

July 4, 1939.

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2,164,409

FINE GRINDING

Filed Aug. 27, 1937

2 Sheets-Sheet 1

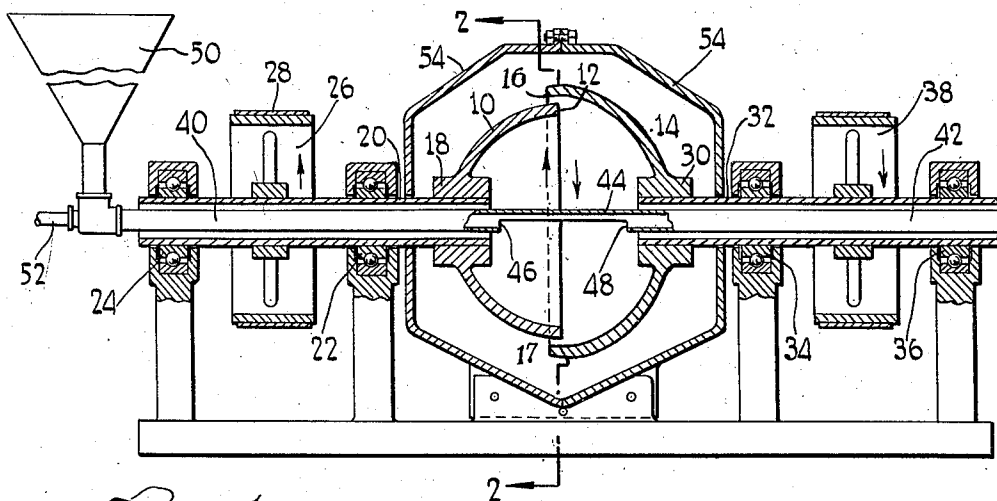


Fig. 1.

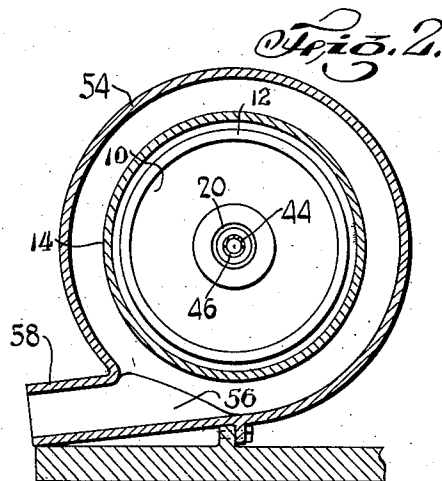


Fig. 2.

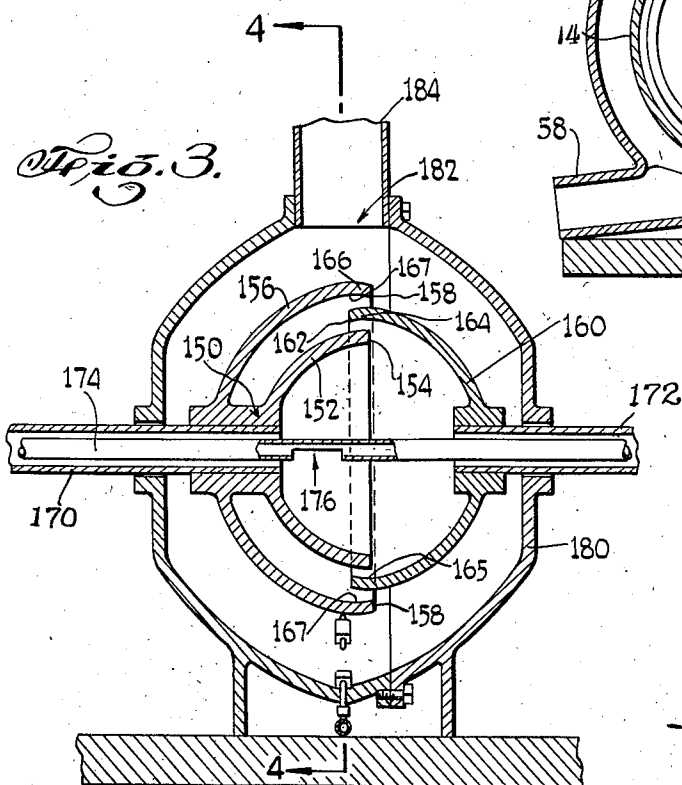


Fig. 3.

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2 Sheets-Sheet 2

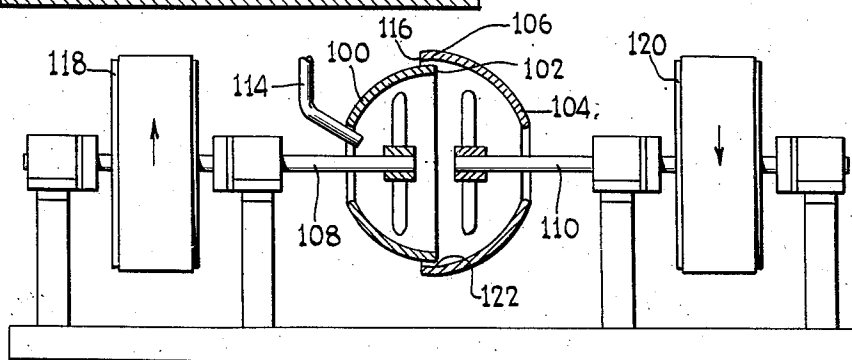
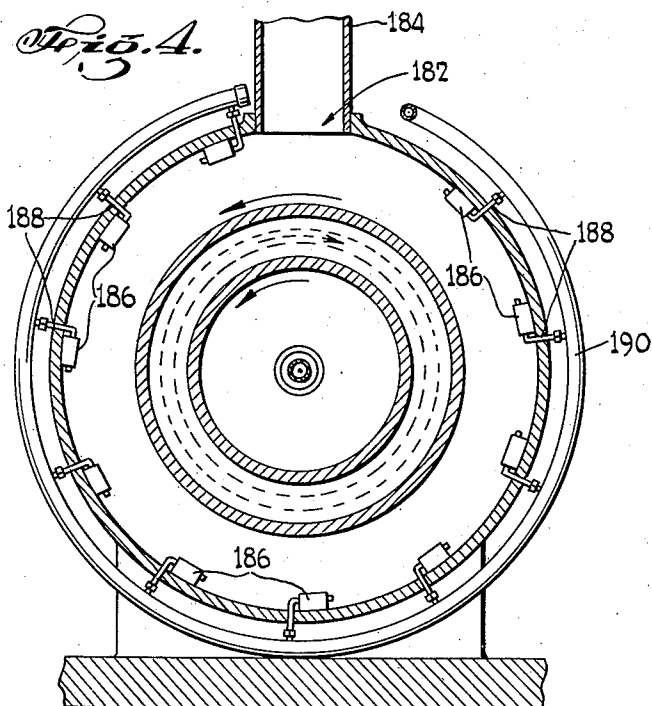


Fig. 5.

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FINE GRINDING

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7 Claims. (Cl. 83-46)

This invention relates to the grinding of comminuted solid materials. It provides improvements in the art of fine grinding which find important fields of use, for example, in the production of powdered pigments for paints, and plastic compositions, in the grinding, wetting, dispersing and homogenizing of pigments and other finely divided solids in admixture with liquids, and generally in the reduction of more coarsely divided solids into finely pulverized or powdered form.

Among the objects of the invention are to provide improved methods and apparatus which are useful for wet or dry grinding and for grinding materials into particles of extreme fineness; to provide methods and apparatus which grind solid materials by attrition and impact between the particles and in which the principal zones of attrition and impact are localized and controlled so that the grinding is effected with a high degree of efficiency and without substantial wear on the apparatus; to provide such methods of grinding which may be carried out with very simple equipment, together with means for carrying them out which are safe, easy and inexpensive to operate and capable of prolonged service without requiring replacement; to provide such improved methods and apparatus which accomplish a selective treatment of materials during the grinding operations by subjecting heavier particles to additional grinding while discharging particles of desired size. Other objects of the invention and advantages of particular novel features thereof will be apparent from the ensuing description.

To attain the above mentioned and other desirable objects I have devised methods and apparatus which subject a continuous stream or streams of the material to be treated, in either granulated or pulverized form and either dry or in admixture with liquid, to intense impact and attrition by moving particles of the material angularly in opposite directions at extremely high velocities and causing oppositely moving particles to collide. In its broader aspects, the method of the invention comprises the steps of accelerating material to be treated to very rapid substantially circular movement under radial confinement and advancing an annular wall of the material axially by centrifugal force, freeing the rapidly moving material from radial confinement centrifugally to project particles tangentially with respect to their previous paths of movement, and impacting the projected particles before substantial loss of their kinetic energy

into a mass of other particles of similar material which are caused to move rapidly in a circular path and preferably in an opposite direction. The improved grinding apparatus I have devised embodies simple and efficient means for performing these operations, together with features of construction which are specially adapted for carrying out the invention in accordance with preferred practical embodiments thereof.

In one embodiment of the invention the material to be ground or likewise treated is accelerated to very rapid circular movement and then projected tangentially into contact with a mass of similar material that is rapidly revolved in a circular path across the paths of projected particles. The mass receiving the projected material is constantly replenished thereby and constantly held in its circular path surrounding the zone of projection by centrifugal force, and treated material is discharged centrifugally from this mass as excess material accumulates therein. A particularly effective grinding wetting, or dispersing action or the like is obtained in this way, through the intense impact and attrition of the particles caused by substantially instantaneous positive reversal of the direction of movement of the projected particles; this action may be repeated as many times as desired without substantial variation in the nature of the apparatus and with no change in the manner of operating it.

Another important feature of this embodiment of the invention is that it may be carried out so as to subject heavier particles to prolonged grinding while discharging those of suitable fineness. This embodiment is especially adapted for the grinding of very fine materials, such as pigments for paints and the like, into powdered form. The travel of the charge is controlled so that the grinding action is effected almost entirely by tangential shear and impact between the particles, with little wear on the apparatus.

In another embodiment of the invention material to be treated, is subjected to successive treatments of the type mentioned above, without intermediate handling or recycling of the material, so that the fineness of the product or the thoroughness of treatment may be controlled by selection of the number of treating stages. Furthermore, various combinations of these treatments with still other grinding methods may be employed in accordance with the invention.

In carrying out my invention I preferably utilize a rapidly revolving axially divergent cup or shell and the action of friction and centrifugal

force to accelerate the wet or dry material to be ground or treated to a velocity which will provide the desired grinding action and thereupon centrifugally project particles of the material from the cup or shell into contact with other particles of similar material moving rapidly in an opposite direction in a path concentric with the path of said shell. The grinding of the material is effected by impact and attrition between the particles. The impacted particles accumulate to a certain extent inside a particle-retaining surface of another shell revolving in a direction opposite to the first shell, and from this the excess particles are continuously discharged by centrifugal force and then either removed from the apparatus or subjected to further treatment of a similar nature. In this way I accomplish thorough grinding of large volumes of material by the use of equipment which may be constructed simply and operated in a safe and economical manner.

Specific embodiments of the improved methods and apparatus are described in further detail below with references to the drawings, which show several illustrative forms of apparatus.

Figure 1 is a schematic view, in vertical section, showing parts of an arrangement of grinding apparatus suitable for use in one embodiment of the invention;

Figure 2 is a vertical section on the line 2—2 of Figure 1;

Figure 3 is a vertical section illustrating another form of grinding apparatus;

Figure 4 is a vertical section on the line 4—4 of Figure 3; and

Figure 5 illustrates the important parts of still another form of apparatus, showing parts which operate on the material to be ground in vertical section.

In the preferred embodiment of the invention, material to be ground is fed into a rapidly revolving cup or shell, accelerated to extremely rapid angular movement in this shell, and then projected tangentially against oppositely moving particles of similar material which are carried in another, coaxial shell and caused to travel in a substantially circular patch across the paths of the projected particles. A multiple grinding effect may be obtained by carrying out these steps several times in succession during travel of the material through the mill, and this embodiment of the invention may be easily adapted to selective grinding of the material.

The axially divergent shell or cup constituting the principal active element of the apparatus can be of various shapes or forms. Shells of frusto-conical form, or in the form of a spherical section or of a paraboloid or hyperboloid, may be used satisfactorily so long as constructed to retain a wall of particles in the path of material projected from an adjacent shell. Their size may vary within a wide range, depending upon the desired degree of grinding and the speed of revolution.

I prefer to revolve each shell and thereby to move particles of the charge material at peripheral speeds of several thousand feet per minute, for example, in excess of two thousand feet per minute. It will be understood that high peripheral speeds and correspondingly rapid movement of the particles of material to be ground may be obtained either by revolving larger shells at lower speeds, or vice versa.

The apparatus illustrated in Figures 1 and 2 comprises a pair of coaxially mounted, oppositely

facing shells or cups 10 and 14, the first having a substantially circular edge or lip 12 and the second an overlapping, concentric marginal portion 17 having an inside surface of greater radial distance from the axis of the shell than the edge or lip 16 in which it terminates 16. Each of the shells has an inside wall which diverges axially from the base of the shell toward its edge. The shells are mounted for rapid revolution with their edge portions in closely spaced relationship so as to utilize fully the kinetic energy of fine materials being ground therein. A suitable mounting means includes a hub 18 integral with shell 10 and fixed to a driven shaft 20 which extends through spaced bearing supports 22 and 24. Shaft 20 may be revolved in various ways, a simple and well known type of drive consisting of a belt pulley 26 on the shaft and a belt 28 passing over the pulley and arranged to be driven from a motor or other power source in a conventional manner. The illustrated mounting and driving means for shell 14 includes a hub 30, shaft 32, shaft supporting bearings 34 and 36 and a belt-driven pulley 38, which are arranged in the same manner as the similar parts just described with reference to shell 10, the only difference in the driving means being that the two pulleys and their connected shells are revolved in opposite directions. It will be understood that any of several known types of mounting and driving means may be used to keep the shells in coaxial, closely spaced relation and to revolve them rapidly in opposite directions.

Means are provided for introducing material to be ground into the inner shell only, or into both of the oppositely facing shells, during revolution of the same. In the embodiment of Figure 1, I use hollow shafts 20 and 32 and feed material into shells 10 and 14 by means of an elongated conduit comprising sections 40 and 42 extending through shafts 20 and 32, respectively, and connected together by a bridge portion 44 within the shells. Conduit section 40 opens into shell 10 at a point 46 intermediate hub 18 and the edge 12. Conduit section 42 opens into shell 14 at a point 48 intermediate hub 30 and edge 16. Thus material fed through each conduit drops into the corresponding shell at a zone away from the edge of the shell, and an unobstructed annular path for passage of the material is provided between said zone and the shell edge.

Conduit 40 communicates with a container, such as a hopper 50, in which a supply of material to be ground may be kept for introduction into shell 10. It preferably communicates also with a pipe or nozzle 52 arranged to propel a jet of fluid under pressure into the conduit and thereby to feed material from hopper 50 through the conduit. When using the improved method and apparatus for wet grinding a forced feed may not be essential; for dry grinding it is needed in order to ensure a uniform and regulated flow of material into the shells. The feeding of material into shell 14 may be carried out by use of the type of apparatus described above; hence further specific illustration of the feeding arrangement is omitted.

The shells or cups 10 and 14 are enclosed within a casing 54, which stops particles of material thrown away from the shells and enables easy collection of the material, for example, by means of a bottom outlet 56 and a discharge conduit 58.

The apparatus of Figure 5 is substantially the same as that of Figure 1. It comprises a pair of

of oppositely facing cups or shells 100 and 104, which are mounted coaxially for high speed revolution in opposite directions on shafts 108 and 110. Shell 100 diverges axially toward a substantially circular edge 102, and it is provided with an annular opening 112 adjacent its base for the introduction of material to be ground, for example, through feed pipe 114. Shell 104 may be of similar shape, but its diameter is greater than the diameter of shell 100. It has a lip portion 106 arranged concentrically and in spaced relation to edge 102 of shell 100. Portion 106 terminates in an edge 116 over which ground material is discharged into a suitable collecting housing (not shown). It will be understood that various housing constructions may be used, and that shafts 108 and 110 may be driven in various ways, for example, through belt-driven pulleys 118 and 120, respectively.

In the operation of this form of apparatus the material introduced into shell 100 is accelerated to rapid angular movement inside the shell and advanced radially to edge 102, from which it is projected tangentially at very high speed. The projected particles are impacted against particles of the same material carried in an opposite direction, in a concentric circular path, by lip portion 106 of shell 104. In this way particles projected from shell 100 in one direction are abruptly reversed in their direction of movement by impact and attrition with other particles, and a tangential shearing and grinding action of greater intensity than obtainable by impacting free particles in space results.

Another important feature of this embodiment of the invention is that it is adapted for discharge of suitably-ground material and retention of coarser material for further grinding. To accomplish this result I construct the overlapping lip portion 106 of shell 104 with an inside wall portion 122 of greater radial distance from the shell axis than the edge 116, so as to provide an annular well or recess across the paths of particles projected from shell 100. A body of the material is retained in this recess by centrifugal force during revolution of shell 104, and excess material is discharged centrifugally as this body builds up inside the level of edge 116. The discharged material, however, is the lighter, more finely ground material. Coarser, heavier particles which have survived the initial grinding action are selectively pressed into the recess by centrifugal force, and they act as a grinding medium for particles subsequently projected from shell 100, until reduced to a fineness resulting in their displacement by additional heavier particles.

The forms of construction illustrated in Figures 3 and 4 utilizes principles involved in the construction of Figure 5, but it differs from the latter in that it subjects the stream of material passing through the apparatus to successive grindings and includes special means for treating dry material discharged from the grinding mill. A series of cups or shells is arranged with each shell facing toward an adjacent shell which revolves in an opposite direction, and edge or lip portions of the shells overlap so that material introduced into the innermost shell is projected into contact with material carried in an opposite direction by the next adjacent shell, thence, after acceleration to rapid movement, in the latter, into contact with oppositely moving material in still another shell outside of but adjacent the latter. The operations may be repeated any desired number of times, and they may be performed in a man-

ner to ensure prolonged grinding of coarser and heavier particles, as described above in connection with Figure 5.

The construction illustrated in Figures 3 and 4 includes two principal rotary members 150 and 160, the former comprising a pair of concentric, axially divergent cups or shells 152 and 156, terminating in substantially circular edges 154 and 158, respectively, and the latter, in this instance, consisting of a single, axially divergent cup or shell terminating in an edge 162. A lip portion 164 adjacent edge 162 of member 160 overlaps the edge 154 of shell 152, and it in turn is overlapped by a lip portion 166 adjacent edge 158 of shell 156. Member 150 is secured to a shaft 170, member 160 to a shaft 172. As described with reference to Figures 1 and 2, both shafts are hollow, and a feed conduit 174 passes through the shafts to permit the introduction of material into shell 150. To this end, conduit 174 is provided with an opening 176 intermediate the base and the edge 154 of shell 152, so that a stream of material to be ground may be introduced into the shell at a zone intermediate the base and edge of the shell by feeding the material to opening 176 from either end of the conduit. The revolution of rotary members 150 and 160 in opposite direction may be effected in any of several well known ways, for example, by the use of belt-driven pulleys as illustrated in Figure 1.

As an additional feature of the invention, I provide special means for collecting material discharged from the revolving shells and for subjecting this material to additional impact and attrition while positively conveying it onward to further processing. It will be understood that this means is particularly adapted for use in dry grinding and that a housing of the type illustrated in Figures 1 and 2, or of any other suitable type, may surround the rotary grinding elements when using the apparatus for wet grinding. In Figures 3 and 4, the rotary members 150 and 160 are enclosed within a casing 180 which is mounted on a foundation in any desired manner. The casing is provided with an outlet port 182 communicating with an off-take conduit 184 at the top. To advance material discharged from the outermost shell 156 to the outlet and to grind it further during movement toward the outlet, a series of tangential jet nozzles 186 is arranged around the inside wall of the casing in the vertical plane of greatest circumference. Each of the jets 186 is connected by a tube 188 with a common header 190, through which gaseous fluid, such as air, is forced under high pressure. The jets act collectively to create a strong circulation of fluid which travels around the outside of the rotary members 150 and 160 and passes out of the casing through the outlet 182. Individually they impart a rapid change of movement to particles of dry material discharged adjacent each nozzle from shell 156, and project the particles from the casing wall into the circulated stream where they impact with other particles in the stream and are simultaneously conveyed to the outlet 182. The material leaving the casing through conduit 184 conveniently may be subject to a cyclone treatment in order to separate particles of different grades of fineness.

The operation of the apparatus shown in Figures 3 and 4 is substantially the same as that of Figures 1 and 5, although the grinding action may be more intense. Material introduced into shell 152 is accelerated to rapid angular movement in this shell and then projected over edge

154 into contact with oppositely moving material retained on lip portion 164 of shell 160. The collision of the particles results in a strong shearing action and effective grinding. After the material received in shell 160 has been reversed in its direction of movement and brought to a high speed within shell 160, it is projected over edge 162 of the latter and thence into contact with rapidly and oppositely moving particles retained on lip portion 166 of shell 156, whereupon the same type of grinding action is repeated. From the edge 158 of shell 156 the ground material is discharged into casing 180, where it is propelled by fluid jets from nozzles 186 into an annular stream surrounding the shells and impacted and subjected to further attrition during passage to the outlet port. The action of the revolving shells in this form of construction may be easily adapted for selective treatment of the particles, as in the construction illustrated in Figure 5. Thus for this purpose lip portion 164 of shell 160 is provided with an inside wall portion of maximum radius adjacent but inside edge 162, so as to form a recess or well for the retention of coarser, heavier particles due to the action of centrifugal force, and the lip portion 166 of shell 156 similarly is formed with an inside recess or well 167 adjacent edge 158.

It will be readily understood to be an important feature of my invention that it permits an intense and effective grinding action to be obtained by the use of simple and durable apparatus. The cups or shells forming the principal parts of the grinding mill involve no complicated structure and may be provided economically. Their operation merely requires the provision of means for imparting revolution at high speeds in opposite directions.

In carrying out the method of my invention the material undergoing treatment is reduced to an extremely fine state of division, and the grinding action is particularly effective because the zones of impact and attrition between the particles are localized so that the particles collide while retaining their maximum energy and so that grinding of all the particles is assured. Another important advantage of the invention is that the grinding medium consists of particles of the material undergoing treatment. There is little wear on the shells themselves, which may be used indefinitely without requiring replacement.

While the invention has been described with particular reference to fine grinding, it is to be understood that it may be used in the grinding of comminuted solids of various grades.

Apparatus of the type illustrated in which the particles are projected from an inner shell against material carried coaxially by an outer shell and are subjected to selective treatment and discharge in the latter, may be used to advantage in the grinding and classifying of material by revolving the outer shell in the same direction as the inner shell but preferably at a differential speed.

The improved method may be carried out by the use of various forms of apparatus, and it is in no way restricted to details of construction illustrated in the accompanying drawings. Numerous variations may be made in the shape of the cups or shells, the manner of mounting and revolving them, the manner of feeding material into the shells and of discharging and collecting the material, without departing from the inven-

tion, which should be construed broadly in keeping with the spirit of the specification and the requirements of the claims.

I claim:

1. The method of fine grinding which comprises feeding material to be ground into a rapidly revolving shell having an axially divergent wall which terminates at a free edge, accelerating the material to movement at high speed in a direction of movement of the shell and centrifugally advancing it axially toward said edge, projecting particles of the material over said edge and tangentially from their previous paths of movement, impacting projected particles inside an adjacent surface rapidly revolving coaxially with but in a direction opposite to said shell, maintaining a layer of coarser material on said surface and in the paths of projected particles by centrifugal force and centrifugally discharging ground material therefrom.

2. The method of fine grinding which comprises accelerating particles of material to be ground to confined angular movement at a speed of several thousand feet per minute, freeing the moving particles from confinement, immediately impacting the freed particles into a mass of similar material moving in a substantially circular path in an opposite direction at a speed of several thousand feet per minute, holding such a mass in said path by centrifugal force, and centrifugally discharging ground material from the mass.

3. Grinding apparatus comprising a plurality of substantially coaxial hollow shells arranged with each shell facing opposite an adjacent shell and with their adjacent edge portions in overlapping relation, means for revolving the oppositely facing shells in opposite directions at high speeds, means for introducing material to be ground into an overlapped shell, and means inside the edge of an overlapping shell operative by centrifugal force during revolution thereof to retain a body of particles moving in a circular path across the paths of particles projected from the edge of an overlapped shell, the overlapping shell being formed so as to discharge ground material past the edge thereof by centrifugal force.

4. Grinding apparatus comprising a plurality of coaxial hollow shells arranged with their adjacent edge portions in overlapping relation, means for revolving said shells at high speeds, means for introducing material to be ground into an overlapped shell, an overlapping shell having inside the edge thereof an inside wall portion of greater radial distance from its axis than its edge, and in the plane of the edge of the adjacent overlapped shell, whereby to retain by centrifugal force a body of the less finely ground particles moving across the paths of particles projected from the edge of said overlapped shell, each overlapping shell being so formed as to discharge ground material past the edge thereof by centrifugal force.

5. The method of fine grinding, wetting, dispersing or the like which comprises accelerating a stream of material to be treated to rapid angular movement and imparting an axial component to such movement by centrifugal force to advance the material in spiral paths, freeing rapidly moving particles of the material from said paths centrifugally to project the particles tangentially therefrom, rapidly moving a mass of the material so projected in a circular path closely surrounding the zone of projection to

impact the particles projected into said mass, constantly holding such a mass in said circular path, by centrifugal force, and centrifugally discharging treated material from the mass.

- 5 6. Grinding apparatus comprising a plurality of substantially co-axial hollow shells arranged with their adjacent edge portions in overlapping relation, means for revolving the adjacent shells at high speeds, means for introducing material to be ground into an overlapped shell, each overlapping edge portion having a recessed inner surface of greater radial distance from the shell axis than its edge whereby to retain a moving mass of the material in the path of particles projected from the edge from the adjacent overlapped shell, a casing surrounding said shells to collect particles discharged therefrom, said casing having an outlet port, and fluid jet means in said casing to project the particles into a stream and convey them to said outlet port.
- 10
- 15
- 20

7. Grinding apparatus comprising a plurality of substantially coaxial hollow shells arranged with their adjacent edge portions in overlapping relation, each overlapping edge portion including a discharge edge spaced radially from the overlapped edge portion of an adjacent shell, means for revolving the adjacent shells at high speeds, and means for introducing material to be ground into an overlapped shell, each overlapping edge portion having a recessed inner surface of greater radial distance from the shell axis than its discharge edge whereby to retain by centrifugal force a moving mass of the material in the path of particles projected from the edge of the adjacent overlapped shell and to discharge treated material past its discharge edge by centrifugal force.

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