the grinding balls.

Referring to Figure 1, the inner wall of the inner cylinder 7 is shown to be constructed as to have a longitudinal series of closely spaced channels or grooves 23 therein each of which completely circles the said inner wall. The grooves are so shaped as to substantially fit that part of the arc of each of those ones of the larger balls 19 shown to be positioned therein. Referring to Figure 2, the larger balls 19 are also shown to be positioned in what may be termed pockets formed by the radially positioned pusher bars or partitions 11, 11^1, 11^2, 11^3, 11^4, 11^5, 11^6, 11^7, 11^8, 11^9, and 11^{10}, which pockets so taper, radially inwardly, that the balls 19 cannot escape therefrom by way of the inner opening in each pocket. The balls in each pocket are as closely spaced as their size will permit.

In order to take advantage of the full reduction potential of my modified ball mill, a charge of smaller size balls indicated in part by the symbol 19', is used to fill what would otherwise be an idle, potential reduction area within the rotor.

The material to be reduced in size or pulverized is introduced into the grinding chamber through the passage 20 indicated as entering into and at the right-hand portion of the upper portion of the grinding chamber. The fines produced in the grinding chamber are removed through the passage 22 at the opposite end of the grinding chamber from the passage 20. Although the passages 20 and 22 are shown and described as at the extreme ends of the grinding chamber, a preferred arrangement, it is possible to relocate them closer together without departing from the principle of my invention.

As a result of the description of the mechanism up to this point, the reducing operation may be stated by way of illustration as follows: as is mechanically apparent, any suitable source of driving power, such as an electric motor, may be used to drive the rotor. Power may be delivered to the rotor by either or both of the stub shafts 15 and 15'.

Rotation of the stub shafts causes similar motion in the rotor forcing the partitions 11 around the grinding chamber. The movement of the partitions 11 urges the balls 19 along in their respective grooves until cascading of the balls 19 takes place due to gravity overcoming their centrifugal force. The cascading action of the balls 19 is limited by the partitions 11 since the inward taper of the pockets between the partitions prevents inward escape of the balls 19. The taper of the pockets also acts to increase the pressure applied by the balls to the material lodged in the grooves. This accelerates the reduction of the material. The rotation of the rotor or cage elevates smaller balls 19'. The smaller balls 19' are raised by the rotor until cascading of these balls takes place due to gravity overcoming their centrifugal force.

The larger balls 19, being exposed as they are to the activities of the smaller balls 19', receive from them supplementary power to act as crushers. The pockets between the partitions 11 act as channels for introducing the material to the grooves 23 after it has been subjected to preliminary reduction by the action of the smaller balls 19'. The material, once having entered the grooves 23 may be ground to a fine powder by the action of the larger balls 19. The pockets also serve effectively as elevators for raising the reduced material into the upper portion of the grinding chamber where the fines will be entrained by the sweeping fluid for removal.

The inner shell 7 and outer shell 2, comprising the cylindrical drum remain stationary at all times, thus, all of the motion for generating the grinding or reducing action of my invention is imparted to the grinding balls 19 and 19' by the rotor. This design limits the energy requirements of my invention to that which is necessary to move the rotor against the resistance of the grinding balls and the charge of material being reduced. The energy requirements of previous devices of this type for moving the mass of the drum are eliminated.

As is readily apparent, the movement of the partitions 11, the preferred direction of which is clockwise as viewed in Figure 2, will forcibly maintain all of the balls in action with respect to each other and all other surfaces contacted by these balls. The rotor is operated at a relatively low angular velocity. The exact revolutions per minute will vary according to that which will produce the most efficient results with the particular material and the size of the charge of grinding balls involved.

The balls 19' will be carried into the upper region of the grinding chamber from which point the raised grinding balls 19' will cascade downwardly with considerable impact momentum. The height to which these balls 18' will be elevated will depend, in part, upon the angular velocity of the rotor. By eliminating the central shaft through the rotor, the cascading balls are enabled to fall upon the material without interference. Thus, all of the velocity obtained by the falling balls is available for reducing the material. This feature alone adds materially to the efficiency of my invention.

All of the principles of reducing or pulverizing utilized in isolated cases, namely, crushing, impact and attrition, not heretofore combined in a single unit, are simultaneously and most effectively brought to bear in the instant invention. By way of explanation: reduction by crushing occurs between those of the balls adjacent the walls of the grinding chamber being forced to roll on surfaces with the material being crushed between the moving balls and the stationary wall surface; reduction by impact is effected by the cascading balls landing with appreciable impact on fragments of the material; and reduction by attrition occurs through the action of any two or more moving balls competing with each other in forcefully rubbing the same material.

Rotation of the partitions 11 not only elevates the balls 19 and 19' but also both the heavies and fines of the material being reduced. A stream of sweeping or transport fluid is passed through the grinding chamber by means of the passages 21 and 22. The fines of the material elevated by the rotor will be entrained by this fluid and removed from the grinding chamber through passage 22. The size of the fines which will be thus removed may be controlled by regulating the volume of fluid being passed through the grinding chamber. The fluid may be either forced through or sucked through the grinding chamber. By placing the input passage 21 and output passage 22 at the extreme opposite ends of the grinding chamber, sweeping of the entire grinding chamber by the fluid is assured.

As to refinements and special features, reference is made to Figures 1 and 2 jointly.

To facilitate assembly, making repairs and replacing parts, the lower halves of cylinders 1 and 7, together with their corresponding heads 2 and 8, are indicated to be separate in construction from their respective upper halves. As more fully shown in Figure 2, the upper halves of these same cylinders and their respective heads are indicated to each be constructed in two equal quarter sections. The flanges 3^1, 3^2 and 3^3, together with the bolts and nuts $3a^1$, $3a^2$ and $3a^3$, respectively, are the means necessary for properly assembled external and internal containers and for securing them in place during operations.

Since it is also elementary that the wear and tear on the inner surface of the lower half of the cylinder 7 will likewise be severe, even though its material may be the most durable available and it is protected in part by the layer of balls contacting it, it stands to reason that the cost of renewing this part is greatly minimized by constructing it in the form of a separate, replaceable unit.

Of course, it is all important that the balls 19 and 19' should also be made of the most durable material obtainable. The additional expense of such material will be more than recovered by the savings effected in replacement, time and labor.

By eliminating the necessity for rotating the entire cylinder portion or the drum of the mechanism, it is possible to utilize insulation plus the inner and outer cylinder construction without increasing the power requirements of the mill. Such a construction, applied to conventional ball mill designs, would appreciably increase their power requirements. Thus, by my design, without increasing the cost of operation, the user can have the benefit of quieter operation

by filling of the space intervening between the inner and outer cylinders, as indicated by the hatchings of this particular space in the drawings, with any one of the many sound proofing materials now available. Because of the high temperature prolonged reducing can create, which may be further increased by using a preheated gaseous medium for sweeping the grinding chamber, a sound proofing material composed primarily of asbestos would be among those preferable in such a case.

Where the matter of rotating a heavy cylinder and its contents is involved, as it is in all of the "drum and ball" reducing mills with which I am acquainted, the matter of wear of the journals and bearings becomes a very serious problem due to the excessive weight supported by these elements. The problem of rapid wear is aggravated by the unbalanced torque loads generated by the mill, plus the exposure of the journals and bearings to the material being reduced and the frequently preheated, material saturated, pressurized, fluid for sweeping the grinding chamber. The arrangement of Figure 1 indicates that no such aggravated journal and bearing problem exists in the case of the instant invention. In my invention the cylinder or drum is stationary, thus, relieving the journals and bearings of this weight. The torque radius is reduced, and the design offsets, at least partially, the load attendant lifting the cascading balls by the weight of the balls acting downwardly on those of the pusher bars moving downwardly through the body of grinding balls in the lower portion of the grinding chamber. Furthermore, my design permits the journals and bearings to be completely isolated from the operating area of my mill. Since the drum or cylinder is stationary, the stub shafts 15 and 15' may pass through the drum or cylinders without contact with any parts other than a dust and pressure seal. The bearings may be mounted outside the drum and sealed from the wear and corrosion promoting materials within the drum.

All of the "drum and ball" mechanisms, with which I am acquainted, introduce the collection and removal fluid into the grinding chamber through an opening in the center of one end head and remove the fluid through a similar opening opening in the center of the other head. To avoid having balls enter these openings, the total number of grinding balls is chosen with a margin of safety to have a top level somewhat lower than the lowest points of these openings. Because of the circular nature of the conventional grinding chamber this necessarily limits the number of grinding balls to somewhat less than one-fourth of the number of balls the grinding chamber could hold if completely filled. The design of my invention makes feasible using enough balls to fill at least one-half of the available cylinder volume. Although such a quantity of grinding balls is frequently neither necessary nor desirable, the capacity is available when needed. Conventional ball mills are incapable of accomplishing this.

When it comes to reducing the harder materials that offer greater resistance thereto, as in the case of anthracite coals as compared to bituminous coals, it is elementary that more can be accomplished with such materials if greater reducing forces are employed. When mere frictional engagement between the grinding balls and the driving force is employed, as is the case in conventional "drum and ball" mechanisms, an inefficient reducing action results as compared to the positive engagement between the grinding balls and the driving force characteristic of the instant invention. The positive engagement between the partitions 11 and the grinding balls 19 insures thorough and constant agitation of all of the grinding balls in the grinding chamber. It is clear that such a solution with respect to reducing the harder materials will automatically serve to accelerate reduction of the softer materials.

From the foregoing, in addition to it being readily apparent that the instant invention permits substantial power savings and a substantial increase in operating efficiency over conventional "drum and ball" mechanisms, it is equally apparent that substantial savings in weight of materials and mounting spaces are effected.

When it comes to efficiency in the matter of collection and removal of the reduced portion of the material involved, it is clear that the action of the partitions 11, of the instant invention, serves to expose all of the material charge to the grinding chamber sweeping fluid. In convention ball mills much of the material charge remains submerged in the ball charge. Thus, efficiency, in this respect, is necessarily greatly in favor of the instant invention.

In conventional "drum and ball" products, as well as in the instant invention, simplification of design calls for introducing the material to be reduced at one end of the cylinder or grinding chamber. Since operating speed or efficiency also depend, in part, upon having the material undergoing reduction equally distributed over the length of the reducing region, which region becomes quite large in some industrial requirements, the even distribution resulting from the extensive thorough agitation of the material by the partitions 11 in the instant invention, increases the efficiency of my invention.

The hazard arising from the operation of an exposed rotating cylinder or drum, common to conventional "drum and ball" practices is eliminated by the design of my invention. The danger of explosion attendant on too small a charge, when the material charge is a combustible material, such as coal, is reduced by my invention since it permits, as a normal operating condition, a larger charge.

Thinking in terms of long lives for the parts directly involved in the various reducing activities, it is important to use the most durable, suitable materials obtainable for these parts. Thus, the fact that the hatching used in the drawings with respect to these parts is that of the standard indication for steel (without qualification) is not to be taken as an intended limitation to steel per se.

The life of the grinding chamber liner or inner cylinder is appreciably extended by the use of the layer of balls constantly in contact with the walls of the lower portion of the grinding chamber. This layer of balls absorbs the impact of the cascading balls, protecting the walls of the grinding chamber against the wear incident to the constant blows occurring in ball mills of conventional design. The convex shape of the heads used on my grinding chamber contribute to both the safety and efficiency of my invention. These heads are so shaped that the charge of free or cascading balls, balls 19 and 19', cannot become jammed between the heads and the rotor. The heads, as they extend outwardly from the straight portion of the grinding chamber, are designed

to curve on a radius at least equal to the radius of the balls with which the mill is charged. Preferably, this radius is greater than that of the balls. The curvature of the heads is designed to become tangent to the straight portion of the inner cylinder at a point sufficiently outwardly from the ends of the rotor to permit the grinding balls free travel between the rotor and the heads. By eliminating all sharp corners and permitting the grinding balls freedom of travel throughout the entire area of the grinding chamber the formation of pockets of material is avoided. These pockets, when the material is combustible, create a serious explosion hazard and their elimination is an appreciable improvement in safety.

My invention has heretofore been described as primarily used for grinding dry, solid fuel. Because of its positive and continuous agitation of both the material being processed and the balls and its adaptability to operation with a pressurized sweeping fluid, it is capable of handling fuels containing high percentages of total moisture. The construction of existing mills of this type has prevented their use with high moisture content materials. For fuels containing inherent moisture only, preheated sweeping fluids are not required for satisfactory operation of my pulverizer. Since a high percentage of surface moisture is acquired in the transportation of solid fuels between the mines and their ultimate point of use, it is necessary to preheat the sweeping fluid to a high enough temperature to vaporize the moisture and dry the fuel as it is pulverized. The design of my invention, permitting the grinding chamber to be insulated and the bearings to be isolated from the grinding chamber, ideally adapts my invention to the use of a heated sweeping medium.

The pulverizer mill described has successfully pulverized and delivered to a burner coals having total moisture contents between 7 and 12 percent without employing a preheated sweeping fluid. Although this type of operation is not desirable from the standpoint of furnace efficiency, it illustrates the capacity of my mill.

My invention will operate with either the dry or wet process and for that reason is readily adaptable and suitable for efficiently grinding and dispersing other materials requiring the wet process such as pigments, for example.

Since my invention, by its design and construction, is suitable to fabrication from steel plate rather than the conventional cast iron castings, an expensive type of fabrication at best, it is structurally suitable for safe operation under pressures of 100 pounds per square inch or more.

The recent development of gas turbines, at present in the experimental stage, requires pulverizers capable of operation under pressures as high as 75 pounds per square inch. Gas turbines require pulverizers capable of continuous and consistent superfine pulverization at low cost. The circumstances of installation of many gas turbines, such as locomotives, make a compact pulverizer an absolute essential. Conventional pulverizer designs, whether or not they are of the "drum and ball" type, are incapable of meeting the specifications of gas turbines. My invention fulfills and meets these requirements.

Numerous modifications of my invention may be made without departing from the principle of my invention. Each of these modifications is to be considered as included in the hereinafter appended claims unless these claims by their language expressly provide otherwise.

I claim:

1. A ball mill, the combination comprising: a stationary, horizontal, cylindrical drum; heads closing each of the ends of said drum; a pair of end members having elongated pusher bars mounted therebetween for forming a rotatable, hollow, cylindrical cage within and extending substantially the full length of said cylindrical drum; said end members defining openings for the passage therethrough of material to be ground; a stud shaft mounted to each of said end members and rotatably carried by said closing means; the inner surface of said drum having a plurality of spaced channels parallel to the direction of rotation of said cage and of segmental, arcuate cross-section; a plurality of balls seated within each of said channels and having a radius substantially equal to the cross-sectional radius of said channels; said balls aligned in rows parallel to the axis of said cage and each row thereof separated from each adjacent row by one of said pusher bars and held by said bars against radially inward movement relative to said cage; said drum having a carrying fluid inlet at one end and a carrying fluid outlet at the other end whereby a fluid may flow through said drum for removing ground material.

2. A ball mill, the combination comprising: a stationary, horizontal, cylindrical drum; heads closing each of the ends of said drum; a pair of perforate supporting ends having elongated pusher bars therebetween for forming a rotatable, hollow, cylindrical rotor within and extending substantially the full length of the cylindrical drum; a stud shaft mounted to each of said supporting ends and rotatably carried by said closing means; the inner surface of said drum having a plurality of spaced channels parallel to the direction of rotation of said rotor and of segmental, arcuate cross-section; a plurality of balls seated within each of said channels and having a radius substantially equal to the cross-sectional radius of said channels; said balls aligned in rows parallel to the axis of said rotor and each row thereof separated from each adjacent row by one of said pusher bars and held by said pusher bars against radially inward movement relative to said rotor; a plurality of grinding balls within said rotor for cascading movement therein; said drum having a carrying fluid inlet at one end and a carrying fluid outlet at the other end whereby a fluid may flow through said drum for removing ground material.

3. A ball mill, the combination comprising: a stationary, horizontal, cylindrical drum; heads closing each of the ends of said drum; a pair of perforate supporting ends having rigid, elongated pusher bars therebetween for forming a rotatable, hollow, cylindrical rotor within and extending substantially the full length of said cylindrical drum; said pusher bars being of rectangular cross-section and having their greater cross-sectional dimension extending radially of said rotor; a stud shaft mounted to each of said supporting ends and rotatably carried by said closing means; the inner surface of said drum having a plurality of spaced channels parallel to the direction of rotation of said rotor and of segmental, arcuate cross-section; a plurality of balls seated within each of said channels and having a radius substantially equal to the cross-sectional radius of said channels; said balls aligned in rows parallel to the axis of said rotor and each row thereof separated from each adjacent row by one of said pusher bars; said

pusher bars at their radially innermost extremity spaced apart less than the diameter of said balls whereby said balls are held by said pusher bars against radially inward movement relative to said rotor; a plurality of grinding balls within said rotor for cascading movement therein; said drum having a carrying fluid inlet at one end and a carrying fluid outlet at the other end whereby a fluid may flow through said drum for removing ground material.

4. A ball mill as described in claim 3 wherein said heads are convex and the inner surface of the drum is curved at the ends of the cylindrical surface on a radius of curvature greater than the radius of said balls whereby to avoid lodging of material to be crushed at that point.

5. A ball mill, the combination comprising: a stationary, horizontal, cylindrical drum; heads closing each of the ends of said drum; a pair of end memberes having elongated pusher bars mounted therebetween for forming a rotatable, hollow rotor within and extending substantially the full length of said cylindrical drum; said end members defining openings for the passage therethrough of material to be ground; a stud shaft mounted to each of said end members and rotatably carried by said closing means; the inner surface of said drum having a plurality of spaced channels parallel to the direction of rotation of said rotor and of segmental, arcuate cross-section; a plurality of balls seated within each of said channels and having a radius substantially equal to the cross-sectional radius of said channels; said balls aligned in rows parallel to the axis of said rotor and each row thereof separated from each adjacent row by one of said pusher bars and held by said pusher bars against radially inward movement relative to said rotor; conduits communicating with the interior of said drum whereby a carrying fluid may flow through said drum for removing ground material.

6. A ball mill comprising: a stationary, elongated, horizontal drum; heads for closing the ends of said drum, said drum and said heads defining a grinding chamber; a pair of stud shafts, one rotatably mounted in each of said heads concentrically of said grinding chamber; a journal exterior of said drum for supporting

each of said stud shafts; a rotor mounted on said stud shafts, including a plurality of pusher bars, mounted within said grinding chamber; power transmitting means on said stud shafts for driving said rotor; a plurality of channels, each of arcuate cross-section, in the inner wall of said drum and surrounding said grinding chamber in a direction parallel to the rotation of said rotor; a first plurality of grinding balls, seated in said channels arranged in rows parallel to said channels and parallel to said pusher bars; said channels, longitudinally of said drum, spaced apart the diameter of one of said balls whereby the balls in each of said rows parallel to said pusher bars are in contact with each other; a second plurality of grinding balls within said rotor.

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