

Jan. 17, 1939.

A. P. DANIEL ET AL

2,144,145

BALL MILL

Filed Feb. 18, 1937

6 Sheets-Sheet 1

Fig. 1.

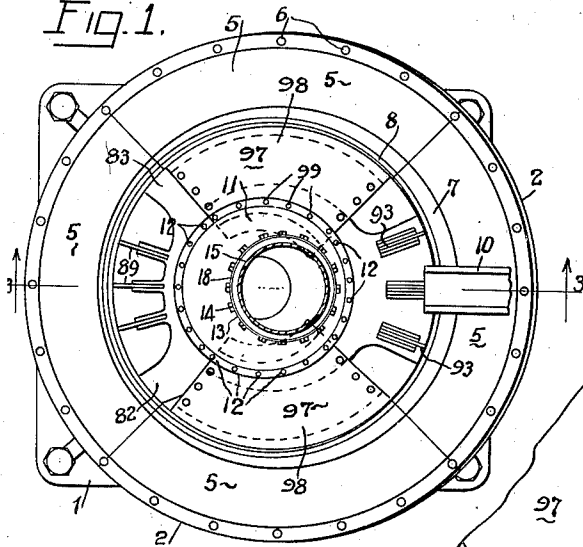


Fig. 7.

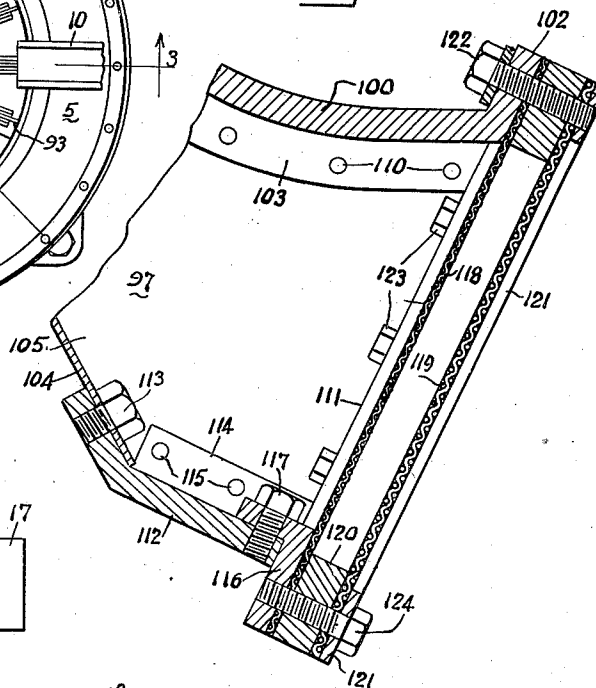
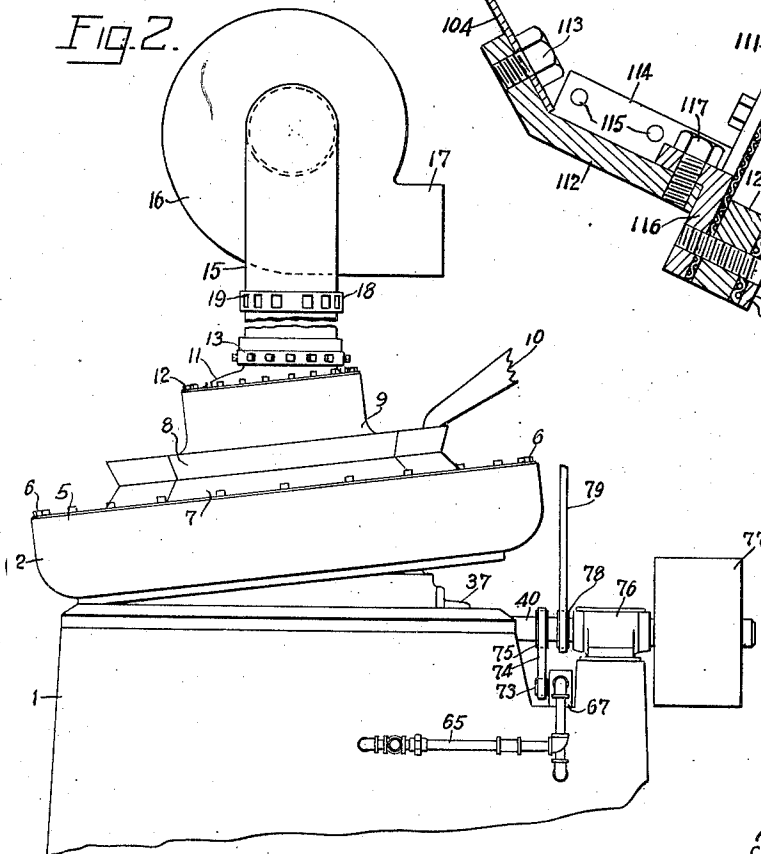


Fig. 2.



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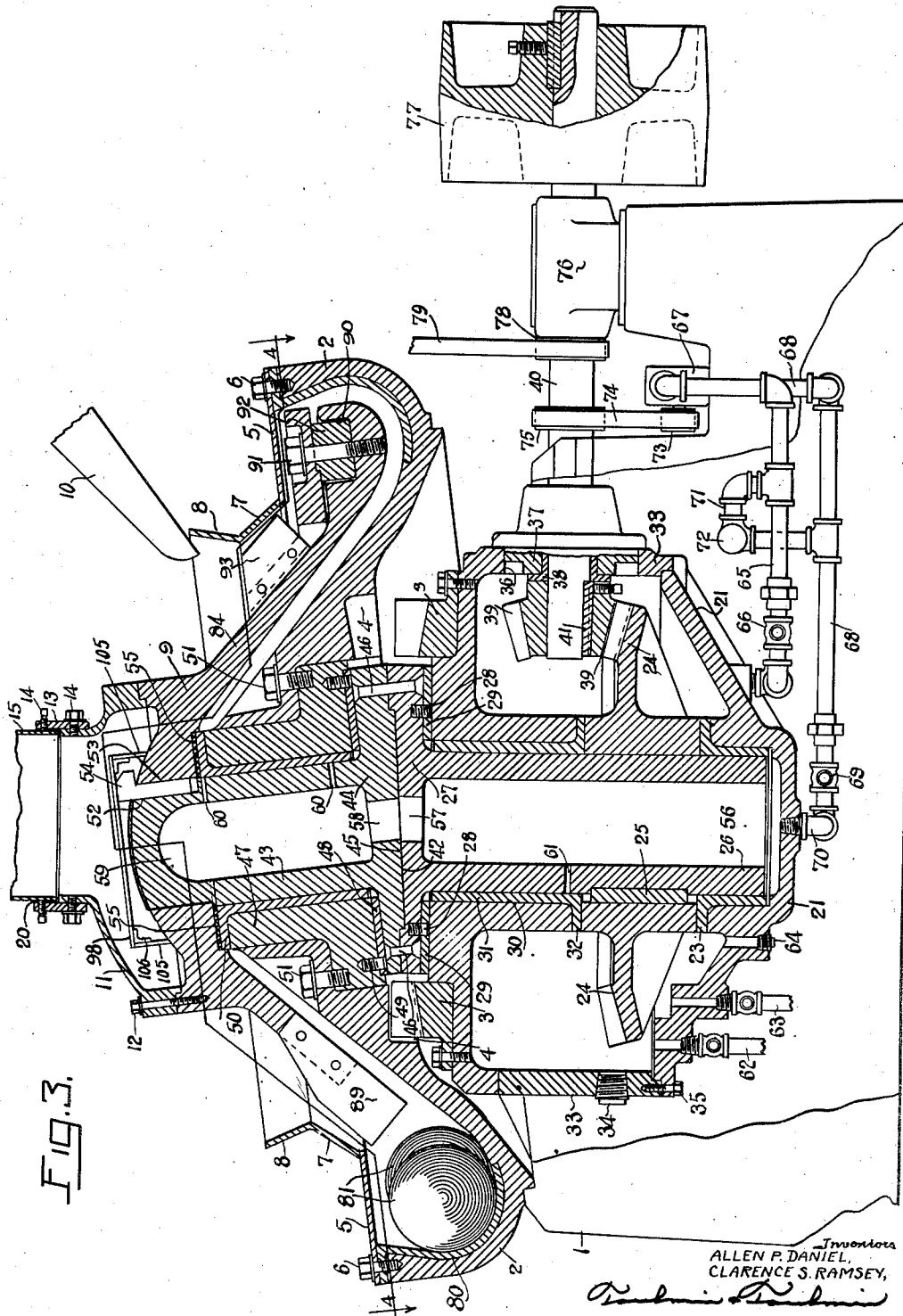
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Fig. 5.

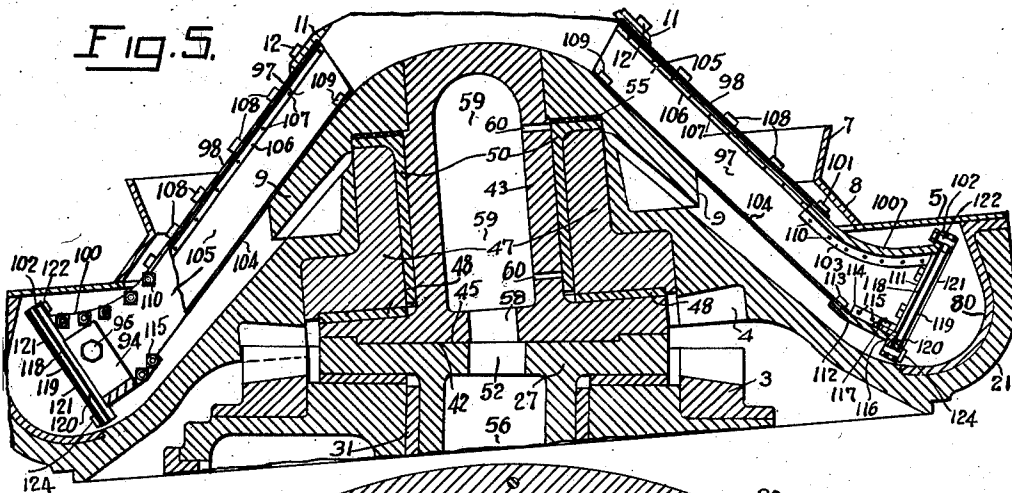
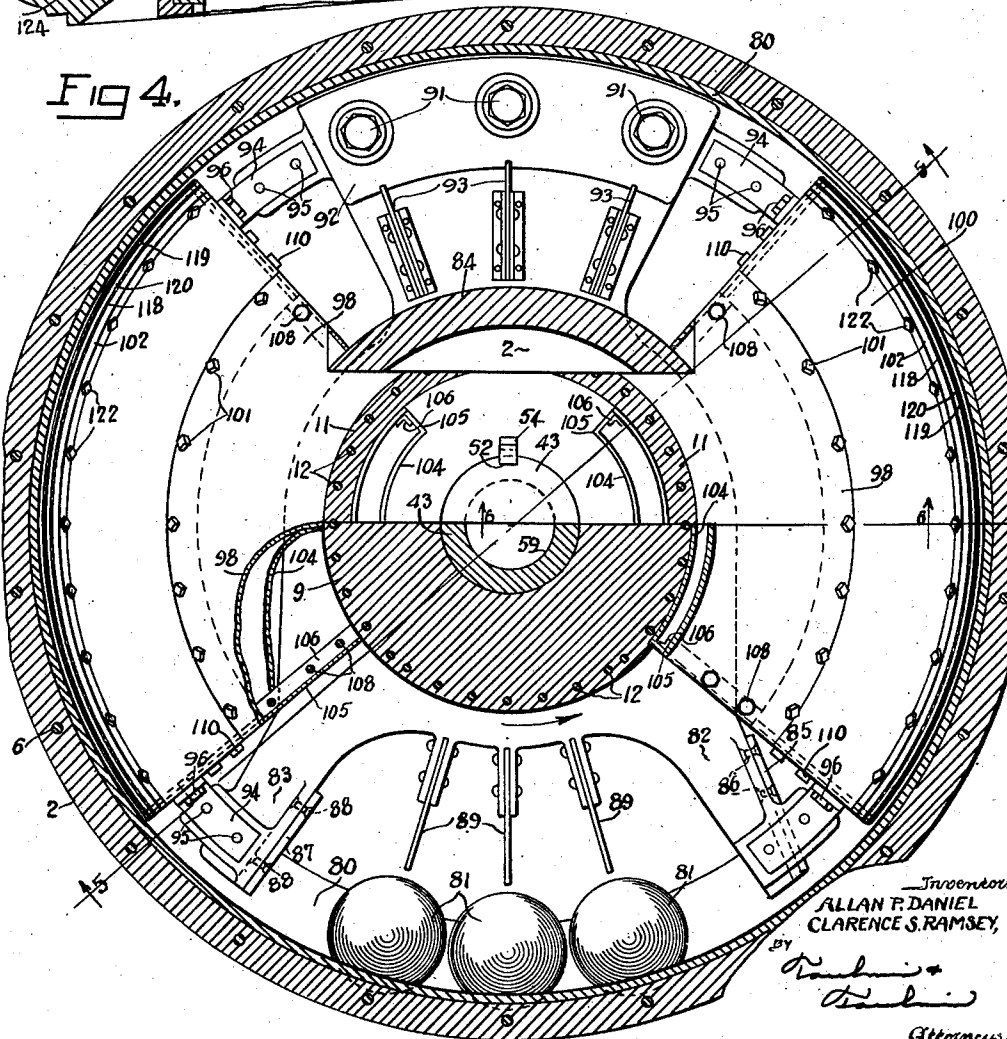


Fig. 4.



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Fig. 6.

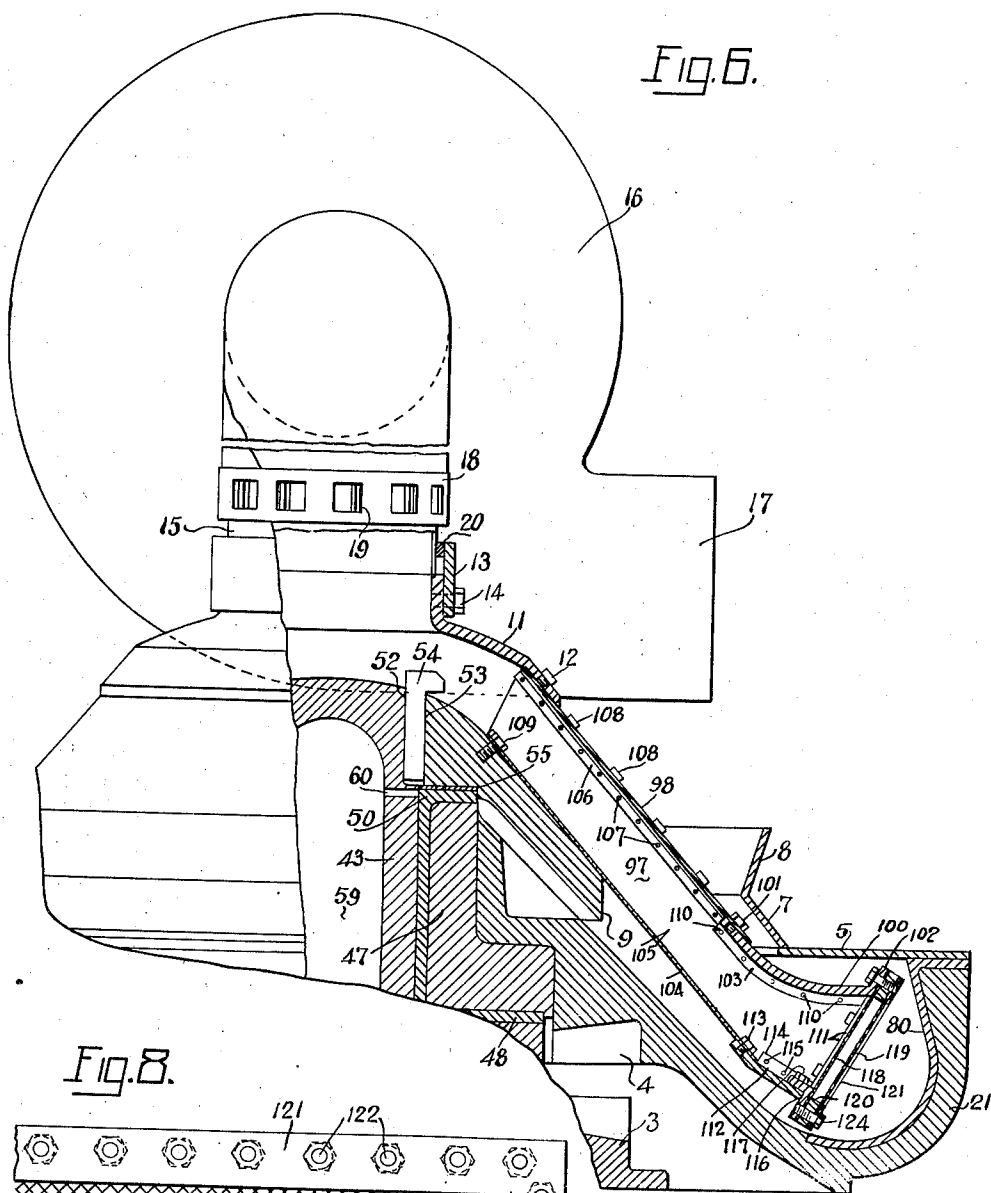
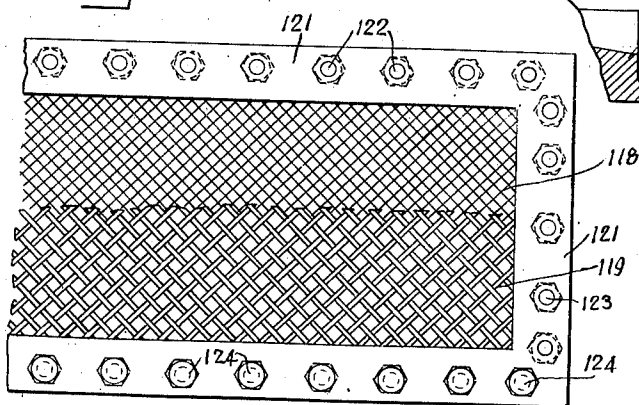


Fig. 8.



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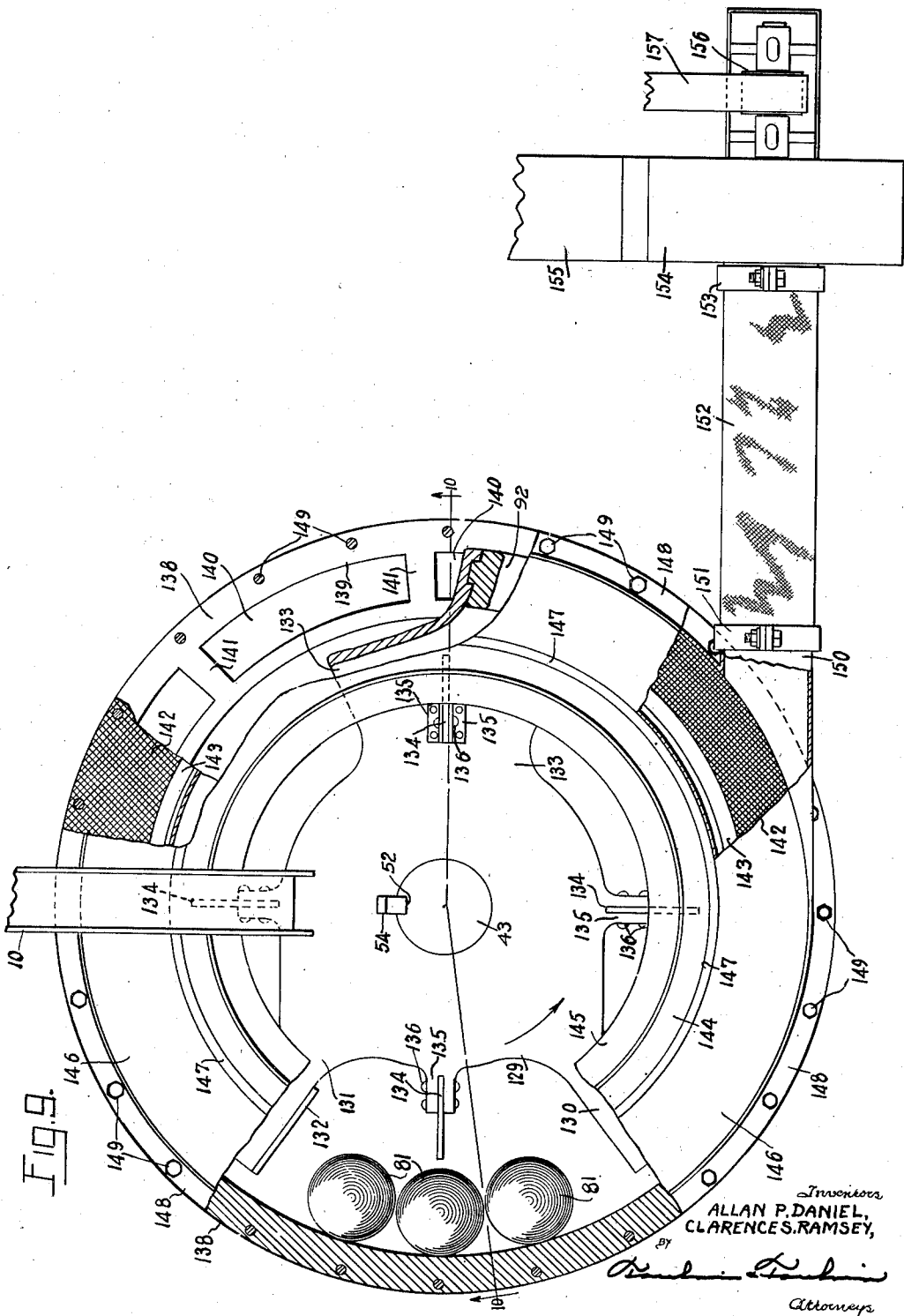
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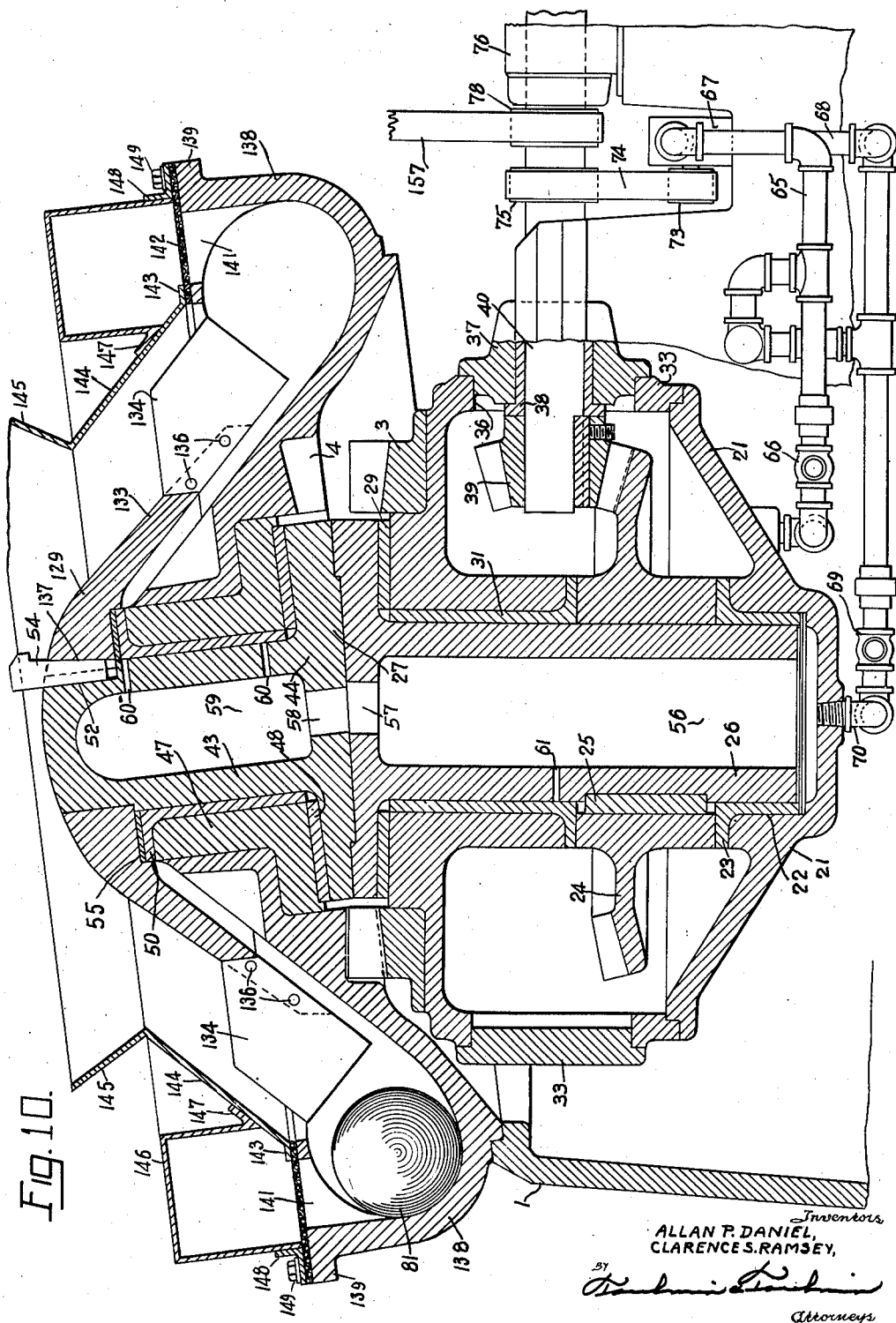
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## UNITED STATES PATENT OFFICE

2,144,145

## BALL MILL

Allan P. Daniel and Clarence S. Ramsey,  
Springfield, Ohio

Application February 18, 1937, Serial No. 126,444

6 Claims. (Cl. 83-45)

This invention relates to attrition mills or ball mills and, in particular, to the provision of such a mill with a continuous supply of material thereto, continuous grinding of the material therein, and continuous removal of the ground material therefrom.

It is an object of this invention to provide in such a machine grinding means comprising a nutating or nodding annular bowl having therein a ball track or ball race about which one or more balls are adapted to travel during nutation of the bowl.

It is a further object of this invention to provide, in such a mill, means for causing nutation of the bowl without rotation thereof.

It is a further object of this invention to provide, in such a machine, a spider member having means adapted to cooperate with the balls and with the nutating bowl to supply material to the ball race for grinding and to spread the material in the path of the balls during continuous operation of the machine.

It is a further object of this invention to provide removable counterweight means on said spider member, which means is adapted to balance or compensate for the weight of the balls in the nutating bowl.

It is a further object of this invention to provide, in such a mill, common means for causing oscillation of the oscillatable spider member and for causing nutation of the non-rotatable bowl having therein the ball race.

It is a further object of this invention to provide, in such a machine, means cooperating with the shaft means for causing nutation of the bowl to prevent rotation of the bowl with respect to the machine, said means comprising cooperating annular gear rings on the bowl and on the base or support of the machine.

It is a further object of this invention to provide means for supplying material in a downwardly and outwardly directed current of air to the ball track or ball race of the machine and for removing the predeterminedly ground material through the screen means in an upwardly and inwardly directed path whereby to aid the separation of the predeterminedly ground material by the force of gravity and/or centrifugal force generated through nutation of the bowl.

It is a further object of this invention to provide, in such a mill, a spider construction, secured for oscillation to the inclined end of a bent shaft; the bent shaft being freely rotatable with respect to a nutating bowl and which shaft is adapted

to cooperate with means preventing rotation of the bowl, for causing the bowl to nutate.

It is a further object of this invention to provide such a spider construction in which, in addition to the above arms, a counterbalance weight supporting arm is provided substantially opposite the balls which are adapted to be disposed between the plow and wear plate arms.

It is a further object of this invention to provide such a spider construction which is adapted to provide support for fan blades for creating, during rotation or oscillation of the spider, a draft of air downwardly into the bowl for providing means for feeding material into the bowl for grinding.

It is a further object of this invention to provide such a spider construction which is adapted to support outlet air ducts communicating at their lower ends with the interior of the bowl and at their upper ends to a source of suction.

These and other objects and advantages will appear from the following description taken in connection with the drawings.

In the drawings:

Figure 1 is a top plan view of the ball mill of our invention, with the fan housing omitted for the sake of clearness;

Figure 2 is a side elevational view of the structure shown in Figure 1;

Figure 3 is an enlarged elevational view, partly in section, taken on the line 3-3 of Figure 1;

Figure 4 is a section taken substantially along the line 4-4 of Figure 3;

Figure 5 is a section taken on the line 5-5 of Figure 4;

Figure 6 is a fragmentary elevational view, partly in elevation and partly in section, the sectional portion being taken along the line 6-6 of Figure 4;

Figure 7 is an enlarged detail view of the screen structure shown in Figure 6, with the coarse screen partly broken away;

Figure 8 is a fragmentary view, in section, of the screen structure shown in Figure 7;

Figure 9 is a top plan view, partly in section, of a modified form of the apparatus shown in Figures 1 and 2; and

Figure 10 is an elevational view, partly in section, of the structure shown in Figure 9, taken along the line 10-10 of Figure 9.

Referring to the drawings in detail, and with reference particularly to Figures 1 and 2, the base 1 is provided with drive means for causing nutation of the bowl 2, which bowl is provided with an annular ring gear adapted to cooperate with

the gear ring on the base 1 to prevent relative rotation between the bowl 2 and the base 1. The bowl 2 is provided with a bowl cover comprising complementary plates 5 secured to the top of the bowl rim by means of screws 6. The plates 5 are provided with integral inwardly and upwardly extending flanges 7 which are joined by upwardly and outwardly extending flanges 8. The plates together with their flanges form a cover for the ball track or ball race in the bowl 2 and the flanges thereof also cooperate with the inclined sides of the rotatable spider 9 to form an annular passageway, through which material to be ground is fed from the spout 10 of any suitable feeding means to the ball track or ball race of the bowl 2.

The rotatable spider 9 is provided with means cooperating with a plurality of balls disposed in the ball track or race of the bowl 2 by means of which material supplied from the spout 10 is subjected to the grinding or crushing force of the balls in the ball race of the bowl 2. From this crushed material, the fine particles are withdrawn through suitable air ducts (hereinafter described) rotatable with the spider 9, which air ducts communicate with the bowl 2 and with the air duct casting 11 which is secured to the top of the rotatable spider 9 by means of bolts 12. The air duct casting 11 is provided with a connector ring 13 rigidly secured thereto by means of bolts 14, which connector ring is adapted to rotate freely, during operation of the mill, with respect to the uptake 15, which uptake 15 is connected to the housing 16 of a fan or blower. The fan or blower is adapted to remove fine particles of ground material from the mill through the uptake 15. The material is discharged through the fan outlet 17 to any suitable collector. Means is provided for regulating the negative pressure or suction induced in the air duct casting 11 and the rest of the air system, which means comprises an annular damper ring 18, which ring is mounted for rotation with respect to the uptake 15 and which ring is provided with spaced apertures 19 adapted to cooperate with similarly spaced apertures in the uptake 15 for the purpose of admitting to the uptake 15 an amount of air depending upon the annular adjustment of the annular damper ring 18 with respect to the uptake 15.

In order to permit of free rotation between the connector ring 13 and the uptake 15, a suitable gasket 20 (Fig. 6) is preferably disposed therebetween and secured in position by means of screws 14'. It will thus be seen that suction or negative pressure may be induced in the air duct casting 11 and associated portions of the path of air and extracted dust or fine particles, the degree or intensity of which suction may be closely controlled by manipulation of the damper ring 18.

During operation, the upper shaft portion supporting the spider 9 oscillates in such manner as to cause nutation of the bowl 2 and this nutation of the bowl 2 causes a plurality of heavy balls to travel about the annular ball track therein by means and in a manner hereinafter more clearly described. The material supplied from the feeder spout 10, through the passageway provided by the outer inclined surface of the rotatable spider 9 and the flanges 7 and 8 of the bowl cover plates 5, is subjected to extreme crushing pressure by the moving balls whereby to crush the material supplied. The finer particles are, due to their slight mass, drawn inwardly and through the air

ducts into the air duct casting 11 by controlled suction in the uptake 15. The heavy particles, due to their greater mass, are retained within the bowl 2 and thrown outwardly therein to be subjected to further crushing action of the balls. The material is continuously supplied and the relatively fine particles of the crushed material continuously removed from the bowl by the above-described suction mechanism and delivered by it to any suitable known collector means such as a bin, container, room or other receptacle.

With reference particularly to Figures 3 to 8, it will be seen that the base bottom 21 of the base 1 is of annular internally stepped construction and forms a lubricant sump, into which lubricant from the respective bearings, hereinafter described, is conveyed by gravity. The base bottom 21 has centrally disposed therein an annular bushing seat 22 adapted to support the base bottom bushing 23. The base bottom bushing 23 is provided at its top with an outwardly extending horizontally disposed flange which is adapted to support the drive gear 24. The drive gear 24 is secured by means of key 25 to the lower shaft 26. The lower shaft 26 is provided at its top end with an enlarged annular head 27, to the bottom surface of which is secured, by means of studs 28, the lower bearing plate 29 which rests upon the annular flat top surface of the base 1.

The base 1 is provided with an annular bushing seat 30 in alignment with and disposed above the bushing seat 22. The bushing 31 is disposed in the bushing seat 30 between the seat and the lower shaft 26 with the lower outwardly disposed annular flange 32 of the bushing 31 disposed between the top surface of the drive gear 24 and the lower surface of the bushing seat 30. The base bottom 21 is suitably rigidly secured to the base 1 and the base 1 is provided at one side and above the base bottom 21 with a closure plate 33 having a screw plug 34 therein. The base bottom 21 is secured to closure plate by bolts 35, one of which is shown. The closure plate is suitably secured (by means not shown) to the base 1. At the opposite side of the base 1 is an annular bearing aperture 36, in which is secured the drive shaft bearing 37 provided with the drive shaft bushing 38.

The drive shaft 40 is supported in the bearing 37 and is provided at its inner end which extends within the enclosure in the base 1 with a drive pinion 39 which is rigidly secured to the drive shaft 40 by means of the key 41. The drive pinion 39 is so disposed as to mesh with the drive gear 24, which drive gear 24 is, as above described, secured by key 25 to the lower shaft 26. Rotation of the drive shaft 40, therefore, is translated by the above described means into rotation of the lower shaft 26. The head 27 of the lower shaft 26 is provided with an inclined top surface having a central annular countersunk portion 42. The upper or stub shaft 43 is also provided with a downwardly disposed flanged head portion 44 which is provided with a central annular stepped portion 45 complementary to and adapted to engage the countersunk portion 42 of the lower shaft 26.

The heads 27 and 44 are provided with aligned bores, through which are inserted suitable rivets or the like 46 in order to rigidly secure the head portions 27 and 44 together. Due to the inclined sections of the heads 27 and 44, the axis of the upper shaft 43 is angularly disposed with respect to the axis of the lower shaft 26. The lower shaft 26 and the upper shaft 43 which are rigidly

secured together by the rivets or the like 46, thus form, in effect, a bent shaft. Disposed about the upper shaft portion 43 of the bent shaft is the bowl support 47 having the upper bearing plate 48 rigidly secured to the lower end thereof by means of suitable screws 49. Disposed between the shaft 43 and the bowl support 47 is the upper support bushing 50 which has, at its top end, an outwardly extending annular flange which rests upon the top surface of the bowl support 47.

The bowl 2 is rigidly secured by means of bolts 51 to the bowl support 47, which bowl support 47 is freely rotatable with respect to the upper shaft portion 43 of the bent shaft. The shaft may, therefore, rotate freely with respect to the bowl support 47 and bowl 2. Rotation of the bowl support 47 and bowl 2 is prevented by the constant engagement of a portion of the annular ring gear 4 on the lower side of bowl 2 with the ring gear 3 on the stationary base 1 of the ball machine. The rotation of the bent shaft, however, due to the angular disposition of the upper shaft portion 43 with respect to the lower shaft portion 26 causes progressive annular engagement between the teeth of the ring gear 4 and ring gear 3, whereby to cause the bowl 2 of the mill to nutate or nod.

The upper shaft portion 43 is provided at its top end with a keyway 52 which is adapted to be aligned with a complementary keyway 53 in the spider 9 in order that the upper shaft portion 43 and the spider 9 may be rigidly secured together by means of the key 54. Disposed between the top surface of the upper flange of the upper support bushing 50 and the lower surface of the spider is a supporting washer 55. By means of the connection provided by the keyways 52 and 53 and the key 54, rotation of the lower shaft 26 and upper shaft portion 43, which causes nutation or nodding of the bowl 2, causes rotation, or oscillation, of the spider 9 which is rigidly secured to the upper shaft portion 43 of the bent shaft.

Pressure lubrication means is provided for the mill, which means includes the central bore 56 in the lower shaft 26 which communicates by means of the reduced bore 57 in the head 27 with the reduced bore 58 in the head 44 of the upper shaft portion 43, which reduced bore 58 communicates with the central bore 59 in the upper shaft portion. Suitable radially disposed bores 60 extend from the central bore 59 to the outer annular surface of the upper shaft portion 43 in order to provide lubrication for the upper support bushing 50, the upper bearing plate 48 and supporting washer 55. Like lubrication bores 61 are provided in the lower shaft 26. The base bottom 21 is adapted to provide a lubricant sump or container into which lubricant may be introduced by withdrawal of the plug 34.

An upper level valve control drain pipe 62 is secured in the base bottom 21, as is also a lower level valve control drain pipe 63. A drain plug 64 is also provided for draining the lubricant from the base bottom. Communicating with the lubricant containing portion of the base bottom 21 is a pump suction line 65 which has a control valve 66 therein. The pump suction line 65 is connected to the oil pump 67. The oil pump 67 has the pump discharge line 68 connected thereto. The pump discharge line 68 is provided with a valve 69 adjacent its end which is connected by means of the fitting 70 to the base bottom 21 below and in alignment with the central bore 56 of the lower shaft 26.

The pump suction line 65 is connected by means

of the by-pass line 71 with the pressure relief valve 72 which is also connected to the pump discharge line 68. The oil pump 67 is provided with a drive pulley 73 which is operatively connected by the belt 74 to the pump drive pulley 75 which is rigidly secured to the drive shaft 40. Lubricant is preferably inserted in the lubricant containing portion of the base bottom 21 by removal of the plug 34 which is thereafter replaced. By manipulation of the control valves and pressure relief valve 72 of the upper level drain pipe 62 or the lower level drain pipe 63, the oil level is suitably adjusted.

Upon operation of the drive shaft 40, the pump 67 will operate and will withdraw lubricant from the sump portion of the base bottom 1 through the pump suction line 65 and return through the pump discharge line 68 to the central bore 56 of the lower shaft 26 and thence upwardly into the central bore 59 in the upper shaft portion 43. Oil will then be supplied under pressure through the bores 60 and 61 in the upper shaft portion 43 and lower shaft 26 to the desired locations. By means of the provision of the pressure relief valve 72 between the pump suction line 65 and pump discharge line 68, when a predetermined pressure, for which the pressure relief valve 72 is particularly adjusted, is exceeded, the pressure relief valve 72 will open to connect the pump suction line 65 and the pump discharge line 68 through the by-pass line 71.

It may thus be seen that, during operation of the mill, lubricant is pumped into the central bores in the bent shaft and supplied therefrom under predetermined pressure to the desired bearing parts which are located outside of the grinding chamber and the inlet and outlet paths, whereby to achieve utmost protection thereof. The lubricant returns into the hollow casing provided for the drive gear 24 and drive pinion 39 by the base 1 and base bottom 21. A constant circulation of lubricant is secured while the mill is in operation.

The outer end of the drive shaft 40 is supported in the bearing 76 and is provided with a suitable drive pulley 77 by means of which it may be connected to any suitable source of power. Adjacent the bearing 76, the drive shaft 40 is provided with a feeder drive pulley 78, to which any suitable feeding means may be connected by means of the feeder drive belt 79 for operation simultaneously with and in synchronism with the mill. The spout of the feeder is designated 10 and its relationship to the mill is described above.

As shown in Figure 3, the bowl 2 is provided with a removable annular lining member 80 having an integral outwardly extending top flange adapted to rest upon the rim of the bowl 2 and be secured rigidly in position by the bolts 6 which extend through the bowl cover plates 5 as well as the flange of the liner 80. The annular liner 80 may be made in a single piece or of a plurality of pieces and may be omitted, if desired, and, when used, may be constructed of any suitable material particularly adapted to use with the material being ground.

As shown in Figures 3 and 4, a plurality of balls 81 (three are shown) is disposed in the ball track or ball race formed by the lower annular surface of the liner 80. These balls (which may be formed of any desired material particularly adapted for use with the material being ground), during nutation of the bowl 2, travel around the annular pathway and cooperate with

the liner 80 to grind material supplied between the balls and the liner 80. The cooperation between the balls 81 and the liner 80 is such that, when the bowl nutates or nods, the balls 81 always seek the lowest portion of the ball track. The greater the speed of nutation (which depends directly upon the speed of rotation of the bent shaft), the greater the speed of the balls in annular direction and the greater the centrifugal force exerted upon the balls by the nutation and the greater the force exerted by the balls on the liner 80. The spider 9 is of substantially frusto-conical vertical cross section and is disposed concentrically with respect to the longitudinal axis of the upper shaft portion 43 of the bent shaft. The spider 9 is provided with three arms, namely, a leading or plow arm 82, a following or wear plate arm 83 and a counterweight arm 84. The plow arm 82 and wear plate arm 83 are so disposed with respect to the upper shaft portion 43 that they are, during operation of the mill, disposed at opposite sides of the balls 81.

In other words, the leading or plow arm 82 is disposed forwardly of the travel of the balls and the following or wear plate arm 83 is disposed rearwardly of the balls in the direction of their travel. The plow arm 82 is provided with a plow 85 comprising a downwardly directed plate of form substantially complementary to the form of the ball track, which plate is rigidly secured by means of screws 86 to the plow arm 82. By removal of the screws 86, a new plow 85 may be attached in order to replace one which is substantially worn during operation of the machine. During rotation of the spider, the plow 85 serves to provide means for satisfactorily spreading the material in the bowl into the path of the balls 81. The following or wear plate arm 83 is provided at its forward surface with a wear plate 87 rigidly and detachably secured to the wear plate arm 83 by means of screws 88.

The wear plate is adapted, at certain times during operation of the mill, to engage the rear-most ball 81 and, as the wear plate is readily removable and replaceable, its use prevents damaging wear to the wear plate arm 83 and permits of compensation for the wear thereof by the balls in the cheapest manner. Disposed between the plow arm 82 and wear plate arm 83 is a plurality of fan blades 89 terminating short of engagement with the balls 81 and which cooperate with the flanges 7 and 8 and the adjacent upper portion of the bowl 2 to deliver a downward draft into the grinding chamber or sphere of grinding of the mill and thus deliver material from the feeder spout 10 to the bowl and, particularly, the ball track. The counterweight arm 84 is disposed at the opposite side of the spider 9 and is provided with suitable recesses 90 and bolts 91 for rigidly and removably securing counterweight 92 to the counterweight arm 84. These counterweights are made removable in order that their weight may be suitably adjusted to compensate for the weight of the balls 81 which are disposed at the opposite side of the bowl in order to prevent the production of excessive and dangerous vibration in the operation of the mill.

Above the counterweights 92, the counterweight arm 84 is provided with a plurality of blades 93 which are similar to the fan blades 89 and similarly disposed, although much shorter than the fan blades 89. These fan blades 93 operate in substantially the same manner as the fan blades 89 and serve substantially the same purpose, be-

ing adapted to create a draft between the adjacent portions of flanges 7 and 8 and the adjacent portions of the rotary counterweight arm 84, which draft is downwardly directed toward the ball track.

Supported by the spider 9 and disposed between the counterweight arm 84 and the plow arm 82 and between the counterweight arm 84 and the wear plate arm 83 respectively, is a pair of outlet ducts (Figures 4, 5, 6 and 7), which ducts are 10 attached to the respective arms by brackets 94 which are secured by screws 95 to the respective arms and by bolts 96 to the respective side wall portions 105 of the ducts 97.

In Figure 1, these ducts are generally designated 97. The details of the ducts are shown in Figures 4 to 7 inclusive. The ducts are arcuate, as shown in Figure 4, and each has its top wall formed by the top plate 98 and top casting 100. The top plate 98 is connected at its upper and 20 inner end to the skirt portion of the air duct casting 11 by means of bolts 12. Cooperating with the top plate 98 to form the top wall of the duct is the top casting 100 which is connected at its upper and inner end by means of bolts 101 to the 25 lower and outer end of the top plate 98.

The top casting 100 is provided at its outer end with an upwardly directed screen support flange 102 and at each side with a downwardly directed side wall support flange 103. The bottom and 30 sides of each duct 97 are formed by a unitary U-section member having a bottom wall portion 104 similar in shape to the top plate 98 and having also integral upwardly extending side wall members 105. Secured to the inner side of the upper 35 edge of each side wall portion 105 is a cover support angle 106 which extends from the upper and inner end of the duct forwardly to the abutting rear edge of the side wall support flange 103 on the top casting 100. The vertically disposed portion of the angle 106 is rigidly secured to the side wall 105 by means of rivets 107. The other portion of the cover support angle is adapted to support the top plate 98 which is secured thereto by means of bolts 108 which extend through the 45 side edges of the top plate 98 and which are screw threaded into the cover support angle 106. The inner end of the bottom wall portion 104 is secured by means of bolts 109 to the spider 9. The upper edges of the side wall portions 105 are 50 rigidly secured to the downwardly extending side wall support flange 103 of the top casting 100 by means of bolts 110.

The side wall portions 105 have their outer ends turned inwardly of the duct to form a screen support flange 111 having its forward surface in the same plane as the forward surface of the upwardly directed screen support flange 102 of the top casting 100. Secured to the forward end of the bottom wall portion 104 by means of bolts 60 113 is the bottom casting 112 which has upwardly directed side wall support flanges 114 at each side to which the side wall portions 105 are rigidly secured by means of bolts 115. Rigidly secured to the outer edge of the bottom casting by means of bolts 117 is the bottom screen support angle 116 which has the forward surface thereof disposed in the same plane as the forward surfaces of the screen support flange 102 and the 70 screen support flanges 111.

The above structure forms a pair of oppositely disposed outwardly flaring downwardly directed ducts which are rigidly connected to the air duct casting 11, by the bolts 12, to the central portion 75

of the spider 9 by the bolts 109 and to the respective arms 82, 83 and 84 of the spider 9 by means of brackets 94 which are secured to the respective arms and which are also secured to the side wall portions 105 of the ducts by means of bolts 96.

Double screen means is provided for screening the ground material before its entry into the ducts. This means comprises the inwardly disposed fine screen 118 which is supported on the forward co-planar surfaces of the screen support flange 102, the screen support flanges 111 and the bottom screen support flange 116 which are co-planar. The coarse screen 119 is disposed parallel to the fine screen 118 and is spaced therefrom by means of the spacer 120 which abuts the edge portions of the respective screens 118 and 119. A strap 121 is disposed outside the coarse screen 119, and the strap, screens and spacer are rigidly secured in position by means of bolts 122 which extend through the screen support flange 102, the fine screen 118, the spacer 120, the coarse screen 119, and which are screw-threaded into the strap 121. The bolts 123 likewise extend through the flanges 111 of the side wall portions 105 through the fine screen, the spacer, and the coarse screen and are screw-threaded into the strap 121. The bolts 124 extend in a direction opposite to the bolts 122 and 123 through the strap 121, the coarse screen 119, the spacer 120 and the fine screen 118 and are screw-threaded into the bottom screen support flange 116.

Due to the fineness of the screen 118, only the finest ground particles may be drawn through this screen, through the ducts, air duct casting and uptake by the controlled suction of the fan. The coarse screen 119 which is, as described above, spaced from the fine screen 118, effectively prevents damage to the fine screen 118 due to the striking thereagainst of coarse particles of substantial mass traveling at high velocity.

#### Operation

Upon application of rotation to the drive shaft 40, the drive pinion 39 causes rotation of the drive gear 24 which is rigidly secured to the lower shaft 26. The lower shaft 26 and its rigidly attached upper shaft portion 43, which together comprise the bent shaft, are rotated. The spider 9 and supported parts including the air ducts rotate in the same direction and at the same speed as the upper shaft portion 43 of the bent shaft. The bowl support 47 is freely rotatable with respect to the upper shaft portion 43 of the bent shaft and is prevented from rotating by engagement of the ring gear 4 of the bowl 2 with the ring gear 3 of the base 1 of the mill.

During the above described rotation or oscillation of the spider 9 which is rigidly attached to the upper shaft portion 43, the bowl is caused to nutate or nod through the progressive engagement of the respective teeth on the ring gears 3 and 4. The balls 81, which rest upon the liner 80 in the bowl 2 in following the low portion of the bowl which moves progressively in an annular path, are caused to travel about an annular path or ball track on the liner 80.

Centrifugal force is, as above described, also imparted to the balls, whereby to cause them to move about the ball track (being disposed in the lowermost portion thereof), whereby to cause them to rotate on their resultant axes and produce centrifugal force which, in turn, forces them out against the liner 80. The ever changing lowermost portion of the ball track or race is always

aligned with the axis of the upper shaft portion 43. In other words, the lowermost point of the ball track is co-planar with the axis of the upper shaft portion 43, and this common plane containing this point and the axis of the upper shaft portion 43, includes the axis of the lower shaft portion. Material is supplied through the feeder spout 10 of any suitable feeding means which is driven by the drive shaft 40 through the feeder drive pulley 78 and feeder drive belt 79. The material is drawn downwardly into the bowl by gravity and by the fans 89 and 93 which rotate with the spider 9, to which they are rigidly secured. The material is directed to the ball track and is spread thereon by means of the plow 85 which travels before, or in front of, the balls 81. The material is subjected to the crushing pressure of the balls 81 and the finer material, being most responsive to the suction in the ducts, is drawn through the coarse or guard screen 119 and fine screen 118, into the ducts and delivered from the ducts into the air duct casting 11 which communicates with the uptake 15. The material then travels through the fan and from the outlet 17 thereof to any suitable collector, as above described.

During operation of the machine, the lubricant pump 67 constantly withdraws lubricant from the base bottom 21 through the pump suction line 65 and returns it under pressure to the central bore 56 in the lower shaft 26 which is in communication with the central bore 59 in the upper shaft portion 43. The lubricant is delivered therefrom through the lubricant feed bores 60 and 61 to the respective bearings and bushings in the machine, which are spaced from the grinding chamber and from the intake and outlet paths thereof, being returned eventually to the base bottom 21, where it is again withdrawn through the pump suction line 65. The pressure regulating valve 72 prevents the production of excessive pressure in the pump discharge line 68, as above described.

The suction in the ducts and in the uptake 15 may, as above described, be controlled by suitable adjustment of the damper ring 18. The flanges 7 and 8 may be formed separate from the bowl cover plates 5 and may be welded thereto, as illustrated in Figure 3 thereof. If desired, horizontal flanges may extend from the flange 7 and rest upon the plates 5, being secured thereto by screws or bolts in known manner.

In Figures 9 and 10 is illustrated a modified form of ball mill or attrition mill constructed according to the principles of our invention. In the mill illustrated in Figures 9 and 10, the construction of the base 1, the drive and lubricating means and the bent shaft comprising the lower shaft 26 and upper shaft portion 43, is substantially the same as that illustrated in Figures 1 to 6 inclusive and described above. The construction of the bowl support 49 is likewise the same as that illustrated in those figures and described above. However, the construction of the bowl, of the spider, of the screen and exhaust means is modified as illustrated in Figures 9 and 10 and as hereinafter more clearly described.

As shown in Figures 9 and 10, the modified form of spider is designated 129 and is provided with a leading or plow arm 130 similar to the plow arm 82 and similarly equipped with a plow (not shown), which is detachably secured thereto in the same manner as is the plow 85 secured to the plow arm 82. The spider 129 is also equipped with a wear plate arm 131 similar to the wear plate arm 83, which is equipped with a wear plate 75

132 similar to the wear plate 87 and attached to the wear plate arm 131 by the same means of attachment as is used for the attachment of wear plate 87 to the wear plate arm 83. An arm 133 is disposed opposite the wear plate arm 131 and plow arm 130. This arm 133 corresponds to the counterweight arm 84 of Figure 3 and is adapted to serve as a fan blade support and is provided with counterweights 92 such as those on the arm 84 illustrated in Figure 3. The arm 133 is also provided with a fan blade 134 rigidly secured thereto within the counterweights by means of brackets 135 and screws or rivets 136. A plurality of these fan blades is arranged at equal intervals about the periphery of the spider 129, which spider is provided with a concentric aperture adapted to engage the top portion of the upper shaft portion 43, being secured thereto by means of the key 54 which engages the above-described keyway 52 in the shaft portion 43 and the keyway 137 in the spider 129.

The construction of the outer portion of the bowl 138 of Figures 9 and 10, as shown, is substantially different from that illustrated in Figure 3, being unprovided with any liner such as the liner 80. The bowl is provided with a flanged portion 139 which projects inwardly a substantial distance over the ball track in the bowl. The bowl is, however, supported in the same manner on the bowl support 49 and is also provided with the ring gear 4 in the same manner as is the bowl illustrated in Figure 3 and described above.

The flanged portion 139 is provided with arcuate slots or apertures 140 which extend about the entire periphery of the bowl and which are separated by webs 141. Superimposed upon the flange 139 and webs 141 and disposed over the apertures 140 therein is an annular member 142 of metal mesh screen. Disposed over the screen 142 with its lower peripheral flange 143 resting upon the internal annular edge portion thereof is the bowl housing. The bowl housing has the upwardly reduced frusto-conical flange 144 extending upwardly and inwardly from the flange 143 and the upwardly and outwardly directed annular flange 145 extending from the flange 144 to form the top of the bowl housing. The bowl housing may be made integrally, of one part, or the flanges 143, 144 and 145 may be formed of separate members welded together. Disposed above the annular screen member 142, outwardly of the bowl housing, is the air duct housing 146 which is annular and of substantial rectangular form having at its inner edge a flange 147 adapted to rest upon the flange 144 of the bowl housing. The flanges 147 and 144 may be suitably secured together by means of screws or, as illustrated, by welding.

An outer annular bracket 148 is suitably secured to the outer wall of the air duct housing 146, which bracket 148 rests upon the outer periphery of the flange 139 and is secured thereto by means of bolts 149 which extend through the screen 142 and into flanges 139 of the bowl 138.

A tangentially disposed outlet 150 of circular cross section is provided for the air duct housing 146, as shown in Figure 9. Attached to the outer end of the tangentially disposed outlet 150, by means of the annular clamp 151, is a section of flexible hose 152 which is connected at its opposite end, by means of the clamp 153, with the inlet of the fan 154. The outlet of the fan 154 is designated 155 and this outlet is suitably connected to any desired collecting means, as is the

outlet 17 of the fan housing 16, described above, provided with connection to such means.

The fan 154 is provided with a drive pulley 156 which is operatively connected by means of the belt 157 with any suitable source of power, it being contemplated that the belt 157 may be driven, if desired, from the power shaft 40. In Figure 9 is illustrated the spout 10 which is inclined, as seen in Figure 3, and delivers its material by gravity. The fan 154 may be mounted in any preferred position and in any desired manner. The mill is provided with a plurality of balls 81.

#### Operation of the modified form

In the operation of the modified form of our invention illustrated in Figures 9 and 10, the bent shaft comprising the lower shaft 26 and integrally attached upper shaft portion 43 is rotated, while, at the same time, the lubricant pump 20 67 is operated to withdraw lubricant from the sump portion of the base bottom 21 and return it at predetermined pressure to the central bore 56 of the lower shaft 26 and the bore 59 of the upper shaft portion 43, whence it is supplied through lubricant bores 60 and 61 to the supporting bushings and bearings.

Rotation of the bent shaft causes oscillation of the spider 129 which is rigidly secured thereto. Rotation of the bent shaft also causes nutation of the bowl 138. The fan blades 134 on the rotatable spider 129 create a downwardly and outwardly directed draft of air between the bowl housing and the bowl, into which downwardly and outwardly directed draft material is supplied from the feeder spout 10. The material is subjected to the crushing action of the rotating balls 81 which travel about the annular ball track in the bowl 138. The finely ground material, which has lesser mass than the remainder of the material, is drawn upwardly through the screen 142 into the air duct housing 146 and through the tangentially disposed outlet 150 thereof by means of the suction created by the fan 154, which fan communicates by means of the flexible section 152 with the tangentially disposed outlet 150.

As the feeder having the spout 10 is preferably connected for synchronized operation by the drive shaft 40, the speed of the feeder will vary directly with the speed of rotation of the spider, which speed is proportional to the speed of nutation of the bowl 138 and to the speed of travel of the balls 81. The force exerted by the balls 81 upon the ball track in the bowl 138 is also proportional to the speed of nutation of the bowl 138.

It is, of course, to be understood that the bowl 138 may be provided with a suitable removable liner such as the liner 80 of the bowl 2.

It will be understood that the above-described structure is merely illustrative of the manner in which the principles of our invention may be utilized and that we desire to comprehend within our invention such modifications as come within the scope of the claims and the invention.

Having thus fully described our invention, what we claim as new and desire to secure by Letters Patent is:

1. In a ball mill, a nutating bowl having an annular raceway, balls in said raceway, means to support and nutate said bowl comprising a power driven shaft having a bent end portion rotatably connected to said bowl, a spider mounted on said bent end portion for rotation

therewith, and a bowl cover mounted on said bowl and having upwardly extending flanges cooperating with said spider to form an annular feed trough.

5 2. In a ball mill, a nutating bowl having an annular raceway, balls in said raceway, means to nutate said bowl comprising a rotatable shaft having a bent end portion rotatably connected to said bowl, a spider rigidly mounted on said bent end portion, a bowl cover mounted on said bowl and having upwardly extending flanges cooperating with said spider to form an annular feed trough, said spider having thereon fan blades adapted to create a down draft in said trough to deliver material in a column of air to said raceway to be ground by said balls.

3. In a ball mill, a nutating bowl having an annular raceway, balls in said raceway, means to nutate said bowl comprising a rotatable shaft having a bent end portion rotatably connected to said bowl, a spider rigidly mounted on said bent end portion, a bowl cover mounted on said bowl and having upwardly extending flanges cooperating with said spider to form an annular feed trough, said feeder having thereon a counterweight adapted to compensate for the weight of said balls and fan blades adapted to create a down draft in said trough to supply material to said bowl to be ground by said balls.

30 4. In a ball mill, a nutating bowl having an annular raceway, balls in said raceway, means to nutate said bowl comprising a rotatable shaft

having a bent end portion rotatably connected to said bowl, a spider rigidly secured to said bent end portion, said spider having thereon air outlet ducts communicating at one end with said bowl, and suction means connected to the upper end of said ducts. 5

5. In a ball mill, a bowl adapted for nutation, a ball raceway in said bowl, balls in said raceway adapted to travel therein, means for nutating said bowl including a rotatable shaft having a bent portion, said bent portion being rotatably connected to said bowl, said bent portion having rigidly mounted thereon counterweight means disposed opposite said balls during operation, to compensate for the weight of the balls in the nutating bowl. 15

6. In a ball mill, a bowl adapted for nutation, a ball raceway in said bowl, balls in said raceway adapted to travel in said raceway due to the force imparted thereto by nutation of said bowl, means to cause nutation of said bowl comprising a rotatable shaft having a bent portion rotatable with respect to said bowl and providing support therefor, and a spider rigidly connected to said bent portion and having thereon fan blades disposed in said bowl adjacent said raceway, whereby the force of air directed to said raceway by said blades is proportional to the speed of nutation of said bowl. 25

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