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APPARATUS AND METHOD TO COMMUNITE SOLID PARTICLES IN GAS

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The invention described herein may be manufactured and used by or for the Government, for governmental purposes, without the payment to use of any royalty thereon.

This invention deals with comminution of finely divided solid particles by means of highly turbulent gas. It relates to improved apparatus and methods for applying such particles to turbulent gas to break them into extremely fine dusts.

Heretofore currents of air have been used quite commonly to separate or classify particles of one size or weight from another and even to grind the particles to some extent. Jets of air in prior grinding mills or colloid mills rub solid particles against each other or else throw the particles against abutting elements of the grinder. Often the gas recirculates the material to be ground as it is blown around in the apparatus. This recirculation indicates defects such as insufficient grinding and such as classification or great variation in particle size. Gas currents become less effective as particle size decreases and as lightness of the material increases. The use of gas in burdensome quantities has heretofore been necessary to obtain notable reduction in size. Such dilution in turn introduces difficulties in separating fine particles from relatively large volumes of gas, requiring elaborate filtering systems. Consequently jet grinding or, in general, comminution depending on air currents, has been of limited use to reduce solid particles to extremely small size, as for example sizes less than about 20 microns.

Another problem evident in comminuting solids, even with gas jets or gas streams, is the problem of heat. Heat develops when a particle is shattered by impact. The intensity of this heat may be considerable, at least locally. With some substances avoidance of local temperature increase becomes critical. Many substances deteriorate or are destroyed by the heat developed locally in pulverization. A suitable example is penicillin, for which some types of grinder are entirely unsuited and even jet-type machines are inefficient to conserve antibiotic activity. Many substances other than pharmaceuticals are even more sensitive or labile, so that the heat problem is burdensome and in some cases is critical.

In pulverizing, deteriorating effects result also from oxidation in some instances, or local static electricity in others, or even from mechanical shock in others. Such effects are difficult to avoid because they develop within the individual particles that are affected.

A broad object of this invention is to comminute small solid particles effectively and with minimum deleterious effect, even to extremely fine particles or the order of 30 microns or less.

A subsidiary object is to accomplish such pulverization that a large portion of these fine particles are of any desired size and are of substantially uniform size. Another object is to produce these fine dusts, with relatively small volumes of gas, so that these dust particles can be readily recovered.

A further object is to obtain substantially homogeneous products in pulverizing solid particles of differing qualities. This is important with pharmaceuticals. For example, vitamin mixtures must be uniform so that uniform dosages may be capsulated. Not only must segregation of some solids from others be avoided, but deterioration of some constituents also must be prevented when rendering to small sizes. Many colloid mills are deficient in these respects. To obtain uniform products of ultra-fine solids, has formerly been extremely difficult, even practically impossible without altering the activity of delicate components.

Various other advantages of this invention will become apparent as exposition of this invention proceeds. It will be understood that suitable equivalents are contemplated in the illustrations and the definitions of the attached claims.

In the attached drawing illustrating a preferred embodiment of this invention, Figure 1 shows generalized apparatus diagrammatically, particularly including a smooth-faced, high-speed comminuting wheel 24. Figs. 2–6 inclusive show various illustrative forms of rotor peripheral face and annular operating zone. In these figures the operating zone is shown in fragmentary view somewhat enlarged relatively to the rest of the structure.

This invention applies extremely turbulent gas to solid particles to tear the particles into very fine dusts. The term gas as used herein is intended to include vapors. Avoided are mechanical impact elements; even impacts of particles against each other are minimized.

The apparatus shown in the drawing illustrates various principles of structure and of operation under this invention. The apparatus is designed to produce extreme turbulence in a shallow comminuting zone of gas 22. Means are provided to conduct small solid particles through this violently turbulent space for comminution, but with relatively little volume of gas. Many benefits of
the invention are made possible by moving a surface bounding the comminution zone at speeds of about 100 to 700 feet per second to produce turbulence. This surface is preferably smooth, but the arrangement diagrammed is effective to pulve-
risate to very fine dusts.

The preferred assembly of the apparatus illustrated in Figure 1, includes a tank 30 for supplying gas under pressure in communication with a feed valve 18, pressure control means 21, and inlet conduit means 22. Connected to the inlet conduit means 22 and by means of flexible hose in upper and lower portions 35, is the agitating chamber 11 provided with an upper inlet hop-
per 32 having removable and sealable closure means 28. Chamber 11 is mounted for reciprocal movement as on the rollers 24 or other suitable support, and is agitated as by means of the eccentric mechanism 25 driven by suitable motor not shown. The lower portion of the agitating chamber 11 is provided with an outlet hopper 33 which is connected by a lower hose portion 36 to the inlet tube 16. Inlet tube 16 communicates with the housing 23 of the grinder 40 at the in-
let port 42 and is in communication through the zone 22 with the outlet tube 13 which is connected to the housing 23 at the outlet port 45. The latter end of outlet tube 12 is in sealed communication with the trap chamber 14.

Although various dust recovery means may be used a very important advantage of this invention is that the dust produced, though ultra-
fine, may be recovered satisfactorily by simple trap 14 in cooperation with bag filter 15 when required. This advantage results from the ex-
ceedingly low volume of gas required by the present invention to convey the solid material through the mill and into the dust recovery ap-
paratus.

Trap chamber 14 is joined by connection 36 to the filter housing 38 and is in communication with the filter bag 15 by means of the conduit 37. The filter housing 38 is connected to the outlet tube 39 and the outlet control valve 17.

The grinder 40 comprises the housing 23 in which the wheel 24 is carried by its shaft 25 for high speed rotation in housing bearings 26 and 27. Shaft 25 is inoperative with the pulley 28 which in turn is driven by a main drive motor not shown. The wheel 24, housing 23, and main drive motor are designed to maintain wheel speeds at any desired peripheral speed up to 700 feet per second or more.

The peripheral surface 21 of the wheel 24 is positioned so that there is a zone 22 between the housing 23 and the surface 21, and so that there is a side clearance 16 between the sides of the wheel 24 and the sides of the housing 23. The sides of the housing 23 may be tapered toward the periphery of the wheel or they may be made substantially normal to shaft 25 as shown in Figure 1. The whole unit 40 may be submerged in a tank 50 containing a temperature controlled environment as a preferred means for maintaining predetermined temperature control throughout the operation of the unit 40. Bath 41 is diagrammed in Figure 1 as surrounding pulley 28. This can be used for a gas bath but when bath 41 is liquid, pulley 28 would preferably be arranged to operate outside of tank 89.

Surface 21 is curved cylindrically, but may be curved otherwise. Shaft 25 is supported mas-
ively in housing 23 and in high speed bearings 26 and 27 arranged to be driven by direct connection from motor or turbine, not shown. Speed of wheel 24 may also be stepped up, as by pulley 28 from a driving pulley. Instead of a pulley drive any suitable, smooth-running driv-
ing means adapted for high speed may be used. Emphasis is placed on solid mounting and sturdy means to rotate wheel 24 at speeds of high speeds. Those skilled in the art may select various smooth-running driving means.

Clearance zone 22 between moving face 21 and housing 23 is of relatively small depth, of the order of 0.01 inch to 0.02 inch being suitable for producing a range of about six microns individual diameters when peripheral speed of wheel 24 is between 200 and 500 feet per second or about 0.03 inch for producing dust averaging below about 20 microns particle size when the perip-
eral speed of wheel 24 is of the order of 100 to 300 feet per second. A portion of the wheel face 21, housing 23 and gas turbulence zone 22 is shown broken away and enlarged for clarity. Spacing up to maximum of about 0.05 inch is suitable.

The optimum of clearance depth of zone 22 de-
pends upon the character of the material to be ground, the degree of subdivision desired and the rate of production desired. For any fixed clearance depth, and for a given material the peripheral speed of the wheel 24 and/or the rate of feed of solid will determine the degree of sub-
division obtained. For example if a material having low internal cohesion, such as graphite, is to be ground to medium fineness in which the particles will have an average order of 30 microns, the clearance depth of zone 22 may be as large as 0.05 inch, with the peripheral wheel speed of wheel 24 as low as 100 feet per second, and a feed rate of 50 lbs. of graphite per hour. Finer subdivision will be obtained by increasing the wheel speed or reducing the feed rate both. Likewise, if it is desired to grind a harder material such as gyspum to a high degree of fineness such that the particles would have an average diameter of 2 microns, efficient condi-
tions would be a clearance depth of zone 22 of 0.015 inch, a peripheral wheel speed of 400 feet per second and a feed rate of 15 lbs. per hour. These conditions are dictated by the circum-
stances that the intensity of the turbulence pro-
duced in zone 22 is increased either by increase in pulley speed or drive speed at a given clearance depth in the clearance depth of zone 22, or both. Also, the length of time which a given particle re-
mains in zone 22 and hence is subjected to the action of turbulence, depends upon the rate of feed. The longer this time, the smaller the size of the comminuted particle and the more nearly uniform will be the sizes of the particles. These intensity and time factors are independently controllable and, therefore, high efficiency of comminution of a wide variety of materials may be attained by adjusting these controls in ac-
cordance with the disclosures set forth.

Operation

Bath 41 is conditioned and maintained at the desired temperature in a manner well-known in the art. Tank 50 is charged with the compressed gas or vapor desired and is set so that pressure and delivery can be controlled by means of valves 18 and 11 and gage 31. A wheel 24 having the proper dimensions to provide zone 22 with the dimensions desired is installed in mill 40 and valves 18 and 17 are regulated to maintain the desired pressure and flow within the mill 40, as described herein. Main motor drive is adjusted to impart the desired R. P. M. as indicated. Pulleys 36 and main motor drive to pulley 28 are ener-
gized.
The particles to be comminuted are introduced into chamber through hopper, and cover is sealed back in place and valves 10 and 11 are next shifted to allow gas to flow through the gas stream carrying the newly comminuted particles. Outlet conduit or duct 13, into trap 14 which removes any part of the newly comminuted particles, through tube 37 and into filter bag 15 which removes the remainder of the newly comminuted particles, through tube 39 and exhaust valve 17. Subsequently, the motors are stopped, and all parts are reversed. Parts 42 and 43 are removed from filter chamber 38 and trap 14. This sequence continues until the comminuted particles are removed from the trap and filter bag 15.

**Example I**

A specific example will emphasize features of this invention shown in Figure 1.

Cylindrical wheel 24 of high tensile strength, about 3.25 inches in diameter, was attached tightly to a steel shaft 25 of 3/8" diameter. The wheel 24 had a peripheral face 21 nearly one inch wide. The steel shaft was sturdily mounted in well-fitted and accurately aligned and well-lubricated high-speed bearings 26 and 27 connected to an air-driven turbine motor which rotated the wheel 24 at any desired speed up to 40,000 or more R. P. M. This is a relatively new order of speed in rotating surfaces. Such speed requires a high degree of care in design and of world-wide skill to avoid rupturing the machine itself. These speeds provide many new and useful results.

The wheel 24 and its shaft 25 and the housing 23 were made of steel in order to obtain the required tensile strength. But other materials may be utilized. For example, wheel 24 may be composed of fiber glass cloth, laminated and resin-bonded to obtain a wheel having a high ratio of tensile strength to density. The peripheral face 21 is relatively smooth. The width of this peripheral face may bear a ratio to diameter of the wheel 24 from about 1 to 0.5 to about 1 to 6 for most practicable purposes.

The peripheral face 21 of the rotating member is coated with a lapped surface. Such surfaces accomplish unusual results at the high speeds utilized in this invention. For example, face 21 of steel was brought to a matte or satiny finish and comminuting effects were studied of the resulting turbulence of air in space 22 at the described ultra speeds of wheel face 21. This was a satisfactory and useful surface, for when solid particles were fed through the turbulence chamber 22 the particles were comminuted to an extremely fine dust. Then face 21 was polished with 400 grit emery paper. The polished surface was etched with an electro-deposited chromium to produce a hard, non-corrosive, substantially highly polished finish. Solid particles fed to zone 22 when this surface was used were comminuted to an equally fine dust. Moreover, when the solid was very labele, such as penicillin, the antibiotic activity of the resulting dust was equal to that of the input material. Therefore, penicillin has lost in antibiotic activity on being comminuted. Production of highly uniform dust of less than about 0.01 inch deep on the peripheral face of wheel 24 tend to deteriorate the quality of such solids as penicillin because of the local heat effects of impact at these tremendous speeds. Moreover, such roughnesses tend to cog and to unbalance the wheel. This is true with waxed substances such as DDT insecticide. Consequently a surface of a high degree of smoothness is preferred for the moving face 21 of this apparatus. At the ultra-speeds of this invention such a surface produces very high turbulence of gas in the peripheral clearance space 22.

The sides of wheel 24 and of housing 23 usually are straight to form straight clearance between them. Impact may be minimized by tapering this clearance slightly and by making such space 26 somewhat wider between walls than the peripheral clearance 22. The location and size of ports 42 and 43 and conduits 10 and 13 may vary. With the wheel discussed in the example, the inlet port 42 and outlet port 43 were a half inch in diameter, with their centers located 3/4 inch below the peripheral face 22. One inlet port and one outlet port suffice, though various numbers and arrangements are useful also. Ports 42 and 43 connected respectively to conduits 10 and 13 each of 3/8" internal diameter. Outlet duct 13 communicates with outlet valve 17.

**Example II**

As an example of processing very labile material under this invention, comminution of penicillin is described. Feed chamber 11 was charged with dry, granular penicillin of size passing a 20 mesh sieve. A source of compressed, dry nitrogen was connected to gas inlet 12 through valve 18 and pressure control indicator 21. Valve 18 was adjusted so that pressure in conduit 12 was 3 p.s.i.g., and the gas flow was throttled to 0.5 cubic feet per minute by valve 17 in the discharge line 33. Discharge line 13 was connected to a conventional trap and bag filter. The wheel 24 of which was 3.25 inches in diameter, and 1 inch wide was brought to a peripheral speed of 500 feet per second, corresponding to 35,000 R. P. M. The feed chamber 11 was vibrated to cause penicillin to flow into the grinder 43 at the rate of about 20 grams a minute. The comminuted product was collected readily in the trap 14 and bag filter 15. The output product was as active antibiotically as the input material. The mass median diameter of the particles produced was 6.3 microns in this example, while the frequency distribution of diameters was such that 95 percent of the particles were of diameters less than 4 microns.

Certain observations may emphasize the important advance in the art resulting from this novel pulverization by turbulence of gas at a surface moving at ultra speeds in a comminution chamber as illustrated at 22 and described herein. First, only relatively little gas flows through the machine. This flow need by only sufficient to carry the particles through the machine and the assembly described. For example, the comminution required only 0.5 cubic feet per minute of gas through-put, instead of the order of 100 cubic feet per minute of gas for comminution by gas jets. Since this volume of gas is small, difficulties of recovering fine dust are minimized. Those familiar with bag filters or with collic-
tion of dusts will appreciate the importance of being able to use a bag filter at all in this case, or of being able to substitute other collecting means if desired.

Another advantage of the small amount of gas deserves considerable emphasis. The flow of the small amount of gas can contribute only insignificantly to the turbulence of gas in the machine. The work done on the suspended material being comminuted is governed by the mechanical energy supplied to the rotating member which produces the required turbulence. This energy is readily controlled. Therefore, a high degree of control of the processing is readily obtained. This avoids the lack of control in attempting to obtain gas turbulence by release of large quantities of costly compressed gas.

A further advantage of small through-put of gas is that it permits materials containing one or more volatile constituents to be processed without significant loss of volatile matter. Different batches of such materials can be blended or be comminuted together to obtain a product of uniform composition, while economic loss of volatile constituents carried away by exhaust gas is minimized.

The small volume of gas through-put permits even costly gases to be used as the atmosphere in which the solid particles are carried through the machine. Thus materials herefore prohibitive become economical. For example, use of nitrogen in small quantity makes feasible the comminution of protein material such as egg albumen that would deteriorate in air. The finer the particle is pulverized, the more surface is bared and the greater the oxidation that would occur in air. Furthermore, with materials that require dry gas, or any given humidity, or require pure oxygen, or can utilize any special gas, the novel low gas through-put makes feasible the use of such gas in the present invention. An additional further advantage is that the pressure at which comminution occurs can be varied readily or can be held at any desired level, simply by adjusting valves 16 and 17. Or similarly, pressure less than atmospheric can be obtained by reducing or varying the flow of compressed gas from tank 30 by means of inlet gas valve 16 and exhausting gas through the outlet 17. Combinations or alterations of these adjustments of valves 11 and 18 produce suitable differential pressures within the pressure range of sub-atmospheric to super-atmospheric.

Another advantage of this invention lies in its ease of temperature control. When the apparatus is placed in a thermally controlled environment, such as in a bath or a liquid bath 41, conduction of heat occurs readily through the housing that confines the working area. Since the working zone 22 is of small cross-section, such heat control extends readily to the particles being comminuted therein. Moreover, this control is both sensitive and substantially complete because of the extremely high turbulence in the working area. Precertained temperatures of the particles being comminuted thus are readily maintained.

To protect individual solid particles against local heating from chance impact along the side of the wheel 24, side clearance 16 greater than that of the intercommunicating peripheral comminution zone 23 avoids deadstick throw or sweep of particles outwardly. This also minimizes impacts against the housing 23 and augments the effect of locating a particle near the periphery 21 to further reduce this throw.

The present invention also permits the compressibility of the fluid to impede the outward throw of the particles. This cushioning action also reduces mechanical shock and local heating of particles. Centrifugal densification of gas outwardly tends to minimize movement of the solid material except in the narrow zone of turbulence at the super-speed surface 21. Consequently reduction to super-fine colloidal dust is substantially confined to the forces of the turbulent gas itself.

Comminution occurs in the space between the rotor periphery 21 and the housing 23 by action of the turbulent gas on the individual solid particles. To be distinguished from impact of particle against particle, this rendering apart by forces of gas acting either in shear or in tension. Such rending apart is evidenced by the fact that with this invention the lower the ratio of solids to gas the finer the comminution obtained. The entire arrangement described makes possible substantially isothermal conditions in reducing solid particles to dust.

It becomes apparent from the foregoing that the present invention provides independent regulation of turbulence, temperature and pressure within the turbulent comminution zone 22, as well as of particle feed.

The effects of static electricity are also avoided. The intimate contact of processed solids with electrically conducting parts of the machine provides adequate conduction to eliminate accumulation of static electricity. Not only does this reduce hazards of explosion, but facilitates separation of such fine particles from the effluent. Mutual repulsion, and consequent suspension, of dust particles herefore worked against collecting super-fine, colloidal dusts.

Size of particles fed to this apparatus varies with conditions and materials. In general, feed size of the order of 100 microns or less is desirable, but even as large as 30 mesh particle feed is suitable with some materials. Particles are readily reduced to less than 20 microns diameter by this invention.

Though this invention is not limited by theory, it appears from research that the speed of the moving peripheral surface 21 and the narrow cross-section of the working space 22 produce exceedingly high turbulence of gas. It also appears that the many high velocity gradients, corresponding to high energy gradients, subject a particle to many intense and changing stresses in shear and intension. When the stresses exceed the cohesive force within the particle, the particle subdivides. Evidently at comminuting speeds of this apparatus, the gas in the peripheral working space is not simply carried along with the moving surface but breaks up into local and individual rotating masses or "rollers." These spin on their individual axes of rotation at much higher rates than when the wheel surface, dependent on their own effective diameters relatively to the rotated wheel, as with gears. Solid particles caught in the spin of these whirling gases rotate at tremendous angular rates to develop disrupting centrifugal forces.

The rate of rotation of the wheel 24, determining the degree of turbulence of the gas and consequently the particle size obtained, varies with different peripheral clearances. Small clearance and high speed subdivide solid particles most effectively. Rate of flow and drift through the
apparatus 40 also affect particle size and size-uniformly of product since lowering the feed-rate increases duration of time to obtain small-particle production. In general, peripheral surface speeds of the wheel above one hundred feet per second are suitable for comminuting solids to very fine particles. Peripheral clearance may be from about 0.01 inch (0.05 millimeter or 250 microns) to about 0.05 inch. In Example 1, when the wheel was 2.55 inches in diameter and about one inch wide at its face, a feed rate of about 20 grams a minute of solid penicillin suspended in gas flowing about 0.5 to two cubic feet of gas a minute was about optimum. These conditions of course vary with different materials and sizes. Too fast a feed clogs the machine and this clogging point is readily observed. The apparatus of Example I showed a rather sharp beginning of comminuting characteristics at about 12,000 R. P. M. (or a peripheral speed of 170 feet per second) increasing rapidly to about 18,000 R. P. M., and increasing slowly thereafter to 40,000 R. P. M.

At the speeds used in this invention, it is essential that all details, workmanship and design be of highest quality so as to avoid rupture in the machine from the centrifugal forces involved. Stresses may develop that exceed strengths of known materials, particularly if unbalanced parts are rotated at these speeds. Projections of various sorts tend to increase unbalance, for the order of magnitude of these speeds and stresses far exceeds those of prior comminuting machines. Consequently, the smooth, satin-surfaced cylindrical wheel as described herein is required to obtain the necessary high-speed surface.

The apparatus of the present invention has been used successfully for comminuting a variety of solids. From this use it has been found that the processing of these materials has fallen within the following preferred ranges: In the comminuting zone 22, a pressure range of from 5 to 5 atmospheres absolute pressure was found desirable; the bath or environment zone at 61 was maintained at temperatures ranging from -10°C. to 50°C.; the particle feed delivered by agitator 38 to hopper 33 is preferred at rates ranging from one gram of solid particles per minute to 30 and more pounds per hour; the rate of feed for gas from source 39 to port 42 is preferred at a range of from 2 to 15 cubic feet per minute; the depth or thickness of zone 22 is preferred not to exceed % of an inch, the optimum thickness being from .01 to .03 of an inch; the peripheral face 21 is preferably provided with a width from ¼ to two times the diameter of wheel 24; and the peripheral speed of wheel 24 is preferred within the range of from 100 to 700 feet per second.

Comminution at temperatures well below freezing increases the brittleness of certain solids and thereby increases the rate at which they may be subdivided. Other solids, however, are comminuted more efficiently in environments maintained at the above-mentioned higher temperature ranges. Environments excessively dry or excessively humid are also sometimes desirable for the comminution of certain solids. Various gases or mixtures of gases have also been found desirable for other solids. All solids are easily and quickly recovered after comminution by the simple recovery means exemplified at 14 and 33.

The depth or thickness of zone 22 may be maintained at predetermined distances by varying the diameter of wheel 24; or by inserting thin liners of sheet material in zone 22 on the underside of housing 23 adjacent to surface 21; or by the use of a conical surfaced wheel in place of cylindrical surface 21. This conical wheel is adjustable along its axis and operates in a conical rather than in zone 22, as shown. Combinations of these means, as well as other means of regulation, may also be used if desired.

This invention and the manner of making and using it is hereinafter described in full, by conciseness and exact terms so that those skilled in the art may make and use it. Its principle and preferred mode of application have been explained.

However, it is intended that this invention includes all modifications and embodiments within the spirit and scope of the appended claims.

I claim:

1. The method of comminuting finely divided particles into substantially smaller particles, comprising agitating finely divided particles in a gas under compression, thereby suspending said particles in said gas, passing said gas with said particles in suspension through a narrow annular turbulent zone having a width not in excess of % of an inch and being bounded on its outside by a rigid stationary wall and on its inside by a hard smooth surface moving at a speed of not less than 100 feet per second.

2. A process for reducing solid particles to fine dust comprising advancing in a narrow zone gas containing solid particles, confining the zone between two walls not more than 0.12 inch apart, causing relative movement between the two walls to the other of at least 100 feet per second, thereby causing high turbulence close to a wall surface and pulverizing the solid particles carried in the gas to fine dust of the order of less than ten microns.

3. A process for reducing solid particles to fine dust comprising advancing in a narrow zone gas containing solid particles, confining the zone between two walls about 0.01 to 0.12 inch apart, causing relative rotative movement between the two walls to the other transversely of the general direction of the gas travel and narrow zone of at least 100 feet per second, thereby causing high turbulence close to a wall surface and pulverizing the solid particles carried in the gas to fine dust of the order of less than ten microns.

4. A process for reducing solid particles to fine dust comprising advancing in a narrow zone gas containing solid particles, confining the zone as an annulus between two arcuate concentric walls about 0.01 to 0.12 inch apart, causing relative rotative movement between the two walls to the other transversely of the general direction of the gas travel and narrow zone of at least 100 feet per second, thereby causing high turbulence close to a wall surface and pulverizing the solid particles carried in the gas to fine dust of the order of less than ten microns.

5. Apparatus for comminuting solid particles comprising in combination a casing containing a substantially cylindrical recess, a substantially cylindrical rotor mounted in said casing and provided with a smooth circumferential surface arranged for rotary movement in said recess and disposed in the recess to form with the casing an operating annular peripheral zone clear along the smooth rotor surface and having uniform radial depth to give clearance of the order of 0.01 to 0.12 inch, driving means arranged to provide said movement at a peripheral speed of at least 100 feet per second, there being a gaseous atmosphere in the peripheral operating zone, a com-
pressed gas supply and conduit therefrom, and means for mixing solid particles in suspension in gas in the conduit, said conduit having an opening for feeding gas and particles into the recess in close proximity to said peripheral operating zone, and outlet means at the opposite side of the rotor in close proximity to said peripheral zone.

6. Apparatus for comminuting solid particles comprising in combination a casing containing a recess, a substantially cylindrical rotor mounted in said casing and provided with a highly polished circumferential surface arranged for rotary movement in said recess and disposed in the recess to form with the casing an operating annular peripheral zone clear along the polished rotor surface and having uniform radial depth to give clearance of the order of 0.01 to 0.12 inch, driving means arranged to provide said movement at a peripheral speed of at least 100 feet per second, there being a gaseous atmosphere in the peripheral operating zone, a compressed gas supply and conduit therefrom, and means for mixing solid particles in suspension in gas in the conduit, said conduit having an opening for feeding gas and particles into the recess in close proximity to said peripheral operating zone and outlet means at the opposite side of the rotor in close proximity to said peripheral zone.

7. Apparatus for reducing solid particles to fine dust comprising in combination a casing containing a recess, a rotor mounted centrally therein, bearings at each end of the rotor and means to drive the rotor, all adapted and being of size and material and being balanced dynamically for rotor peripheral speeds of at least 100 feet per second, the rotor having a circular and smooth peripheral face, the casing recess and the rotor peripheral face conforming to each other and defining a clear annular operating zone between rotor and casing having uniform radial depth to give about 0.01 to 0.12 inch clearance along the peripheral face, there being a gaseous atmosphere in the peripheral operating zone, a source of supply of gas, a conduit therefrom having an opening into the casing recess at one side of the rotor in close proximity to the annular operating zone, means to feed gas from the conduit into the annular operating zone, means to feed solid particles with the gas into the operating zone, and an outlet opening for solid particles and gas from the zone, located in the casing in close proximity to the rotor periphery on the opposite side of the rotor from the feed inlet.

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