June 7, 1938. E. B. MYERS 2,119,887

APPARATUS FOR DISINTEGRATING SOLIDS

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Fig. 1.

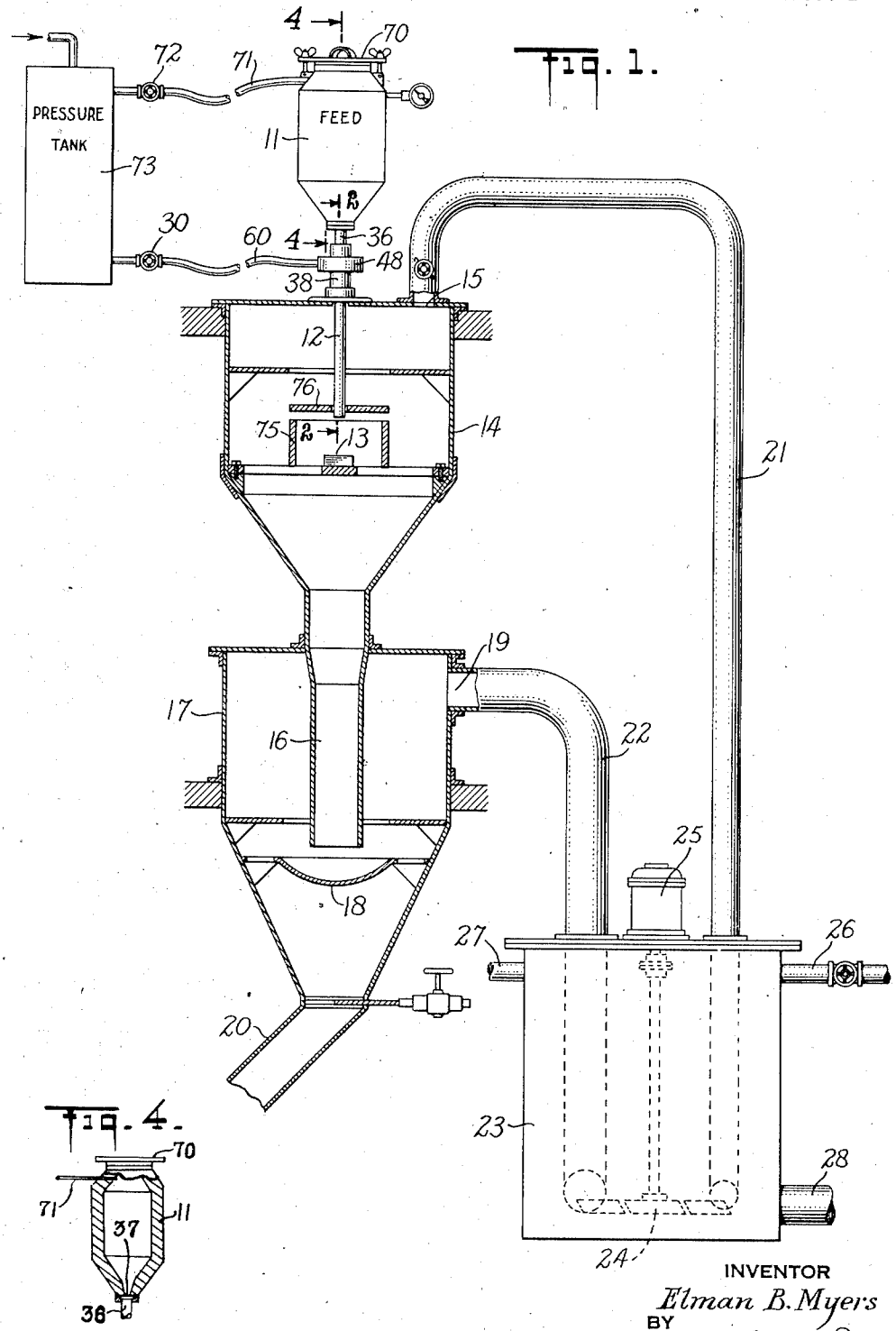


Fig. 4.

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Fig. 2.

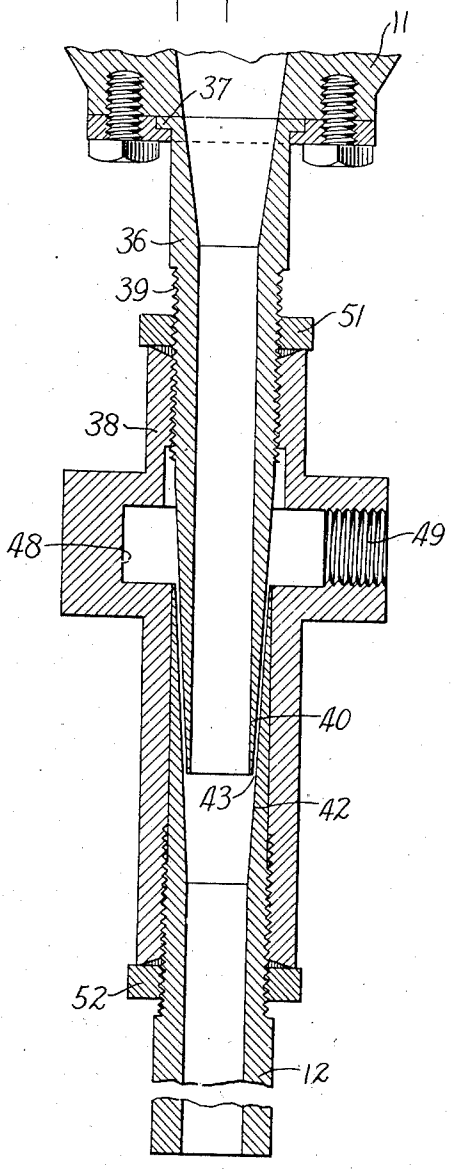
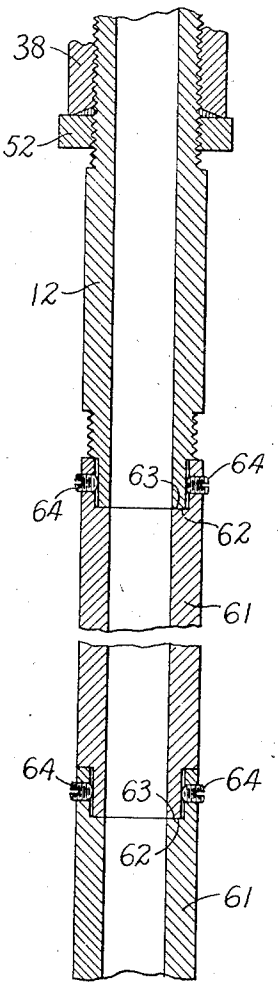


Fig. 3.



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APPARATUS FOR DISINTEGRATING SOLIDS

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Application November 5, 1936, Serial No. 109.235

7 Claims. (Cl. 83—46)

The present invention relates to an improvement in and apparatus for crushing or disintegrating solids by impact.

This application is in part a continuation of my prior application, Serial Number 33,932, filed July 31, 1935.

The general idea of impelling solid particles against a rigid obstacle for the purpose of reducing the particle size has long been known; but, so far as I am aware, there is no accepted pulverizing or crushing practice based thereon which produces commercial quantities of finely divided products at economically acceptable cost. This may be due to the fact that known methods have failed to provide sufficient acceleration to develop effective disintegrating energy on impact, or to fully utilize the energy developed, or both or that previously known impact apparatus has been found ineffective because the gas stream blows back against the material, or because, in terms of amounts of fine particles produced, it has been expensive in operation and inadequate as compared with other available pulverizing devices.

Accordingly, an object of my invention has been to provide apparatus whereby the particle size of solid materials varying widely in specific weight, frangibility, and other properties may be reduced to minute dimensions in quantity and substantially below the cost of producing the same degree of pulverization by known methods employed in industry.

According to my improved method for commercially acceptable pulverization of solids by impact, a gas under suitable pressure is discharged through an annular orifice and passes in a confined stream into and through an acceleration zone. The particles of material to be pulverized are delivered under pressure into said stream co-axially therewith and are accelerated thereby until they attain a suitable velocity or such value of kinetic energy that upon impact against a rigid obstacle they will be disintegrated to the required degree. The rate of feed of material into the gas stream is conveniently regulated by varying the feed pressure; and the combined stream of gas and particles is discharged from the acceleration zone against the rigid obstacle while the particles are at substantially unreduced velocity and in unconfined condition.

The energy required to disintegrate any given material by impact will depend upon its properties. Generally speaking, more frangible materials can be pulverized with expenditure of less energy than tougher or less frangible materials.

Sufficient kinetic energy for this purpose can be developed at various pressures of the entraining gas employed. For commercial purposes, the lowest effective pressure will be preferred. Heretofore it has been thought necessary with the entraining gas at normal temperatures, to use pressures up to five hundred pounds; but I have found that substantially lower pressures may be successfully used. For example, with apparatus providing an acceleration zone through which the compressed gas and the material pass together without constriction at any portion of the passage, I have obtained commercial pulverization of solids at usual working temperatures and differing widely in their specific weight and frangibility with the gas at around 100 lbs. pressure and at normal temperature.

For apparatus having a given diameter of bore and with a given maximum gas pressure available, the different velocities required to develop energy for pulverizing different kinds of materials are conveniently obtained by varying the length of the barrel or bore which defines the acceleration zone. In practice, the hardness and frangibility of a given material will in general determine what energy and therefore approximately what velocity is needed to produce disintegration thereof. At normal temperatures, solids of low specific weight require a relatively short acceleration zone, whereas those of relatively higher specific weight require longer barrels to develop the same or equivalent muzzle velocity. There is probably a theoretically ideal length of barrel or acceleration zone for each kind of material, assuming that gas temperature, pressure and other pertinent factors remain constant.

One form of apparatus suitable for employment in my improved method and presenting one embodiment of my improved apparatus is illustrated in the drawings accompanying the present specification and in which—

Figure 1 is a diagrammatic view in elevation with portions broken away to disclose interior constructions;

Figure 2, a central longitudinal section on the line 2—2 of Figure 1 showing more clearly the details of a portion of the apparatus conveniently identified as the "gun";

Figure 3, a fragmentary view in central longitudinal section showing a segmental construction for quickly and conveniently changing the effective length of the barrel portion of the gun shown in Figures 1 and 2; and

Figure 4 is a view partly in central longitudinal

section showing more clearly the construction of the feed hopper.

Referring to Figure 1, the apparatus therein shown includes a hopper 11 having a removable and preferably air tight cover 10. A pipe 71 provided with a valve 72 supplies compressed gas from a tank 73 to the interior of the hopper. Material to be pulverized is fed by pressure of said compressed gas from said hopper into a gun, the barrel 12 thereof being arranged with its muzzle opening opposite a plate or anvil 13 of alloy steel or other substance having appropriate hardness and density. A secondary anvil, as the ring 75 is arranged to impede particles deflected from anvil 13 and a third anvil in the form of a plate 76 intercepts particles deflected from the ring 75.

The anvils and the muzzle end of the gun barrel 12 are located in a chamber 14 having an outlet opening 15 at its upper end and a bottom outlet conduit 16. The latter opens into a second chamber 17 which, in the form shown, operates to a certain extent as a classifier for certain kinds of materials. It contains a bed-plate 18 arranged opposite the discharge end of the conduit 16 and has an outlet opening 19 at its upper end for lighter particles and an outlet chute 20 at the bottom for heavier particles. It will be understood that any desired or necessary type of classifier, separator or other mechanism may be substituted for that herein shown, depending in part on the characteristics of the material pulverized.

The apparatus shown in Figure 1 is also provided with parts adapted more particularly for the further classifying and separating of certain kinds of free milling ores in the pulverized state and includes a conduit 21 extending from opening 15 in disintegrating chamber 14. A conduit 22 extends from the discharge opening 19 in chamber 17, both of said conduits 21 and 22 being arranged to discharge into a tank 23 which, for purposes of ore treatment, may contain water. An agitator 24 is arranged within tank 23 and operated by a motor 25. The tank 23 is also provided with an inlet pipe 26 for supplying water or other liquid, an air vent 27 and a discharge pipe 28, the latter opening into a bottom portion of the tank. Other types of classifying and separating devices will be used where needed in place of those shown.

Referring now to Figure 2, the gun portion of my improved apparatus comprises an inlet tube 36 having an end opening for admitting a supply of solid material in suitable form for pulverizing treatment. A flange 37 provides means whereby tube 36 is secured to the discharge end of hopper 11, Figure 1. The gun also includes the barrel or acceleration tube 12 axially aligned with feed or inlet tube 36 and conveniently assembled therewith by means of a hollow casing 38 open at its ends and having portions interiorly screw threaded to engage correspondingly threaded portions of the members 36 and 12 respectively. An annular chamber 48 in said casing provides a passageway or manifold to which air or gas under pressure is admitted through a lateral opening 49 and a pipe 60 from supply tank 73, Figure 1. A nut 51 locks member 36 to the casing and a nut 52 locks member 12 thereto.

The bore of barrel or acceleration tube 12 has an interiorly tapered portion 42 at its inlet end to receive in spaced concentric relation an exteriorly tapered portion 40 of the discharge end of tube 36, the outer contour of which parallels the inner contour of said interiorly tapered portion 42. The tapered exterior surface 40 of feed tube 36 is adjustably spaced from the similarly tapered portion 42 of the interior surface of the barrel 12 and forms therewith in effect an injector nozzle having an annular passageway or orifice 43 for the discharge of gas under pressure from chamber 48 into the acceleration zone of barrel 12 which extends from said orifice 43 to its muzzle with undiminished cross-sectional area. The wall surfaces of said passageway 43 converge toward the central longitudinal axis of the barrel or acceleration tube at a sufficiently flat angle therewith to insure free discharge of the gas stream into and through the barrel when the parts are adjusted at or near optimum position, for example, as shown in Figure 2, thereby avoiding "blow back" through tube 36 which is likely to occur when the angle of convergence of the jet is substantially over 5°. In the illustrated gun, Figure 2, the jet angle is about 3° and the longitudinal adjustment of the jet orifice and the cross-sectional area thereof, as shown in said Figure 2, provide an effective operating arrangement.

Provision is made for controlling the longitudinal position and the extent of opening or cross-sectional area of the orifice 43 of the nozzle above described by adjusting the tube 36, or the barrel 12, relatively to the casing and in such a way that endwise movement either of said tube or of said barrel takes place in relation to the other. Thus, when tube 36 is rotated in one direction, the orifice area is increased; and rotation thereof in the opposite direction diminishes the orifice area and therefore the amount of entraining air or gas discharged therethrough at a given pressure.

The threaded portion of tube 36, for example, is provided preferably with micrometric threads 39 coacting with similarly formed threads in the casing 38. Obviously, where rotating movement of tube 36 is calibrated in suitable terms, the relative positions of the feed tube and the acceleration tube and the amount of gas discharged through the orifice or passageway 43 can be accurately controlled by manipulation of said tube.

As shown in Figure 3, provision is made for changing the effective length of barrel 12 and therefore of the acceleration zone in which useful kinetic energy is developed for disintegrating the solid particles by impact. This is conveniently done by attaching or removing tubular segments, as 61, each having an annular shoulder 62 which bears snugly against a co-operating end portion 63 on the barrel or on another segment, as the case may be. Set screws 64 or other suitable devices hold the barrel and the segments in assembled relation and so that each added segment provides in effect a continuous and uninterrupted elongation of the barrel and the acceleration zone formed by its bore.

The barrel 12 and the segments may be of any desired dimensions consistent with the probable uses to which the apparatus will be put. Ordinarily where material of fairly uniform specific weight and frangibility is to be disintegrated, a barrel member of the proper length and diameter will be provided and used in normal operation. In other cases a barrel of suitable diameter and minimum length is supplemented by one or more segments and provision is made as required for adjustments to obtain proper spacing between the muzzle end of the gun and the anvil 13. Thus, where pipes 60 and 71 are in the form of

flexible hose, the gun assembly may be moved longitudinally in relation to the anvil or to disengage the barrel 12 from the chamber 14.

In operation, assuming a given gas pressure and temperature and that the proper orifice position and area and therefore the proper volume of entraining gas have been effected by the orifice area adjusting means hereinabove referred to and with cover 10 of hopper 11 securely in place, valve 30 is opened to supply gas under pressure for discharge into the gun through orifice 43. Solid material in a convenient particle size for the purpose is now forced from hopper 11 into the inlet end of the tube 36 by opening valve 72 to admit pressure through pipe 71 into said hopper. The stream of entraining gas discharges through the nozzle passageway 43 at such an angle and in sufficient quantity to entrain and accelerate movement of the stream of material forced or otherwise admitted into tube 36 and discharged with the gas through barrel 12. Under these conditions, said barrel 12 provides a passageway through which the entrained solid material is forced with its velocity accelerating at a rate depending largely on its particle size and its specific weight and to an extent depending on the length of the barrel. The combined stream of gas and solids is discharged preferably at maximum velocity through the muzzle of barrel 12 and against anvil 13, Figure 1. Some particles rebound from anvil 13 and strike ring anvil 75 with sufficient force to be further reduced in size. Additional disintegrating effect is produced by particles striking the plate 76 either on rebound from anvil 13 or on deflection from ring anvil 75.

The distance from the barrel 12 to the anvil 13 is such that there will be no appreciable loss of velocity and therefore of kinetic energy between the time the solid material leaves the muzzle and the time it strikes the anvil. In the case of many materials which industry now utilizes in fine particle size, i. e. under 200 mesh, a distance of from six to eight inches between the end of the barrel muzzle and the impact face of the anvil 13 will be found effective. The shorter distance is appropriate for substances of relatively low specific weight while, in the case of heavier substances, the distance may be greater, although no useful purpose is served in exaggerating this dimension.

It will be apparent from the foregoing description that no arbitrary or precise values of barrel length or muzzle velocity to insure effective disintegration can be set forth to apply universally to all substances or invariably to any given substance or kind of substance. Accordingly, the examples hereinafter given represent typical conditions of operation employed and results observed in disintegrating various kinds of solid materials which differ chiefly in hardness, and also in other characteristics or properties. For convenience in comparison, these operations were conducted with a gun having a bore of one inch diameter, which, when employing gas at normal temperatures and economically attainable pressures, produced disintegration of solids to fine particle size in commercial quantities. It is contemplated that guns of different caliber may be used with corresponding effect on capacity or volume of output.

Example #1 (talc)

The material pulverized was talc, hardness 1, 100% thereof being minus 4 mesh (i. e. $\frac{3}{16}$ inch) in size and about 28% thereof being minus 200 mesh in size. Air at about 100 lbs. pressure was used to force the material from the hopper into the gun.

Employing a gun of 1 inch diameter and with the entraining air discharging therein at about 100 lbs. pressure, temperature 72.7° F., the percentage of fines of minus 200 in said talc was increased by one passage through the gun.

From 28% to 41.5%, using 3 inch length barrel
From 28% to 49 %, using 18 inch length barrel
From 28% to 54.5%, using 36 inch length barrel
From 28% to 58 %, using 65 inch length barrel

Thus with a 65 inch barrel the material was treated to produce 30% additional fines under 200 mesh from 5 tons per hour of total solids treated, or at the rate of 1½ tons of additional product of minus 200 mesh size per hour.

Example #2 (marble chips)

The material treated was marble chips, hardness 4, 99% thereof being minus 4 mesh (i. e. $\frac{3}{16}$ inch) in size and only about 3.1% thereof being minus 200 mesh in size.

Under substantially the same conditions as those set forth in Example 1, the percentage of fines of minus 200 mesh in said marble chip material was increased by one passage through the gun.

From 3.1% to 12 % using 3 inch length barrel
From 3.1% to 13.8% using 18 inch length barrel
From 3.1% to 19.5% using 36 inch length barrel
From 3.1% to 22.2% using 65 inch length barrel

With the 65 inch barrel the treated material produced approximately 19% additional fines under 200 mesh in size from over five tons per hour of total solids treated, or at the rate of about 1 ton of additional product of minus 200 mesh size per hour.

Example #3 (quartz)

The material pulverized was quartz granules, hardness 7, 94% thereof being minus 4 mesh in size and about 3.8% thereof being minus 200 mesh in size.

Under substantially the same conditions as those set forth in Examples 1 and 2 above, the percentage of fines of minus 200 mesh in said quartz granules was increased by one passage through the gun.

From 3.8% to 7.3% using 3 inch length barrel
From 3.8% to 12.5% using 18 inch length barrel
From 3.8% to 15. % using 36 inch length barrel
From 3.8% to 18. % using 65 inch length barrel

With the 65 inch barrel the treated material produced 14% additional fines under 200 mesh in size from 5½ tons per hour total solids treated, or at the rate of over ¾ tons of additional product of minus 200 mesh size per hour.

The results above tabulated were obtained under conditions employing about 400 cubic feet of free air per minute at around 100 lbs. pressure and with from 80 to 100 lbs. feed pressure in hopper 11. With more recently developed types of compressors this pressure can be adequately supplied with about 75 horsepower.

As appears from the results above noted and from experience in pulverizing many other kinds of materials according to my invention, I obtain different percentages of fines of minus 200 mesh depending in general on the softness or hardness of the substances treated. In each case, however, the amount of fines actually produced is mate-

rially greater than it is possible to obtain with presently known apparatus or methods at comparable cost per unit of fine product produced.

Example #4 (crude sulphur)

The material pulverized was crude sulphur fed to the gun under 50 lbs. pressure and at the rate of 9 tons per hour. The gun or entrainment pressure was about 100 lbs., and 400 cubic feet per minute of free air were delivered through the nozzle. Power for the compressor was about 65 H. P.

By a sedimentation classifying method, direct output material passed once through the gun showed no particles of more than 92.5 microns radius. About 55% of said material consisted of particles under 25 microns in radius, i. e. below any size which can be detected by the palate or sensory nerves of the tongue. 25% were of less than 13 microns radius.

After three passes through the gun, the sample showed no particles of more than 75 microns radius by the sedimentation classification. About 79% of said material was below 25 microns radius. About 37% were of less than 13 microns radius. A slight Brownian movement was observed and indicates particle sizes approaching micron dimensions.

After five passes through the gun, the sample showed 78% below 25 microns in radius and over 44% were less than 13 microns radius.

Where a portion of the product was recovered as separated fines under 37 microns radius, about 70% thereof were less than 13 microns radius.

In treating this same raw material under the conditions above set forth i. e. with 50 lbs. feed pressure I obtained about 2 tons per hour of product of minus 300 mesh (i. e. 47 microns diam.) per hour. By using 100 lbs. feed pressure, the amount of this product was increased to about 3½ to 4 tons per hour.

The advantageous results are in part due to the fact that my method involves more efficient development and utilization of the disintegrating energy whereby a greatly increased percentage of the treated material is reduced in particle size by one passage through the gun, and in part to the use of force feed whereby the amount of material passed through the gun per hour more closely approaches its ultimate capacity. By employing the supplemental or secondary anvils as the ring 15 and the plate 16, I utilize the unspent energy in those particles which are not pulverized by their initial impact on anvil 13; and by employing air pressure of about 100 lbs. to force the solids from hopper 11 into the gun, the feed rate is increased to nearly ten times that obtained by gravity and the suction produced in the gun, usually a vacuum of about 22 inches under ordinary operating conditions.

I claim—

1. Impact apparatus comprising an acceleration tube having an inlet end and a discharge end, a feed tube arranged to discharge particles into said acceleration tube and to provide an annular passageway between end portions of said tubes to deliver into said acceleration tube gas under pressure and in an annular stream with its boundaries converging at an angle of less than 5° to its longitudinal axis, means for supplying gas under pressure to said annular passageway, pressure means for feeding particles into said feed tube, and an anvil interposed in the path of particles discharged from the discharge end of the acceleration tube, a ring arranged wholly beyond said discharge end of the acceleration tube and having a substantially cylindrical inner impact surface encircling the path of movement of said particles from the discharge end of said acceleration tube to the anvil to provide a secondary anvil positioned in the path of particles deflected from said first mentioned anvil, and a housing enclosing the discharge end of the acceleration tube and said anvil and said ring.

2. Impact apparatus comprising an acceleration tube, a feed tube arranged to discharge particles into said acceleration tube and to provide an annular passageway between end portions of said tubes to deliver into said acceleration tube gas under pressure and in an annular stream with its inner boundaries converging at an angle of up to 5° to its longitudinal axis, means for supplying gas under pressure to said annular passageway, pressure means for feeding particles into said feed tube, and an anvil plate opposite the discharge end of the acceleration tube, a ring having its inner surface positioned to intercept particles deflected from said plate, and another plate presenting an anvil surface arranged opposite to portions of said first mentioned plate.

3. Impact apparatus comprising an acceleration tube, a feed hopper, means for applying compressed gas to solid materials in divided form in said hopper to force said materials into one end of said tube under pressure, an injector nozzle arranged to discharge gas under pressure into said tube and in a stream which initially encircles the solid material fed thereto from the hopper, a main anvil spaced from and opposite the discharge end of said tube, and a secondary anvil positioned wholly beyond the discharge end of said tube and having a continuous cylindrical impact surface spaced from the main anvil and concentrically surrounding a portion of the path of movement of the material between the tube and the main anvil, and a housing enclosing said anvils and the discharge end of said tube.

4. In impact apparatus, an acceleration unit including a feed tube and an ecceleration tube having opposed spaced parallel surfaces forming an injection nozzle arranged with its discharge orifice opening into a mid-portion of said unit, said acceleration tube including separate attachable and detachable sections of substantially the same cross-sectional bore area and means cooperating with said acceleration tube sections and operable without varying the relative positions of the parts forming said injection nozzle for varying the effective length of said acceleration tube.

5. Apparatus for crushing material by impact wherein said material is supplied to an acceleration tube through a feed tube having its delivery end extending centrally into the inlet end of said acceleration tube and is accelerated therein by gas under pressure and discharged therefrom in an unimpeded stream against an anvil arranged opposite the discharge end of said acceleration tube at sufficient velocity to be crushed by impact with said anvil, characterized in that said delivery end of the feed tube is provided with a central bore opening into the acceleration tube and has an outer surface disposed at an angle of less than five degrees to its longitudinal axis and said inlet end of the acceleration tube has an inner surface arranged in opposed spaced parallel relation to said outer surface and forms therewith in effect an injector nozzle passageway for supplying gas under pressure to said acceleration tube in an annular stream laterally enclosing the path of material delivered cen-

trally into said aceleration tube through the bore of said feed tube, and said acceleration tube has an acceleration and discharge end portion provided with a bore of substantially undiminished cross-sectional area in the direction of movement of material therethrough which cross-sectional area is substantially the same as that of the bore of said delivery end of the feed tube and said acceleration and discharge portion being arranged in relation to the feed tube and the anvil to discharge material freely from the delivery end of said feed tube into crushing impact with the anvil in an unimpeded stream of undiminished cross-sectional area from said delivery end of said feed tube to the impact surface of said anvil.

6. Apparatus for crushing material by impact wherein said material is supplied to an acceleration tube through a feed tube having its delivery end extending centrally into the inlet end of said acceleration tube and is accelerated therein by gas under pressure and discharged therefrom in an unimpeded stream against an anvil arranged opposite the discharge end of said acceleration tube at sufficient velocity to be crushed by impact with said anvil, characterized in that said delivery end of the feed tube has an outer surface disposed at an angle of less than five degrees to its longitudinal axis and said inlet end of the acceleration tube has an inner surface arranged in opposed spaced parallel relation to said outer surface and forms therewith in effect an injector nozzle passageway for supplying gas under pressure to said acceleration tube in an annular stream laterally enclosing the path of material delivered centrally into said acceleration tube through said feed tube, and said acceleration tube has an acceleration and discharge end portion provided with a bore of undiminished cross-sectional area in the direction of movement of material therethrough and extending a part of the distance from the feed tube to the anvil and with its discharge opening positioned to discharge material freely from the delivery end of said feed tube into crushing impact with the anvil in an unimpeded stream of undiminished cross-sectional area from said delivery end of said feed tube to the impact surface of said anvil.

7. In impact apparatus, an acceleration unit including a feed tube and an acceleration tube having opposed spaced parallel surfaces forming an injection nozzle having a discharge orifice opening into a mid-portion of said unit, a supplementary acceleration tube section having substantially the cross-sectional bore area of the feed tube, and means for releasably attaching said section to the discharge end of said acceleration tube.

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