

E. CADENACCIO.

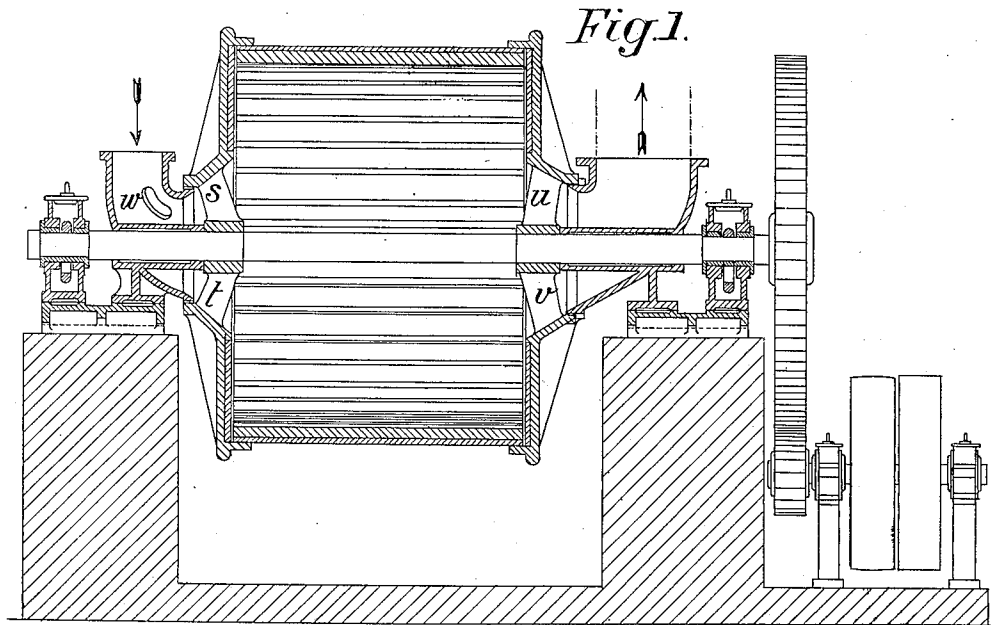
BALL MILL.

APPLICATION FILED AUG. 14, 1907.

925,288.

Patented June 15, 1909.

3 SHEETS—SHEET 1.



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Fig. 3.

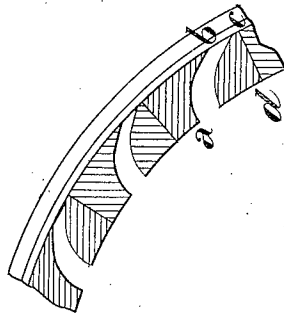


Fig. 5.

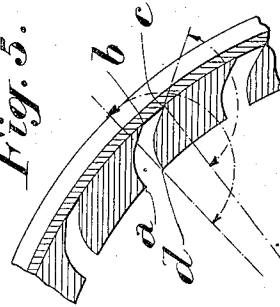


Fig. 2.

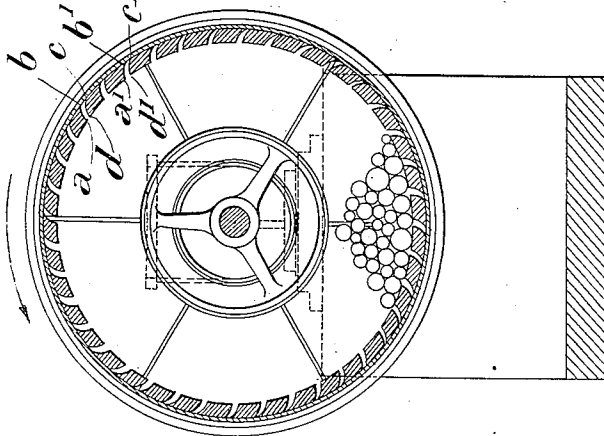
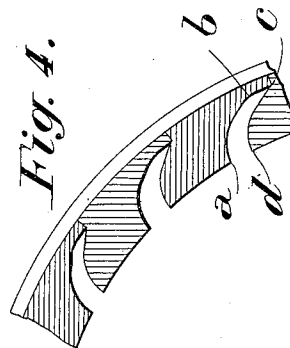


Fig. 4.



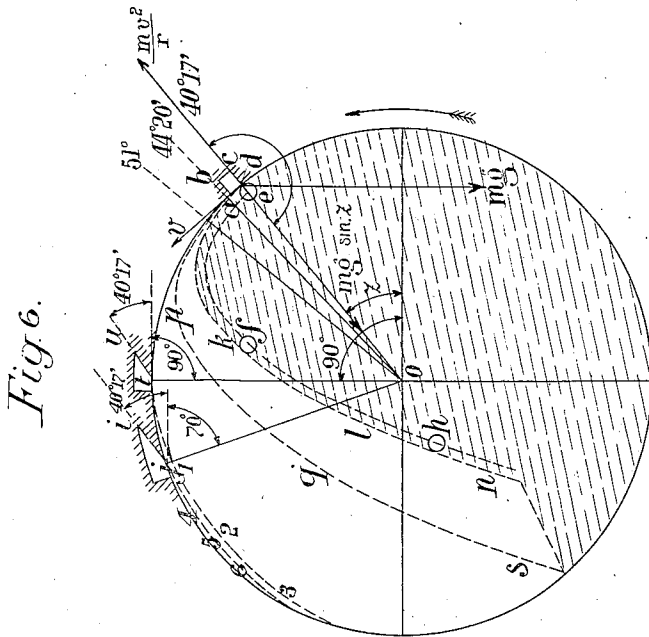
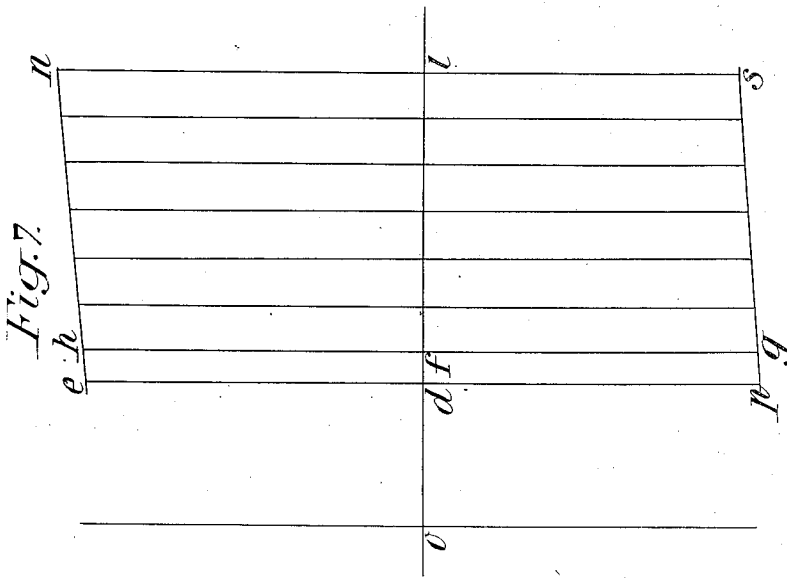
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BALL MILL.

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3 SHEETS—SHEET 3.



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UNITED STATES PATENT OFFICE.

ETTORE CADENACCIO, OF SESTRI PONENTE, ITALY.

BALL-MILL.

No. 925,288.

Specification of Letters Patent.

Patented June 15, 1909.

Application filed August 14, 1907. Serial No. 388,534.

To all whom it may concern:

Be it known that I, ETTORÉ CADENACCIO, a subject of the King of Italy, and resident of Sestri Ponente, Italy, have invented certain new and useful Improvements in Ball-Mills, of which the following is a specification.

In the annexed drawings: Figure 1 shows a longitudinal section and partial side elevation of my improved ball mill; Fig. 2 is a cross section of the same; Figs. 3, 4 and 5 show on enlarged scale detail sectional views of the casing plates; Figs. 6 and 7 are diagrammatical views illustrating the characteristic differences between the function of this mill and that of any other.

This ball mill is essentially composed of a large drum the casing whereof consists of plates of steel, hard cast iron, or any other hard material. These plates may simply be secured to both bottoms of the drum or they may be surrounded exteriorly by a metallic band. Provided upon the inside of this system of plates, are hollows, depressions or grooves $a, b, c, d, a^1, b^1, c^1, d^1$, (see Fig. 2) which may be formed directly in the material of the plates or by leaving intervals between the plates. In the latter case the bottom of each groove may be formed by the said metallic band covering the set of plates. These depressions or hollows may be extended over the whole, or only a part, of the inner length of the drum and their section may have several forms (by way of example three forms have been shown in Figs. 3, 4, 5 of the annexed drawings.) However, for the reason to be presently stated, the form and the inclination of the rear surfaces c, d, c^1, d^1 , etc., have a special importance for the good working of the grooves and consequently of the mill. The drum is completely closed at its periphery owing to the perfect joints made between the plates or by means of the covering band, and on the two opposite sides or bottoms, which are provided with plates made also of hard material, I provide two mouths st and uv (Fig. 9) with which I combine the rims of two fixed hoppers. The left hand hopper is intended to introduce the material which is to be ground and the air (the introduction of the latter is aided, if necessary, by one or more conven-

iently arranged holes w) while the ground material escapes through the right hand hopper, through which it is sucked together with the air by means of any pneumatic suction apparatus arranged beyond the second hopper and in communication with the latter by means of a tubular connection. In the drum are introduced the bullets of hard material which during the rotation of the drum perform the crushing and the pulverizing of the material to be ground.

In order to understand the function of this mill and the difference which exists between the form of its grooves and the mills known until now, which have been based upon an erroneous hypothesis of the function of ball mills and did not at all take into account the very important part played therein by the centrifugal force, I shall refer to the statement of Mr. Hermann Fischer cited by the "*Zeitschrift des Vereines Deutscher Ingenieure*" of March 26, 1904, Tome 48 No. 13 pages 437 to 441.

Fig. 6 of the annexed drawing shows a drum having the inner diameter of 1 meter and supposed to be rotated at the speed of 34 revolutions a minute; during this rotation it carries with it the balls and the material to be crushed. A ball e resting upon the wall of the drum separates itself therefrom as soon as the component of its weight, in the line of the radius, *i. e.* $mg \sin. Z$, has

become equal to the centrifugal force $\frac{mv^2}{r}$

and moves according to a throwing line or parabola corresponding to the equation:

$$y = x \frac{\cos. t}{\sin. z} - x^2 \frac{g}{2v^2} \sin. z$$

represented by the line efh , see *Zeitschrift des Vereines Deutscher Ingenieure*, page 438. The space of the drum occupied by the bullets and by the material to be crushed during the rotation of the drum is that marked in the Fig. 6 by dotted lines and placed at the right of the lines kln . In the free space which is situated at the left hand side of the side line, will fall the material contained in the grooves and in the manner which we shall demonstrate. Considering

the particle d of the material, which is situated at the lowermost place of the groove $a b c d$, this particle will be influenced by the

5 action of the two forces $mg \sin. z$ and $\frac{mv^2}{r}$

which are opposed to one another. It will fall in the interior of the drum as soon as

10 $mg \sin. z$ is greater than $\frac{mv^2}{r}$, that is to say

as soon as the angle z will be larger than $40^\circ 17'$ and it will describe in its motion a parabola *i. e.* it will follow the line $kl n$, the

15 equation of which for $z=40^\circ 17'$ is

$$y=1.18x-3.7x^2=x(1.18-3.7x).$$

Now in order to determine when the groove
20 may be emptied of the material which it contains, let us suppose, that the depth of the groove is 4 centimeters and that the particle c , which is situated at a distance of 54 centimeters from the axis of the drum and,
25 for simplifying the calculations, let us make $m=1$. The component of its weight $g \sin. z$, which is directed to cd , will be equal to the

30 centrifugal force $\frac{v^2}{r}$ when $z=44^\circ 20'$. At

this moment the particle c will begin to descend according to line cd , arriving at the point d when $z=51^\circ$.

I have shown in Fig. 7 the values de, fh, ln of $g \sin. z$, which correspond to the lengths od, Of, On of the arcs, when the angle z has the values $44^\circ 20', 45^\circ, 51^\circ$, and have connected thereto the points e, h, n by the line $e, h n$. As the force $g \sin. z$ acts in
40 a continuous manner on the particle c , the total of the infinite number of these values de, fg, ln , that is to say

$$45 \quad \frac{Ol}{Od} g \sin. z dz$$

will evidently represent the way which the particle c would follow in the interval of rotation from $44^\circ 20'$ to 51° if it were only
50 submitted to the action of the force $g \sin. z$. the line ehn is approximately a straight line and the calculation of the surface $denl$ made by the integration also corresponds very nearly to the result obtainable if said figure be considered a trapezium. The centrifugal force on the contrary diminishes
55 gradually in the proportion as c falls downward that is to say the angle z increases from $44^\circ 20'$ to 51° . In the first case the value is

60 $\frac{v^2}{r}=6.85$ in the latter case $\frac{v^2}{r}=6.34$. These

values are shown in Fig. 7 by dp, ls . It may in the same manner be supposed (without
65 any appreciable difference in our calcula-

tion) that the centrifugal force has varied uniformly, and consequently I may connect the point p with the point s by a straight line. As the centrifugal force acts also in a continuous manner on the material c , the total of the infinite number of the values $dp, fg \dots ls$ will evidently represent the way the material c would have made in the opposite direction to the preceding one during the interval of the rotation comprised between
70 $44^\circ 20'$ and 51° , if it had only been subjected to the action of the centrifugal force. The difference between the two surfaces $dkln$ and $dpqs$ will therefore represent with a very narrow approximation the way which
75 the material c will have made by the simultaneous and constant action of the two opposed forces, in the direction co (Fig. 6) when the angle z will have been increased from $44^\circ 20'$ to 51° . When effecting the
80 operation one really finds that this difference is of 0.04 meter, as we had the intention to show. As soon as the angle 51° is passed, the particle which at $44^\circ 21'$ had been at the point c of the groove, *i. e.* which has
85 been at the remotest point from the center, will therefore leave the groove and will fall into the interior of the drum and in its fall will describe the parabola pqs (Fig. 6). The two parabolæ $kl n, pqs$ inclose ap-
90 proximately the section of the space into which falls the material leaving the grooves when the latter as we have supposed, have their rear walls directed according to the radii *i. e.* when the said walls form with the
95 respective radii an angle of 180° . On the contrary when the rear wall of the grooves forms an angle of $90^\circ + 40^\circ 17' = 130^\circ 17'$ with the radius (angle otu), the above said wall will have the inclination $40^\circ 17'$ with
100 reference to the horizon, when $z=90^\circ$ and the material contained in the grooves will begin to fall into the interior of the drum from the point t and will form the parabola 1, 2, 3 the equation of which is $y=1.55x^2$
105 and will continue to fall in proportion to the rotation of the drum, into a small space placed at the left of the said curve 1, 2, 3. If the angle comprised between the above said rear wall and the radius is equal to
110 $70^\circ + 40^\circ 17' = 110^\circ 17'$ (angle Ojn) the above named surfaces will have the inclination of $40^\circ 17'$ with reference to the said horizon when $z=110^\circ$; the material contained in the groove will begin from the
120 joint j to fall into the interior of the drum where it will move according to the parabola 4, 5, 6 the equation of which is:

$$y=-0.36x-1.75x^2=-x(0.36+1.75x)$$

125 and it will continue to fall in proportion to the rotation of the drum into the very small space which is situated at the left hand side of the above named parabola 4, 5, 6. It is evident in any case that if the rear faces of 130

the grooves have the same inclination with reference to the radius (whatever might be this inclination) the fall of the material contained in the said grooves will take place at the same points of the circumference and during a very limited part of the arc and the portion which will be utilized of the void space of the drum (*i. e.* that which is crossed by the said material) will also be very limited. This is a very serious inconvenience which may be seen in all the mills known until now, provided with grooves and wherein the material is sucked in. It is on the contrary very important that the free space of the drum be used as much as possible for the fall of the material from the grooves in order to facilitate the subsequent separation of the said material according to its degree of fineness and its evacuation through the escape opening by means of the air draft. To this effect the rear surfaces of the grooves will be arranged in my mill according to inclines having different inclinations with reference to the radii that is so to say that they have different angles which gradually vary from one to the other within suitable limits for instance between about 180° and 110° in such a manner that (and one could calculate it easily) the above stated condition be satisfied. If however one desired to have the same form for all the grooves, their rear surfaces will be constituted according to a certain convex outline. The latter may be easily determined in such a manner for instance that the said tangent at the point *d* forms with the radius an angle of about 180° and at the point *c* an angle of about 110° (Fig. 5); these points are then connected by a suitable curve so that the fall of the material is gradually effected. Figs. 3 and 4 of the annexed drawing show the first disposition, Fig. 5 the second one. Fig. 2 shows the second arrangement.

In order not to complicate uselessly the calculations, I have not considered the smaller resistances that is to say the friction during the descending motion of the material and the resistance of the air. Their action may be neglected in comparison with that of the force of gravity and of the cen-

trifugal force and it cannot sensibly modify the obtained results. In the construction of the mill it is however possible to compensate the aforesaid resistance due to friction. If one adopts the form shown by Figs. 3, 4 and 5 the angle formed between the tangent to the curve *cd* at the point *d* with the radius will be made a little greater than 180° . In this manner, the resistance due to friction will be compensated at the moment when the material should begin to leave the grooves. Similar proceedings will be resorted to when it is desired to compensate with resistances due to friction at the moment when the material should finish to leave the said grooves. If the form of the grooves is that shown by Figs. 3, 4 and 5 it will be sufficient to increase slightly the minimum angle of about 110° which the rear surface forms with the radius.

Having now fully described my said invention what I claim and desire to secure by Letters Patent is:—

1. In a ball mill the combination with a cylindrical drum casing, means for rotating the latter and means for causing an air draft to pass through said casing, of a plurality of grooves longitudinally arranged in the inside of the wall of said drum casing, the rear walls of the said grooves being curved according to a convex curve throughout their length, substantially as and for the purpose set forth.

2. In a ball mill the combination with a cylindrical drum casing, means for rotating the latter and means for causing an air draft to pass through the said casing, of a plurality of grooves longitudinally arranged in the inside of the wall of said drum casing, the rear walls of the said grooves being curved according to a convex surface and the front walls according to a concave surface, substantially as and for the purpose described.

In testimony whereof I have hereunto set my hand in presence of two witnesses.

ETTORE CADENACCIO.

Witnesses:

DOTTOR VINCENZO PASQUERO,
A. FERRARI.