

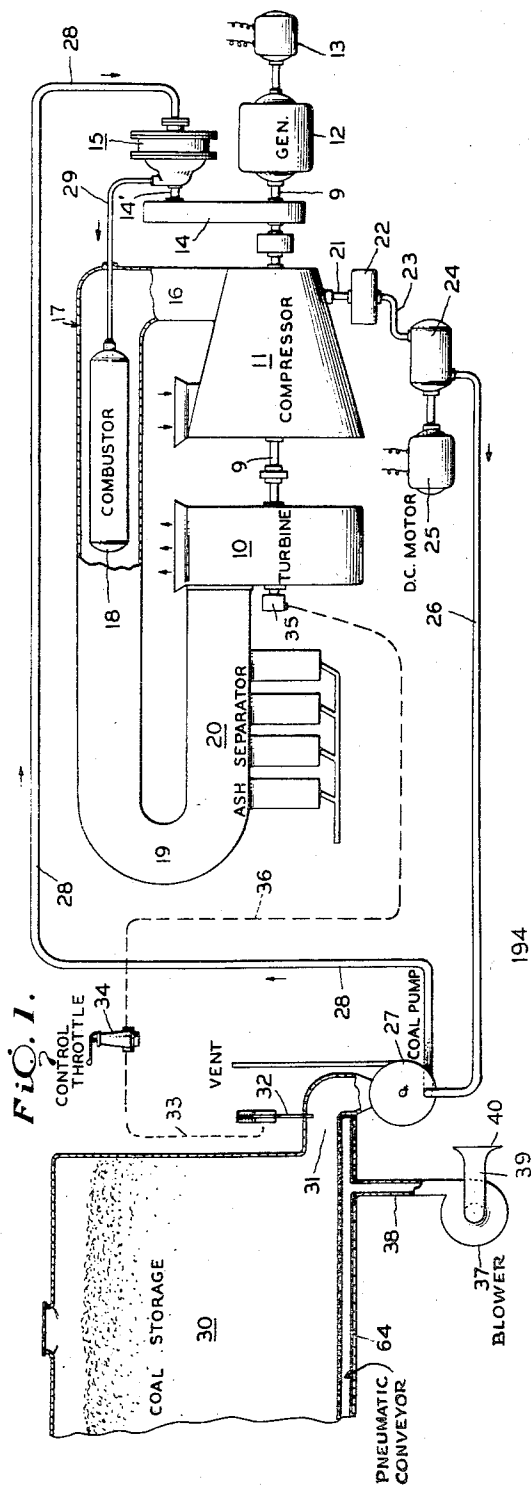
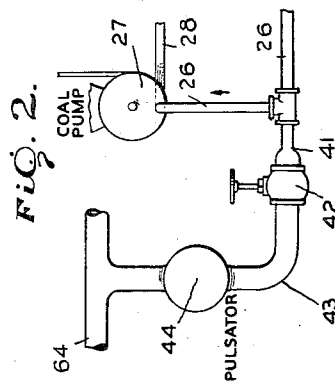
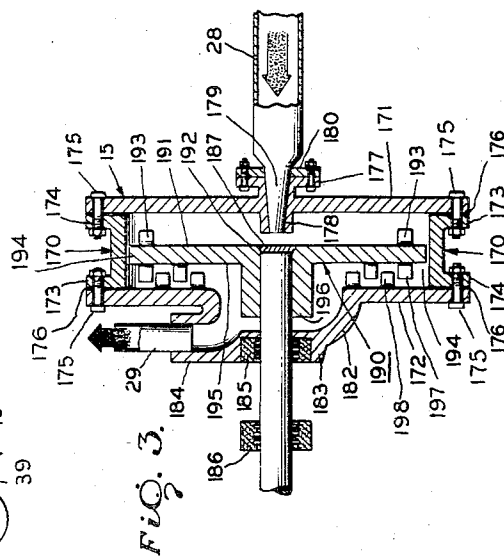
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IN-LINE PNEUMATIC-MECHANICAL UNIT PULVERIZERS

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IN-LINE PNEUMATIC-MECHANICAL UNIT PULVERIZERS

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This invention relates to in-line pneumatic-mechanical unit pulverizers. More particularly, the invention relates to unit pulverizers of the type adapted for use in gas turbine power plants using motive fluid generated by the pressurized combustion of fluidized coal, all as more fully set forth and claimed in my application, Serial No. 423,978, filed February 23, 1954, for Powdered Coal-Burning Gas Turbine Power Plant With Pneumatic Conveying System Therefor.

Riley et al. (Mechanical Engineering, November 1925, vol. 47, No. 11a, at page 1047), define a unit pulverizer as follows: "The term 'unit pulverizer' is used to define the type of pulverizer which discharges the pulverized product directly into the furnace where it is burned; as distinguished from a pulverizer which discharges into a 'bin' or 'storage system.'" Conventional unit pulverizers are operated under suction, that is, a suction fan is incorporated in the discharge chamber of a pulverizer, the inlet or hopper is at atmospheric pressure, and the hopper feeds by gravity into the pulverizer.

In power plants of the type disclosed and claimed in the pending application of John I. Yellott and Peter R. Broadley, Serial No. 330,077, filed Jan. 7, 1953, for Coal-Burning Gas Turbine Power Plants, etc., for example, coal for generating gasiform motive fluid is required to be mechanically handled and transferred from the coal bunker to the coal crusher, and/or pulverizer, and thence into the combustive air feed line to the combustor. In such a system, considerable power must be made available for motivating the mechanical coal-handling equipment. Additionally, a pressure differential of 10-20 p. s. i. is usually required to be established and maintained between the coal-bearing, primary, conveying or combustive air stream delivered to the combustor, and the secondary air delivered to the combustor casing for cooling and dilution of the products of combustion of the primary air-borne combustible to form a turbine-actuating motive fluid therewith.

It has now been found that an improved coal supply for pressurized combustors can be made by incorporating a novel, pneumatic-mechanical unit pulverizer in the combustive air feed line, immediately in advance of the combustor. One form of the novel unit pulverizer of the invention herein is characterized by a rotary disk mounted for rotation in a sealed housing; an axial impact surface of hard material in the center of the disk; and a convergent pulverizer nozzle inlet in the housing, discharging against the impact surface. Additionally, the rotary disk is coupled to the turbine shaft, through reduction gearing, or any other suitable coupling means, to rotate therewith, and under any suitable speed ratio. The combustive or primary air circuit can be cooled to prevent spontaneous combustion ahead of the combustor, and the combustive air is delivered to the combustor at a pressure which, desirably, will exceed the secondary air pressure in the combustor by not over 20 p. s. i.

With a reduced pressure differential, generally of the order of one (1) atmosphere, obtaining between the

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cooled fuel-laden combustive air stream and the secondary air in the combustor, superheating of the combustive primary air stream to a temperature above the threshold ignition temperature of the entrained fuel particles is avoided. Additionally, by utilizing the centrifugal force of the improved combination pneumatic-mechanical unit pulverizer of the present invention for effecting the reduction of the fuel particles to a desired particle size, the carrier stream of combustive air is no longer required to be maintained at the high pressure necessary to insure adequate impacting of entrained solids against impact surfaces of non-rotating or fixed impact surfaces, as used hitherto.

The improvements of the present invention have been found to give optimum operative results when the rate of flow or feed of the primary air-borne fuel to the combustor is directly controlled as a function of the load on the turbine in response to the controller, as in a locomotive or marine installation, as well as in stationary power plants.

The fluidizing air for the pneumatic coal-feeding system, can be supplied independently, or taken as a small side stream of the combustive air stream (140° F.), as shown in the drawings. As will be described herein-after, and as set forth and claimed in my companion application, Serial No. 411,930, filed Feb. 23, 1953, for Improved Pneumatic Material Handling System and Apparatus, now Patent No. 2,805,896, normally limp, pulsatable and distensible aerators, function both as supports or bottoms for fluidizable masses of particulate solids, and as diffusers for the fluidizing air to be introduced into the masses of superposed solids.

It is, therefore, among the features of novelty and advantage of the present invention to provide a novel, pneumatic-mechanical unit pulverizer adapted for use in pressurized combustion systems for the generation of motive fluid for gas turbines.

Another feature of novelty and advantage of the invention herein is the provision of in-line pneumatic-mechanical unit pulverizers characterized by freedom from "blow-back" when used in combustive air-borne fuel feed lines of pressurized combustors.

A further feature of novelty and advantage of the invention herein is the provision of in-line pneumatic-mechanical unit pulverizers comprising pill-box type hermetic cylindrical casings embodying convergent nozzle entrants and unrestricted discharge openings, the entrants being oriented to discharge solids-laden, pressurized carrier air streams against rotors mounted for rotation in the casings, the rotors and casings incorporating intermeshing concentric annular rows of impact members.

An additional feature of novelty and advantage of the invention herein is the provision of pneumatic-mechanical unit pulverizers of the character described, and embodying convergent nozzle entrants discharging against abrasion-resistant, impact surfaces of rotors mounting impact blading downstream of the axial entrants.

Yet another feature of novelty and advantage of the invention herein is the provision of pneumatic-mechanical unit pulverizers of the hermetic, pill-box type, having vaned rotors incorporating concentric rows of impact vanes intermeshing with similar rows of vanes in the casings, the casings having both axial entrants and discharge outlets on opposite faces of the pulverizer casings.

A special feature of novelty and advantage of the invention herein is the provision of a pneumatic-mechanical unit pulverizer of the character described, incorporating a driven rotor in a hermetic, pill-box type casing, the rotor being disk-shaped and mounting impact blades on both faces, the blades on at least one face coacting with apposed fixed blades on the inside of the casing to define a plurality of labyrinthine paths for

pneumatic fluid-borne particulate matter passed through the casing under pressure, whereby the particulate matter is further reduced in particle size.

It is also a feature of novelty and advantage of the invention herein to provide an in-line pneumatic-mechanical unit pulverizer particularly adapted for incorporation in the pressurized combustor feed line of a motive fluid generator of a gas turbine power plant, the diameter of the entrant to the pulverizer being reduced to at least one-half that of the feed line.

With these and other features of novelty and advantage in view, which may be incident to the improvements herein, the invention consists in the parts and combinations to be hereinafter set forth and claimed, with the understanding that the several necessary elements comprising the invention, may be varied in construction, proportions, and arrangements, as well as in mode of operation, without departing from the spirit and scope of the appended claims.

In order to make the invention more clearly understood, there is shown in the accompanying drawings means for carrying out the same into practical effect, without limiting the improvements in their useful applications to the particular constructions, which, for the purpose of explanation, have been made the subject of illustration.

In the drawings, like numerals refer to similar parts throughout the several views, of which

Figure 1 is a schematic showing of a coal-burning gas turbine power plant incorporating pneumatic coal delivery means, and a novel multi-stage, pneumatic-mechanical unit pulverizer in the delivery line to the combustor;

Fig. 2 is a detail of a schematic showing of a fluidizing air supply means for the coal bunker of Fig. 1, and

Fig. 3 is an enlarged vertical section through the pneumatic-mechanical unit pulverizer of Fig. 1.

Turning now to the drawings, there is shown in Fig. 1, diagrammatically, a novel gas turbine electric power plant, the generators being powered by a gas turbine utilizing motive fluid generated in a pressurized coal-burning combustor. The power plant is comprised of a gas turbine 10, directly coupled to and driving a secondary air compressor 11. Main D. C. generators 12, for motive power, or other uses, are driven by the turbo-compressor shaft 9, as is the auxiliary D. C. generator 13. A gear box 14, houses reduction gearing, not shown, which couples the turbo-compressor shaft with the drive shaft 14', of a novel pneumatic-mechanical unit pulverizer 15. The unit pulverizer 15, is more particularly described hereinafter. A secondary air duct 16, conveys diluting and cooling air from the compressor 11 to combustor casing 17, in which is spacedly mounted a combustor 18. The combustor 18 is preferably of the type disclosed and claimed in the application of F. D. Buckley, Serial No. 257,165, filed Nov. 19, 1951, for Cold Wall Combustor With Flexibly Mounted Flame Tube. The combustor delivers fly ash and incompletely burned powdered coal and aggregates, suspended in the motive fluid, through a U-duct 19, into a battery 20, of reverse flow vortical whirl separators, as more particularly set forth and claimed in the application of John I. Yellott and Peter R. Broadley, Serial No. 330,077, filed Jan. 7, 1953, for Coal Burning Gas Turbine Power Plants, etc. The cleaned motive fluid from the separator is delivered to the turbine, and the spent fluid is vented to the atmosphere, desirably through a regenerator.

The combustor 18 is specially adapted to burn a gasiform combustible comprising a streaming entrainment of pulverized coal particles in a pressurized stream of combustible, or so-called primary air, and at a pressure slightly above that of the secondary air which flows into the combustor casing 17. One method of preparing such a combustible air-borne suspension of pulverized coal is readily apparent from the drawings, in which a novel, wholly pneumatic, non-mechanical coal feeding system

is illustrated, and which system operates in the following manner:

A side stream of secondary air is withdrawn from compressor 11, through line 21, intercooler 22, and line 23, to the booster compressor 24, driven, at substantially constant speed, by D. C. motor 25 which is powered by D. C. generator 13, or by a suitable variable speed coupling to the turbine shaft. The so-formed, and relatively cool ($<140^{\circ}$ F.) conveying air is then delivered, through line 26, to the coal pump 27, wherein it picks up a controlled charge of crushed coal, from the bunker, and delivers the resulting streaming entrainment of primary air-borne coal particles, through line 28, to the pneumatic-mechanical unit pulverizer 15. It is to be noted that the inlet to the pulverizer 15, (Figs. 1 and 3), incorporates a convergent nozzle 179, of the type disclosed and claimed in my prior Patent No. 2,651,176, issued Sept. 8, 1953, for Coal Fired Gas Turbine Power Plants. From the pulverizer 15, the combustible air-borne suspension of pulverized coal in combustible air is delivered to combustor 18, through line 29.

A bunker 30, is provided with a valved outlet 31, controlled by slide valve 32 (Fig. 1), and discharges into coal pump 27; which may be of the type shown in my pending application, Serial No. 361,802, filed June 15, 1953, now Patent No. 2,750,234, as a true division of my application Serial No. 196,288, filed Nov. 17, 1950, for Pulverized Fuel Gas Turbine Power Plant, now Patent 2,675,676, issued April 20, 1954. The valve 32, is regulated, through connection 33, by controller 34, which, in turn, is controlled by governor 35 on the turbine shaft. In this manner, the amount of coal fed to the combustor is maintained as a direct function of the desired output of the turbine.

Fluidizing and conveying air for the fluidized coal in the bunker may be delivered to the bunker by aerating blower 37, through line 38. The blower intake may open directly into the ambient air. In the form shown in Fig. 1, an intake 39, having a bell mouth 40, supplies air to the blower. In the fluidizing air supply system shown in Fig. 2, a bleed-off line 41, is provided with a pressure regulator 42, which discharges into the bunker 30, through line 43. The line 43 may incorporate any suitable pulsator, designated generally by the numeral 44. The aerating blower 37, can be regulated to deliver fluidizing air at any desired pressure and rate of flow.

The system illustrated in Fig. 2, and described immediately above, is operated as follows: With a flow of 125 C. F. M. of conveying air through line 26, and pressure regulator 42 set to pass a flow of 5 C. F. M. to the fluidizing air supply line 43, a flow of 120 C. F. M. of conveying air will be delivered to combustible air feed line 28, through coal pump 27. Because of the drop in pressure of the side stream of fluidizing air, on its passage through the reducing valve or pressure regulator 42, the volume of the fluidizing air stream is increased, and its temperature is somewhat reduced, so that it is supplied to the bunker in a relatively cool state.

The special structural feature of the present invention, which is of particular importance in the system described above, is the novel pneumatic-mechanical unit pulverizer 15, one form of which is shown in Fig. 1, in the power plant assembly, and in section in Fig. 3. The pneumatic-mechanical unit pulverizer, designated generally by the numeral 15, comprises a cylindrical body section 170, having a front cover 171, and a rear cover 172, suitably joined thereto, to form a hermetically sealed unit. To facilitate assembly and dismounting of the unit, for the emplacement and replacement of the moving parts, and of the casing elements, the body section 170, may be flanged at both ends, as indicated by flanges 173, 174. The sections of the casing, or pulverizer housing, are joined and secured by bolts 175. Suitable gaskets 176, are interposed between the sections in the usual manner. Front cover 171 mounts a flanged central boss

177, having a tapered axial entrant aperture 178, receiving the convergently tipped nozzle or discharge end 179, of combustible air feed line 28. The nozzle end of line 28 is fixedly and hermetically secured in place by plate or flange 180, which is integral therewith. The flange 180 is apposed to the flanged boss 177, with a suitable gasket therebetween, and the assembly is joined by bolts.

The rear cover 172, of the unit pulverizer is provided with a dished boss 182, having a central axial aperture 183, and a lateral discharge outlet 184, which receives the inlet end of line 29, comprising the feed pipe to the burner of combustor 18. The aperture 183 is provided with a suitably packed bearing 185, which is in spaced alignment with a second bearing 186, normally mounted in gear casing 14. The bearings 185, 186, provide spaced supports for drive shaft 14' of the pulverizer rotor 190. The rotor 190 has an anterior or front face 191, centrally apertured at 192, and is provided with a plurality of radially disposed, outwardly projecting, peripheral blades or impact vanes 193. The rim of the disk forms an annular gap 194, with the inner surface of casing section 170. The posterior or rear surface 195, of the rotor, has a centrally apertured, axial boss 196, adapted to receive the end of drive shaft 14' in a drive or shrink fit, and with or without keys or splines for locking. The posterior surface 195 is also provided with a plurality of spaced, concentric annular rows of outwardly projecting impact blades or vanes 197, adapted to intermesh with interposed, like rows of fixed vanes or blades 198, integral with, or fixedly mounted on the inside of rear cover 172. An axial impact facing 187, of tungsten carbide, or like material, is disposed on the inner end of drive shaft 14', the latter being suitably retracted in the boss 196, to form a cup for receiving the carbide. The carbide insert, which is characterized by high abrasion and impact resistance (hardness on Moh's scale: >9), may be preformed, and the preform brazed in place, or it may be deposited from weldrods, by suitable electric or gas welding techniques.

The operation of the novel unit pulverizer is simple, and readily apparent from the drawings. The rotor is caused to rotate at a suitable speed by reduction gearing driven by the turbo-compressor shaft. The anterior and posterior vanes on the rotor are hard-surfaced, as is the inner surface of the pulverizer casing. With a crushed coal-laden combustible air stream being fed to the pulverizer 15, the stream, on passage through the convergent nozzle entrant to the first stage of the pulverizer, is accelerated, with a drop in pressure, and with a concomitant pulverization of the major portion of the contained coal particles, all as specifically described in my Patent No. 2,651,176, above identified. The streaming entrainment is projected against the axial impact surface 187 of the rotor, and the particles are further reduced in size. The increased velocity of the expanding conveying air stream is augmented by the centrifugal action of the rotor, and the particles are still further reduced by impact against the anterior vanes, followed by their further projection and impact against the inner surface of the casing. The anterior vanes exert a positive centrifugal action on the particles with which they come in contact. The gap 194, between the rotor and the inner surface of the casing is sufficient to pass particles of selected size, but will retain oversize particles, which are further abraded until they are reduced to the proper size. The radially expanding, solids-bearing air stream presents a relatively thin sheet in the fore-chamber of the pulverizer, and a maximum impact of the particulate solids against the inner wall is assured by reason of the paths imposed on the particles, as a result of the centrifugal force exerted by the rotor, aided by the efferent expansion of the conveying air stream as a thin, essentially flat, spinning disk.

It will be seen that the novel pulverizer 15, performs

a number of important functions in an economical and efficient manner. The power required is readily available from the turbine itself. Additionally, the pulverizer also serves as a fluidizer for the pulverized particles. In this latter function, the beating of the air-borne pulverized solids by and between the fixed and rotating vanes of the posterior chamber results, of necessity, in the formation of a true aerosol.

The improvements described immediately above make for a much improved and simplified gas turbine power plant, which improvements are further enhanced by the preliminary fluidization and handling of crushed coal ($\leq \frac{3}{8}$ in.), using wholly pneumatic non-mechanical conveying equipment.

It is apparent that a novel pneumatic-mechanical unit pulverizer, particularly adapted for use in a coal-burning, gas turbine-powered power plant, has been provided.

There has been described and illustrated devices capable of performing all of the specifically mentioned objects of this invention, as well as others which are apparent to those skilled in the art. Various uses of the present invention may be made employing the described structures. Accordingly, it is apparent that variations as to operation, size and shape, and rearrangement of elements may be made without departing from the spirit of the invention. Therefore, limitation is sought only in accordance with the scope of the following claims.

What is claimed is:

1. In a pressurized combustible air feed line of uniform diameter, for feeding a streaming entrainment of combustible air-borne fuel particles into a pressurized combustor, the improvement comprising a pneumatic-mechanical unit pulverizer in the feed line, the pulverizer consisting of a rotor encased in a hermetic casing; driving means for the rotor; an entrant, of a diameter not over one-half the diameter of the feed line, axially disposed in one face of the casing, said entrant receiving the upstream section of the feed line and oriented to direct the pressurized streaming entrainment against an apposing face of the rotor, the axis of the apposed rotor face being provided with an impact surface having the hardness and wear-resistance characteristics of tungsten carbide; cooperating concentric rows of impact blades on at least one face of the rotor and an apposed face of the casing; and a discharge outlet in the casing hermetically coupled to the downstream section of the feed line, the outlet being so constituted and arranged as to cause the streaming entrainment to radially traverse the bladed face of the rotor, whereby when the rotor is driven, and a streaming entrainment of combustible air-borne fuel particles is delivered to the combustor through the feed line, the particles are subjected to myriads of impacts between the fixed and rotating blades and are thereby reduced in size and are fluidized in the carrier air stream.

2. An in-line pneumatic-mechanical unit pulverizer adapted for the conjoint pulverization and fluidization of streaming entrainments of combustible air-borne coal particles flowing in a feed line to a pressurized combustor, comprising, in combination, a hermetic, pill-box type casing; a rotor disk mounted for rotation in the casing, and having close tolerance with the wall thereof; intermeshing concentric rows of impact blades on at least one face of the rotor and an apposed inner face of the casing; separate means for rotating the disk; co-diametral inlet and discharge openings in the casing so constituted and arranged as to cause a streaming entrainment of pressurized air-borne coal particles to traverse a radial path across at least the bladed face of the rotor, whereby the particles are reduced and fluidized; and an entrant of reduced diameter in the inlet opening.

3. Unit pulverizer according to claim 2, characterized by the fact that with a 24-inch rotor the inlet and outlet openings receive a 2-inch feed line, and the entrant of

the feed line in the inlet opening is not over 1-inch in diameter.

4. Unit pulverizer according to claim 2, characterized by the fact that the casing inlet and discharge openings are coaxial with the rotor, on opposite sides thereof, and both faces of the rotor disk are traversed by the streaming entrainment of pressurized air-borne coal particles.

5. A pneumatic-mechanical unit pulverizer of the character described, comprising, in combination, a sealed housing having a cylindrical body with front and rear cover walls incorporating bosses with axially aligned openings severally serving as a material inlet and a shaft opening and material discharge; a shaft hermetically journaled in the shaft opening; a disk in the housing, mounted for rotation on and with the shaft, and dividing the housing into a front or anterior, centrifugal impact and expansion chamber, and a rear, or posterior, material concentrating, fluidizing, and discharge chamber; a plurality of equiangularly disposed, radial vanes extending from the surface of the disk into the input chamber, whereby particulate solid material, carried in a pressurized stream of gasiform fluid, is impacted against the axis of the disk, and then centrifugally projected to and impacted against the inner surface of the wall of the housing as a spirally expanding, substantially flat, discoid air stream, and the entrained particles are beaten and projected by the rotating vanes; a plurality of concentric rows of radial vanes extending from the rear face of the disk into the posterior discharge chamber; a plurality of concentric rows of fixed radial vanes extending from the inner face of the rear cover into the annular gaps formed by and between the annular rows of rotating vanes on the rear face of the disk; and forming a multiplicity of labyrinthine, radially inward extending tortuous passages with the disk vanes; and a reduced material discharge opening in the shaft housing.

6. A pneumatic-mechanical unit pulverizer, of the character described, comprising, in combination, a rotatable disk having a flat front face, and a centrally apertured, bossed rear face, a journaled driving shaft secured in the boss of the rear face of the disk; a plurality of forwardly directed, equiangularly spaced, concentric radial vanes secured to the front face of the disk, and extending inwardly from the periphery of the disk to conjointly define a central well with the front face of the disk; an hermetic housing spacedly encasing the disk, said housing having centrally apertured front and rear bosses; a convergent nozzle axial inlet in the

front boss of the housing, for a pressurized, gas-borne stream of particulate material to be reduced, said inlet facing the axis of said disk; and a peripheral discharge opening in the rear boss of the housing.

7. Pneumatic-mechanical unit pulverizer according to claim 6, characterized by the fact that the axial inlet receives a conduit adapted to convey a pressurized, gas-borne stream of particulate material to be reduced, and the diameter of said conduit, upstream of the said inlet, is enlarged, whereby the velocity of the entrained solids in said stream is accelerated on passage through the inlet.

8. Pneumatic-mechanical unit pulverizer according to claim 5, characterized by the fact that the axial inlet serves as an entrant for a conduit adapted to convey a streaming entrainment of particulate solids in a pressurized stream of gaseous fluid, and said conduit is reduced in diameter immediately in advance of said inlet, whereby the velocity of the stream is accelerated.

9. A pneumatic-mechanical unit pulverizer, comprising, in combination, a hermetic casing including a cylindrical body portion and centrally apertured front and back covers; the diameter of the casing being greater than its depth; a rotor disk mounted for rotation in the housing and having close clearance with the body portion of the casing; combination impact-impeller vanes on the front and rear faces of the rotor and on the inside of the back cover, the vanes on the back cover intermeshing with the vanes on the rear face of the rotor; axial inlet means in the front cover incorporating a convergent nozzle; axial outlet means in the back cover at least equal in diameter to the axial inlet means in advance of the nozzle, the rotor dividing the casing into an upstream or front chamber, and a downstream or rear chamber.

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