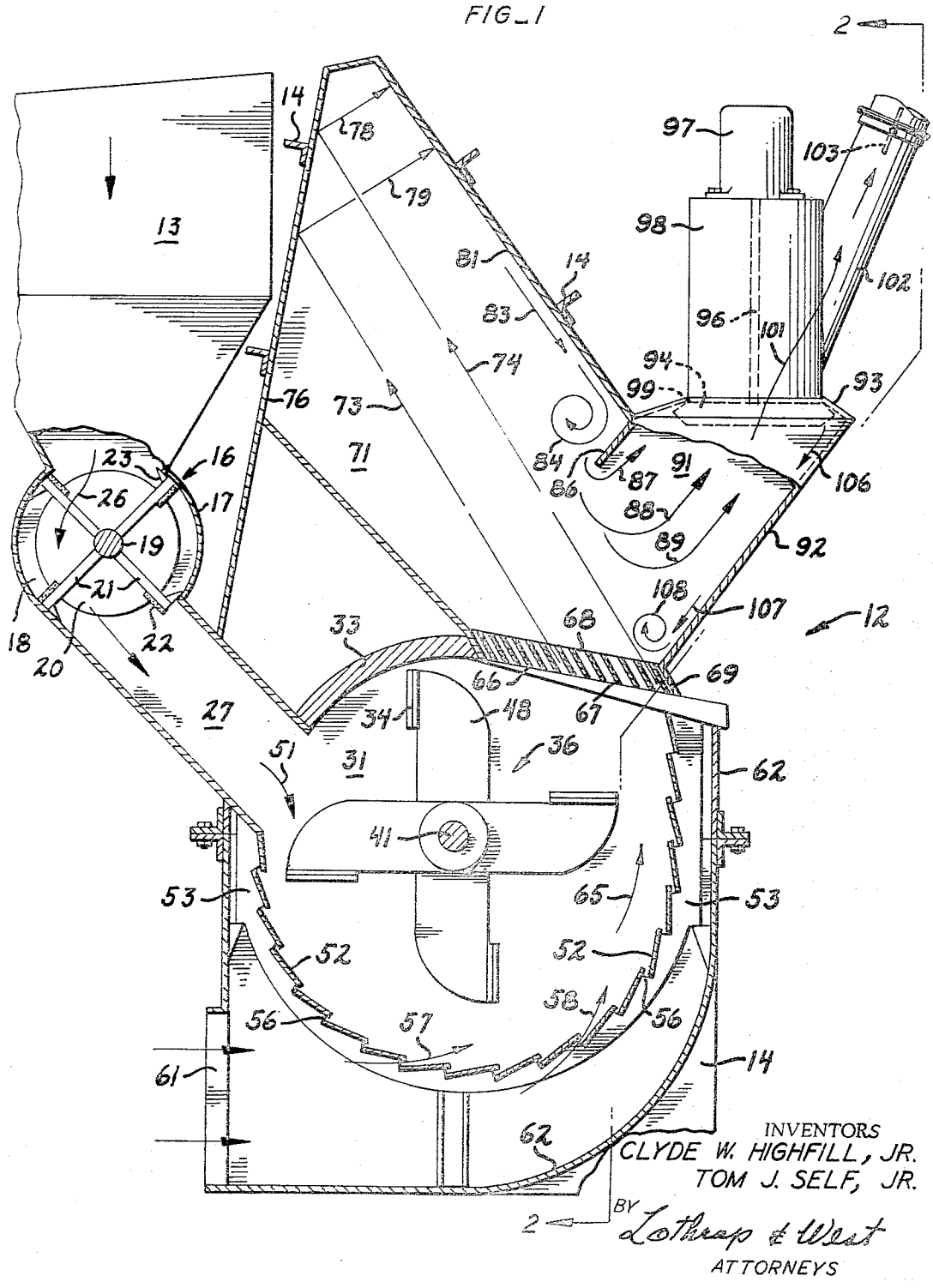
Aug. 1, 1967 C. W. HIGHFILL, JR., ETAL 3,333,777

GRINDING MILL

Filed April 19, 1965 2 Sheets-Sheet 1

FIG_1



INVENTORS
CLYDE W. HIGHFILL, JR.
TOM J. SELF, JR.

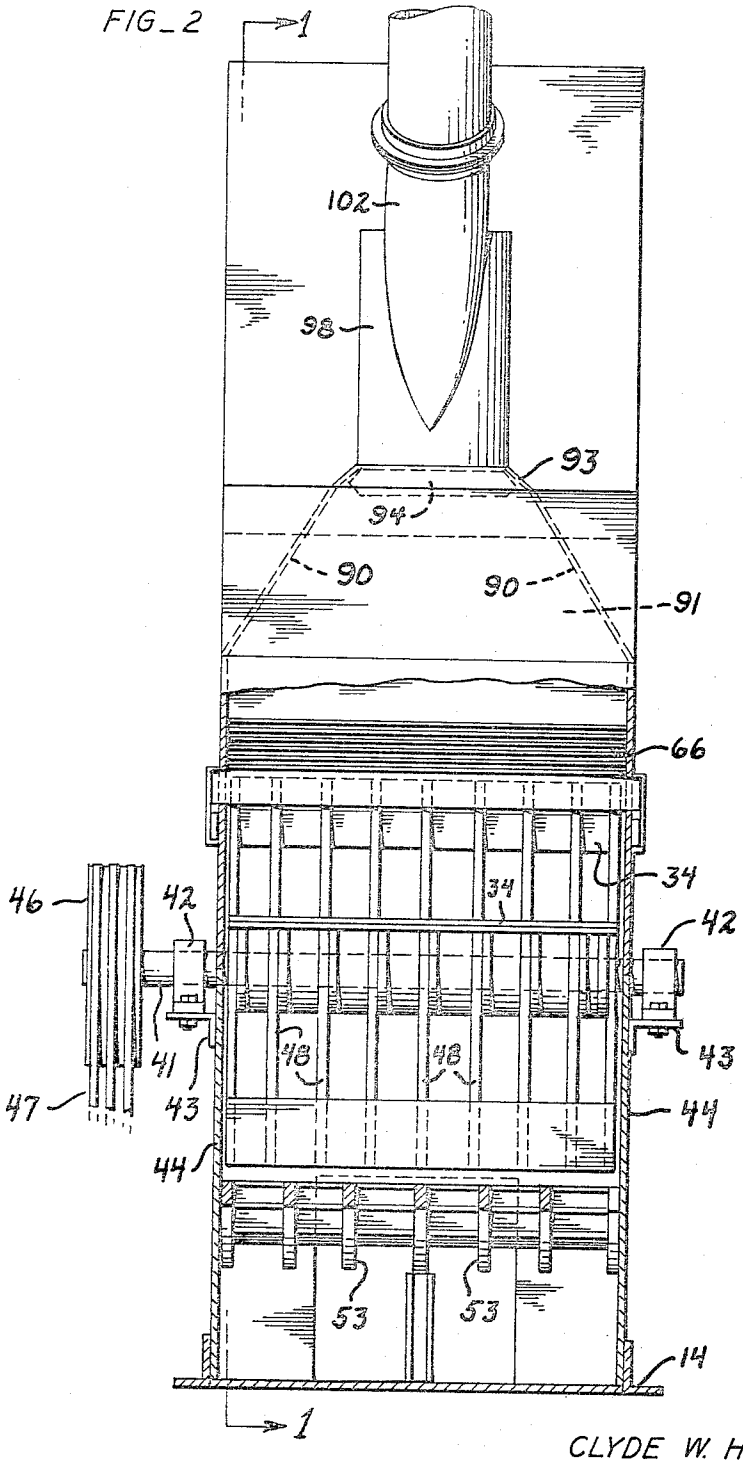
BY Lothrop & West
ATTORNEYS

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FIG_2



INVENTORS
CLYDE W. HIGHFILL, JR.
TOM J. SELF, JR.
BY Lothrop & West
ATTORNEYS

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3,333,777

GRINDING MILL

Clyde W. Highfill, Jr., 5949 Sampson Blvd., Sacramento, Calif. 95824, and Tom J. Self, Jr., 8782 Stevens Drive, Orangevale, Calif. 95662, assignors of eighty percent to said Highfill and twenty percent to said Self

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The invention relates to devices for crushing, grinding and otherwise comminuting materials, such as rocks, clay, ore and other minerals.

Both the market place and the patent literature are replete with devices for pulverizing materials obtained from the earth.

In the main, however, devices of this nature which are capable not only of comminuting material to fine particle sizes, but also of sorting or classifying so as to pass only particles smaller than a predetermined size, are complicated and expensive, and require numerous different expensive pieces of apparatus occupying a considerable area of floor space for their operation.

It is therefore an object of the invention to provide a grinding mill which is relatively economical and compact in size, yet which eliminates the need for additional apparatus, such as screens, filters, re-crushers and lengthy belt conveyors.

It is another object of the invention to provide a grinding mill in which the pulverized product consists of fine particles which are spherical in general configuration, rather than jagged, as are the particles in many prior art devices.

It is a further object of the invention to provide a grinding mill which sorts the output and allows only particles below a predetermined size to pass.

It is another object of the invention to provide a generally improved crusher-grinder.

Other objects, together with the foregoing, are attained in the embodiment described in the following description and shown in the accompanying drawings in which:

FIGURE 1 is a front elevational view, with portions being shown in section, the plane of the section being indicated by the line 1—1 in FIGURE 2; and

FIGURE 2 is a side elevation, portions being shown in section, the compound plane of the section being indicated by the line 2—2 in FIGURE 1.

While the crusher-grinder apparatus of the invention is susceptible of numerous physical embodiments, depending upon the environment and requirements of use, substantial numbers of the herein shown and described embodiment have been made and used and all have performed in an eminently satisfactory manner.

The grinding mill of the invention, generally designated by the reference numeral **12**, is customarily used to pulverize or comminute, materials, such as rock, ores and other minerals which vary substantially in size and shape. For convenience, the raw material will be referred to as rocks, although it is to be clearly understood that the utility of the machine is not confined to rocks alone.

The raw material is conveyed to the mill **12** in any appropriate manner and is deposited in a hopper **13** mounted on suitable framework members **14** adapted to support the various components of the mill.

By gravity, the rocks move downwardly into an air-lock **16** comprising a hollow, circular cylindrical housing **17**, enclosed at opposite ends by end plates **18**. Axially disposed within the housing is a shaft **19** journalled in suitable bearings on the end plates. One end of the shaft extends beyond the bearing and is provided with appropriate fittings, such as sprockets or pulleys, not shown, adapted to be rotated as by a ten horsepower electric motor and at a speed of 25 r.p.m.

The power equipment and transmission accessories form no part of the invention, as such, are off-the-shelf items, and are thus not shown in the interests of greater clarity of disclosure of the novel features of the invention.

Mounted radially on the shaft **19** is a plurality of plates **21** extending axially from one end to the other end, radially, to the inner walls of the housing **17**. A plurality of welded gusset sectors **20** spaced along the shaft afford great strength and rigidity to the plates. As an air seal, the back sides of the plates **21** are provided with resilient wipers **22** which wipe against the walls as rotation occurs.

On the front sides of each of the plates **21**, a plurality of teeth **23** is rigidly secured. Preferably, the teeth are of a hardened variety such as power shovel teeth, and are placed side by side in axial alignment between the opposite ends of the housing. As rotation of the air lock shaft and the plates proceeds in a counterclockwise direction (see FIGURE 1) the points of the teeth dig into the adjacent overlying rocks. This action not only fractures or ruptures a certain number of the rocks, but it also keeps shifting and moving the overlying rock layers, and thus prevents their forming a bridge spanning the bottom of the hopper. Also, as is indicated by the arrow **26**, the teeth and the radial plates carry a charge of rocks around through the air lock and discharge them into an inclined chute **27** through which the rocks fall by gravity into a hammer chamber **31**.

It is to be noted that at this juncture the rocks have already been subjected to a considerable amount of breaking and cracking, owing to the fracturing effort of the shovel teeth **23**, somewhat comparable to the splitting effected by a geologist's pick or a stonemason's hammer. The shock imparted by the teeth, furthermore, tends to weaken the rocks along cleavage planes and renders them highly susceptible to additional fracture and comminution in the hammer mill station.

The hammer chamber **31** is substantially of hollow, circular cylindrical configuration and axially is coextensive with the axial dimensions of the air-lock **16** and the chute **27**.

In the upper left sector, as appears most clearly in FIGURE 1, the hammer chamber wall comprises a very thick and strong arcuate plate **33**, face-hardened on its concave surface to coact with the revolving, face-hardened hammer heads **34** of the hammer member **36**. In other words, the heads **34**, which revolve in a counterclockwise direction, in FIGURE 1, not only break the rocks emerging from the chute **27** by impact but the heads **34** also fling rock fragments outwardly by centrifugal force. Some of these fragments strike the heavy arcuate, striker plate **33** where further comminution occurs. In addition, some of the rocks, particularly those of a size capable of spanning the distance between the arcuate striker plate and the adjacent hammer head, are dragged or scraped along the case-hardened arcuate plate **33** and are thereby subjected to an abrasive action. The radius of curvature of the plate **33** is somewhat sharper adjacent the entrance of the chute **27** with the result that the gap or space between the concave surface of the plate and the hammer head decreases as the hammer head approaches the chute. In this fashion, any interposed rocks are subjected to a severe, increasing wedging or compressive stress, tending further to crush and comminute the rocks.

The hammer member **36** includes an axial shaft **41** suitably journaled in bearings **42** (see FIGURE 2) mounted on brackets **43** secured to the opposite end walls **44** of the hammer chamber **31**. A pulley **46** mounted on one end of the shaft is provided with suitable belts **47** leading to a power source, not shown, such as a 50 horsepower electric motor, running at a speed of 250 r.p.m.

The hammer heads **34**, previously referred to, are face-

hardened, elongated plates extending substantially between the opposite end walls **44** of the hammer chamber with a small clearance at each end; and the plates **34** are secured, as by welding, to the leading edges of a plurality of hammer arms **48**. For greater strength, each hammer arm **48** includes a plurality of axially spaced, parallel plates formed to the shape of the arm member designated as **48** and shown in FIGURE 1.

As the revolving hammer head **34** swings into the discharge throat area of the chute **27**, the head strikes with great force against the incoming rocks which follow the path indicated by the arrow **51**; and, as a result of this impact, extensive fragmentation occurs.

Furthermore, since all materials, even rocks, possess a certain degree of resiliency, deflection of many broken rock particles takes place; and this action, in addition to centrifugal force tends to drive the rock particles downwardly and rearwardly against a plurality of spaced, partially overlapping plates **52**, extending axially between the opposite end walls **44**.

The overlapping plates **52** are strongly secured in place by a plurality of axially spaced, parallel, arcuate ribs **53**, mounted on the frame **14**. The inner, or concave edges of the ribs **53** are notched, as appears most clearly in FIGURE 1, to receive the longitudinal, overlapping plates **52**. Thus, not only are the overlapping plates themselves strongly made, but they are provided with a very rigid backing; and, as a consequence, the plates **52** further crack such rocks as are impelled against them by the hammers.

The overlapping plates **52** also serve another important purpose. The overlapped portions of adjacent plates are spaced apart a fraction of an inch, and a plurality of axially elongated passageways **56** is thereby provided. In cross-section, as most clearly appears in FIGURE 1, the passageways **56** converge, so that as air moves through the passageways, air velocity increases. The passageways are also so inclined that air flow therethrough, as indicated by the arrows **57** and **58**, is approximately tangent to the periphery of the hammer chamber, although not precisely so.

The high velocity air movement originates at a blower (not shown), driven, for example, by a 40 horsepower electric motor. The blower air enters through the intake **61** of a scroll casing **62** encompassing the overlapping plate portion of the hammer chamber.

The plurality of high velocity, substantially tangential air jets, such as are shown by the arrows **57** and **58**, dislodge all rock fragments and particles from the plates since the overlapping plates are all inclined to a greater or less extent, with respect to the horizontal, thus causing the fragments to move by gravity into the path of the next lower air jet.

By the time the rock fragments have been subjected to impact against the overlapping plates **52**, the particle size is fairly small, or small enough so that the high velocity tangential air streams can pick up and quickly accelerate the particles in an upward direction as indicated by the arrow **65**, where they strike a louver **66**. A certain portion of the fragments are also impelled against the louver **66** by the counter clockwise movement of the hammer arms.

The louver **66** comprises a plurality of sturdy, spaced, parallel plates **67** axially extending between the end walls **44** (see FIGURE 2). The individual plates **67** of the louver are spaced apart a predetermined distance dependent upon the size of the particle it is intended that the louver shall pass. In the embodiment here shown, the spacing between the plates is ⅜ of an inch, it having been found that the velocity and quantity of the air entering the hammer chamber from the 40 horsepower blower is sufficient to impart a very high velocity to particles this size, and thus drive these particles against the plates, thence upwardly through the louver openings **68** and into an impact chamber **71**, or ricochet chamber.

Fragments larger in size than ⅜-inch are also flung

with considerable speed against the lower edges of the louver plates where further fragmentation occurs. Particles incapable of passing through the louver drop back into the path of the hammer, which causes additional shattering, both on direct impact with the hammers, as well as upon further impact with and abrasion along the concave face of the thick arcuate plate **33**.

It will be noted that the louver plates **67** which, in this embodiment, are one inch thick, four inches wide and four feet long, are inclined at an angle of approximately 65 degrees with respect to the horizontal, this also being the angle of inclination of the top plate **69** of the overlapping plates **52**. The louver plates **68** thus also serve as vanes, or guides, directing the high velocity air and the smaller entrained particles into parallel streams or paths moving upwardly and to the left (see FIGURE 1) as indicated by the arrows **73** and **74**.

At this juncture, it is important to point out that in bringing the violent upward current of air, and entrained particles, into parallel alignment, a spin is imparted to the small particles which pass through the louver. In other words, the particles are moving at a high speed in a generally vertical direction as they strike the louver plates, or more specifically, the lower faces of the louver plates. Since the faces are inclined, the impact of the vertically moving particles results in two components of force; the vertical component resulting in a shattering effect with the horizontal component deflecting the particle laterally and imparting a spin, as the particle "bounces" off the inclined face. A consequence of this action is that a certain number of the sharp corners on the small rock fragments are abraded away, tending, along with the subsequent steps to be described to produce a finished product which is generally spherical in configuration.

Upon leaving the louver area **66** and passing upwardly and to the left into the ricochet chamber **71** along numerous paths, two of which are indicated by the arrows **73** and **74**, the small rapidly moving particles are hurled against a first impact plate **76**, or ricochet wall.

The impact plate **76** is disposed at a predetermined angle which, in this embodiment, is approximately 80 degrees. As impact occurs, additional comminution takes place, particularly of the larger particles, as well as a deflection off the wall **76**, as indicated by the arrows **78** and **79**, the angle of deflection being approximately equal to the angle of incidence, as appears in FIGURE 1. Further abrasion of any sharp corners also arises, from deflection off the wall **76**, as well as a spin which is opposite in direction to the spin imparted by the oppositely inclined louver plates **67**.

Following the deflection paths **78** and **79**, the particles strike against a second impact wall **81**. The wall **81** is so inclined (approximately 55 degrees in this embodiment) that in the main, the particles impact normally, or perpendicularly, against the second wall **81**. In this configuration, maximum shattering effort is imparted to the impinging particle and further pulverization is effected. Particles which are spinning at the instant of impact are also further rounded by abrasion of the corners against the face of the second impact wall **81**.

Upon reaching this stage, a great majority of the particles are in a finely pulverized and quite rounded condition. These small particles tend to move downwardly and toward the right, as in FIGURE 1, along a path **83** and into a swirl **84**, occasioned by a baffle **86**, where additional mutual abrasion and corner rounding takes place, the particles being jostled together in the turbulent air flow pattern.

In advancing beyond the baffle plate **86**, the air current follows the paths approximately as indicated by the arrows, **87**, **88** and **89**.

Such few fragments as were not reduced to very small size by the time impact with the second wall **81** took place, fall downwardly, since their mass is greater than the small particles following the route **83**, and drop into the path of the rapidly upwardly moving particles in the

routes **73** and **74**. Interference between the rising material and the falling material results in further mutual comminution and additional abrasion and rounding. Furthermore, the falling fragments are again swept upwardly into impact, as before, with the ricochet walls **76** and the second impact wall **81**. Particularly hard particles may be subjected several times to this cycle. Eventually, however, proper reduction in size is achieved and the flow continues, as previously described, into the pattern indicated by the arrows **87**, **88** and **89**.

This flow pattern is upwardly and in a right-hand direction, as appears in FIGURE 1, through a trunk **91**. The trunk is partially defined by a side wall **92** and end walls **90** which converge, as shown in FIGURE 2, into a substantially flat, conically shaped, fan housing **93**.

Disposed within the fan housing **93** is a fan **94** including a plurality of radial blades mounted on a vertical shaft **96** driven by a variable-speed electric motor **97**, the motor being mounted on the top of a hollow, circular cylindrical housing **98**. Encompassing the upper periphery of the fan **94** is a shroud **99**. The clearance between the fan **94** and the shroud **99** is very small, being on the order of 0.006 inch maximum, so as to prevent passage, through the annular clearance space, of any particles larger than 0.006 inch.

Rotation of the fan **94** serves to screen, or classify, the fine particles entrained in the air flow pattern indicated by the arrows **87**, **88** and **89**. The motor **97** is preferably 3 to 5 horsepower, and includes appropriate controls enabling the speed to be varied between 3600 and 4800 r.p.m. The blades of the fan, in this embodiment, are sixteen in number and measure approximately three inches in height and eighteen inches in diameter. By varying the fan speed, an extremely accurate sizing of the particles which can pass the fan is obtained. By increasing the fan speed, smaller sizes only can pass through the fan, in the manner indicated by the arrow **101**, and move upwardly through a discharge conduit **102**. A damper **103** interposed in the outflow line **102** provides still further control owing to the back-pressure capabilities afforded by the damper.

Beyond the damper, the air flow and the entrained, very finely comminuted particles, are led to a separator, not shown, of, for example, the conventional cyclone variety.

Particles entering the fan station **94** are subjected to violent buffering by the blades. Those larger particles which are incapable of passing through the fan blades to the discharge conduit, tend to move toward the upper right-hand portion (see FIGURE 1) of the trunk **91**, and form a flow pattern indicated by the arrows **106** and **107**, terminating in a turbulence indicated by the arrow **108** adjacent the inflow from the right-hand portion of the louver **66**. Here, the larger, rejected particles undergo abrasion not only by reason of the swirl **108**, but also by virtue of the powerful "sand-blast" effect of the inflowing air and entrained particles in the stream indicated by the arrow **74**.

Abrasion continues and in time the larger particles in the swirl **108** are captured by the blast **74** and are forced to follow the comminution cycle in the riochet chamber **71**, as previously described.

As a consequence of the numerous impingements between the rock material and the various hard metal surfaces, together with the impact of the rock particles, inter sese, pulverization proceeds to a very fine degree. Operational adjustments are readily effected by the damper **103**, and control of particle size is nicely achieved by varying the speed of the classifier fan **94**.

In addition, as previously explained in detail, the end product particles are, in the main, very close to being spherical in configuration. This latter result is of especial importance where the comminuted particles are to be wetted, so as to form the raw material for the manufacture of building bricks or fire bricks, for example. Much less chemical wetting agent is required where the particles are rounded than where they are jagged, owing, it is believed, to the fact that the exposed surface area of a sphere is a minimum with respect to the volume. An economy is therefore effected in that a much smaller amount of chemical additive is needed.

It can therefore be seen that we have provided a compact, yet durable and long lived device which can readily be adusted to provide a wide range of desired particle sizes of generally spherical configuration.

What is claimed:

1. A grinding mill comprising:

(a) a frame;

(b) a hopper on said frame;

(c) a substantially circular cylindrical hammer chamber mounted on said frame with the axis of said chamber in horizontal attitude, the lower walls of said chamber comprising a plurality of spaced and partially overlapping plates arranged in approximately tangential fashion, the spaced and overlapped portions of said plates forming a passageway for tthe approximately tangential flow of air from outside said chamber into the interior thereof; said hammer chamber further including a louvered portion located adjacent the top of said hammer chamber, and an arcuate crusher plate portion adjacent said louvered portion;

(d) a hammer rotatably mounted on said frame and located within said hammer chamber;

(e) a scroll casing mounted on said frame and encompassing said overlapping plate portion of said hammer chamber;

(f) blower means for delivering air to said scroll casing;

(g) an inflow conduit connecting said hopper and said hammer chamber;

(h) rotatable air lock means interposed in said conduit for the movement of material from said hopper to said hammer chamber without a counterflow movement of air;

(i) an impact chamber mounted on said frame above said hammer chamber, the lowermost portion of said impact chamber being defined by said louvered portion of said hammer chamber, said impact chamber further including a plurality of impact walls disposed at predetermined angles of inclination to receive the impact of material emerging from said louvered portion;

(j) fan means mounted on said impact chamber for withdrawing fine particles therefrom, said fan means including a plurality of rapidly rotating blades encompassed by a shroud spaced therefrom a short distance on the order of the diameter of the maximum desired particle size; and

(k) an exhaust conduit connected to the outflow side of said fan means.

2. The device of claim **1** wherein said hammer includes a plurality of radial arms mounted on a shaft journaled on said frame, the leading surface of each of said arms including an axially mounted, face-hardened plate portion arranged so as to strike the material emerging from said air lock means and said inflow conduit.

3. The device of claim **2** wherein said louvered portion includes a plurality of spaced parallel plates disposed at a predetermined angular attitude relative to said impact walls.

4. The device of claim **3** wherein said fan means includes means for adjusting the spacing of said shroud relative to the periphery of said fan blades, and means for selectively changing the rotational velocity of said fan blades.

5. A grinding mill comprising:

(a) a frame;

(b) a hammer chamber on said frame;

(c) means for introducing material into said hammer chamber;

(d) rotatable hammers in said chamber and rotatably mounted on said frame, said hammers being arranged to strike the material introduced in said chamber;

(e) blower means for delivering air into said chamber through openings in the walls thereof;

(f) a louver mounted on and forming a portion of the wall of said chamber, said louver being effective to guide a flow of air and entrained material particles in a predetermined direction;

(g) a plurality of impact walls arranged at predetermined angles to receive the impact of materials directed by said louver, said impact walls forming an enclosure adjacent said hammer chamber and communicating therewith through said louver; and

(h) an exhaust line connecting with said enclosure.

6. The device of claim 5 further characterized by particle classifying means interposed in said exhaust line for passing particles less than a predetermined size and for rejecting and returning to said enclosure particles larger than said predetermined size.

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WILLIAM W. DYER, JR., *Primary Examiner.*