Sept. 23, 1969 N. H. ANDREWS 3,468,489

COMMINUTING APPARATUS

Filed Oct. 22, 1965 2 Sheets-Sheet 1

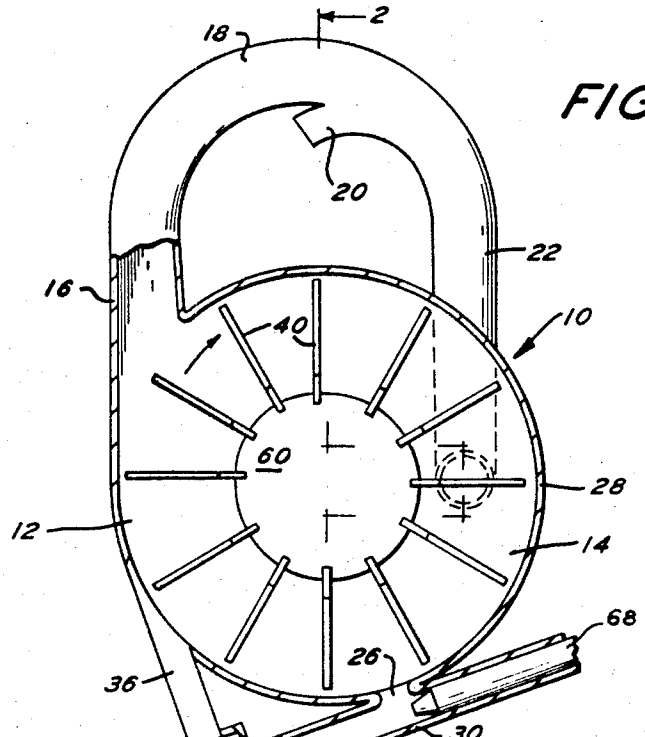


FIG. 1

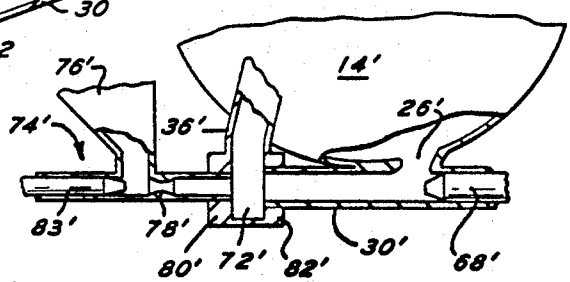


FIG. 3

FIG. 2

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FIG. 4

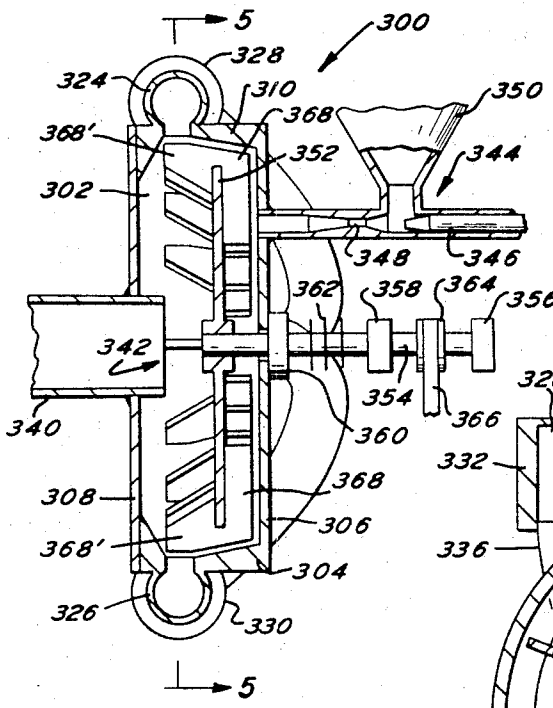


FIG. 5

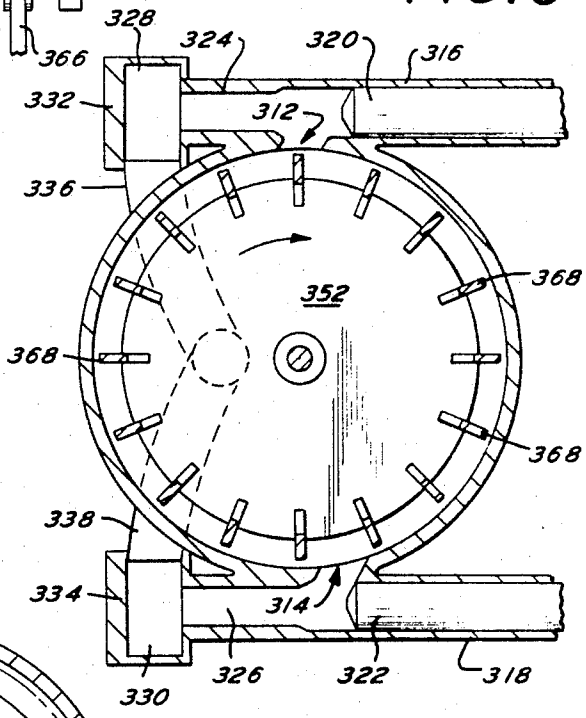
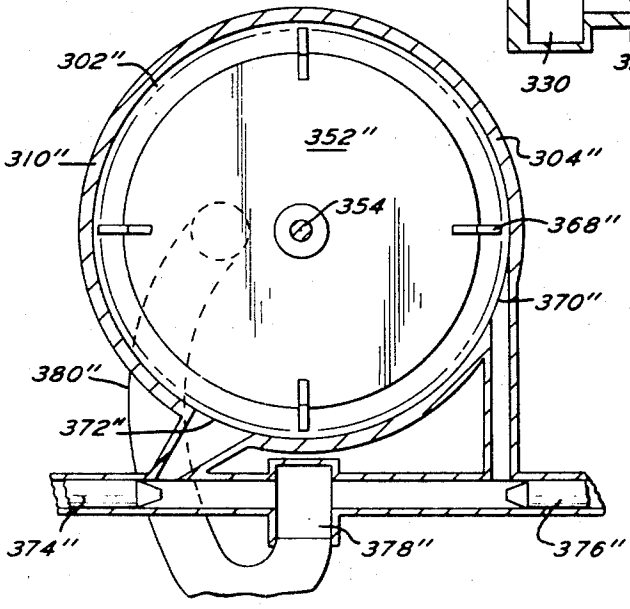


FIG. 6



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3,468,489

COMMINUTING APPARATUS

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Continuation-in-part of application Ser. No. 417,932, Dec. 14, 1964. This application Oct. 22, 1965, Ser. No. 509,251

Int. Cl. B02b *13/04*

U.S. Cl. 241—39 12 Claims

ABSTRACT OF THE DISCLOSURE

The present invention relates to a comminuting apparatus wherein a rotary impact device is combined with a high pressure jet impact device and wherein the jet device is so placed with respect to the rotary device that a maximum acceleration of the impacted material is gained for impacting and classification thereof.

This application is a continuation-in-part application of my co-pending applications Ser. No. 401,191 filed Oct. 2, 1964 and Ser. No. 417,932 filed Dec. 14, 1964, now abandoned.

My co-pending application Ser. No. 401,191 is directed to a new and unobvious improvement in the efficiency, as well as a broadening of the field of application of devices generally referred to as micronizers, reductionizers, and Jet-O-Mizers. The aforesaid application Ser. No. 401,191 describes a method, and a means for affecting the method, of circulating material and gas within a grinding chamber adjacent the inner peripheral wall into grinding jets. The material and gas are circulated adjacent the chamber peripheral wall by means of mechanically driven and rotating vanes. The circulation of the material and gas against the peripheral wall and into the jets results in a more successful utilization of jet energy in that generic type of device.

High pressure jet grinding, as such, is not new. The art goes well back into the 19th century. In fact some of the devices presently in use are substantial equivalents of developments made by a certain Luckenbach around the turn of the century. Later, improvements such as set forth in U.S. Patent 1,935,344 were made over the Luckenbach type of device. Additional improvements, such as illustrated in U.S. Patent 1,948,609 materially reduced maintenance in these early devices.

However, it was not until the development of the micronizer described in U.S. Patent 2,032,827 that high pressure jet pulverizing was applied on a broad basis. The reason for the acceptance of jet pulverizing after the invention set forth in Patent 2,032,827 was two-fold. Patent 2,032,827 recognized two fundamental facts. First, it recognized that an enormous amount of horsepower is required to sustain the flow of high pressure gas from a nozzle of even moderate size. For example, it might require more than 100 horsepower to maintain the required pressure in the throat of a half-inch nozzle. Secondly, it was recognized that the nozzle energy is dissipated at a very short distance. The overall result is that if material does not enter a jet stream at a point close to the nozzle, it is not accelerated to the maximum possible velocity. Since particle velocity is important to the comminuting efficiency of such apparatus, it is apparent that increases in velocity increase the efficiency of the apparatus.

In those types of devices where the material flows by gravity to the nozzle, it is actually aspirated into the jet stream and consequently does not enter the stream in large quantities at the point of maximum energy release. The gravity flow type of mills usually have opposed jets for impacting material upon itself, or such mills have a

jet and anvil where the jet directs the material against an anvil.

From the foregoing, it will be recognized that large particles cannot enter a jet stream at the point of greatest energy release. Consequently, jet comminuting devices are limited in the starting sizes of the feed product to a much finer size than most other types of pulverizing apparatus.

However, granular coarser material can enter the jet stream closer to the tip of the nozzle than extremely fine material. Not only does extremely fine material resist gravitational entrance into a high velocity jet at the point of discharge, but when most materials become extremely fine they have very poor flow characteristics. In fact, many materials would not gravitationally flow through the restricting means necessary to concentrate material returning to the jet at the point of jet release, it being noted that this is a very small area. The advantage of the micronizer described in Patent 2,032,827 was that the arrangement of the jet's rapidly circulated material being ground into the jet at the point of energy release.

The most important contribution of the micronizer is in the art of fine grinding. Chemical Metallurgical Engineering, volume 45, No. 5, May 1938 states that before the invention of the micronizer "dry grinding in the subsieve range (625 to 2500 theoretical mesh) has been commercially impractical and possible only at high cost." At the time of the invention of the micronizer high velocity jet impact grinding with relatively large amounts of extremely fine material produced by chance fracture was known. However, no successful way of separating the extremely fine fractions produced from the bulk of the otherwise circulating material was known.

By directing the nozzle in the micronizer, or reductionizer, or Jet-O-Mizer at an angle to the periphery of the grinding chamber, a considerable amount of the energy of the gas stream is directed into maintaining the speed of circulation of the gases within the grinding chamber. In this manner, these devices function both as classifiers and as grinders. This dual function is the result of having a rotational velocity within the classifying chamber that is related to the amount of input gas, such that it will classify to the desired particle size.

As has been pointed out in U.S. Patent 2,032,827 and again in my co-pending application Ser. No. 401,191, the rate of material feed affects the rate of material circulation within the grinding chamber. Thus, in part, the above-identified co-pending application is directed to maintaining the rate of material and gas circulation adjacent to periphery of the classifying chamber independent of considerable variations in the rate of the feed, as well as relieving the jets of circulating the gas. This permits the jets to be constantly supplied with the maximum amount of material which they are capable of efficiency reducing to the desired particle size. In those devices where all the gas and material are circulated together, and in fact, in any device, a continual rate of feed must be regulated to the grinding ability of the device if a controlled end product size is desired.

In devices such as those disclosed in Patent 2,032,827 angular impact is not as effective as direct impact. Consequently devices such as disclosed in U.S. Patent 2,704,635 and later modified to the form shown in U.S. Patent 2,735,626 use opposed jets combined with circulatory classifiers. As pointed out by A. G. Pendelton in the December 1963 issue of Chemical Process Engineering Magazine, a British publication, "the volume of gas circulating in the mill in often as much as twenty times that introduced at the nozzle and exhausted at the outlet." This quote has reference to the Jet-O-Mizer type of apparatus using the same type of classification as disclosed in Patents 2,704,635 and 2,735,626.

It therefore is apparent that all previous re-entrant circulatory stream devices require that great quantities of gas be re-circulated if any practical classification is to be provided. Moreover, all the re-circulated gases must be accelerated by the energy of a jet stream issuing from a nozzle. The necessity for expending a portion of the energy issuing from a nozzle in order to accelerate the circulating gases reduces the effectiveness of this form of jet grinding.

Also to be considered are those forms of devices disclosed in U.S. Patents 2,634,516 and 2,672,296. This type of device functions in a manner similar to that described in Patent 1,935,344 but with quite different exterior classification. Also to be noted are Patents 2,909,331 and 2,932,458 which disclose grinding apparatus similar to early Luckenbach patents such as U.S. Patent 697,505 with an external whizzer type of classification.

In connection with devices such as those disclosed in U.S. Patent 1,948,609, a fairly efficient grinding can be effected even in the two hundred mesh range. But generally speaking, Jet pulverizers of this type are only useful in the much finer range. Adapting the whizzer type of classifier to the opposed jet devices extends the range of their application into the subsieve range. However, when extremely fine material is required as the finished product, the circulating load becomes so fine that difficulty in introducing the material into the jet at the point of highest velocity becomes a limiting factor materially affecting the efficiency of the device, especially when products of low micron sizes are desired.

Again referring to volume 45, No. 5 of Chemical and Metallurgical Engineering, in connection with the size of feed material in reference to the operation of the micronizer: "It is not desirable to feed material which is too fine when this can readily be avoided as it has been observed that a top size of ⅛ inch to ¼ inch does not lower the capacity of the machine and has been found beneficial in a number of applications." (Note that ⅛ inch and ¼ inch would of course be related to the size of the jets.) In more recent years, this has been additionally explained by the amount of extreme fines produced as a result of the extremely high velocity fracture of the larger pieces, as well as the further reduction by the turbulent impact in the differential accelerating rate of coarse and fine materials as they co-react in a jet stream. Quite large pieces are not adaptable to entering a jet stream, and consequently jet mills are frequently fed the product of intermediate grinding mills such as hammermills. Hammermills operating on material actually requiring grinding (as distinguished from dispersal of agglomerates) are usually employed in the coarser sizes than jet mills are most frequently used. There is of course an area of overlapping of the effective use of each device on some materials.

It is therefore the general object of the present invention to provide means to take advantage of the known efficiency of direct impact comminuting, such as is used in the jet and anvil type of grinding devices as well as the opposed jet type, and improve their efficiency by providing means for separating the material under circulation from a major portion of its supporting gases and accelerating the material being reduced into the jet or jets while at the same time assisting the rate of circulation of the circulating gases.

It is another object of this invention to provide means whereby the material being reduced is mechanically accelerated into a jet or jets by vanes which also assist the rate of circulation of the circulating gases.

There is still another object of the present invention to provide comminuting apparatus having novel rotating vanes.

It is a further object of this invention to provide comminuting apparatus having dual chambers and novel communication means between said chambers.

It is another object of this invention to provide a comminuting apparatus having hammer mill grinding means in combination with novel classification means.

It is still another object of the present invention to provide comminuting apparatus wherein material being comminuted is mechanically introduced into a jet after it has been separated from the majority of its supporting fluid, and then returned to such fluid after impact, together with mechanical circulating means for acceleration through a classification means.

It is a further object of this invention to provide a novel comminuting apparatus having hammer means for introducing material into a jet in a condition separated from the majority of its supporting fluid, and means to return the material after impact to said fluid, together with mechanical circulating means for acceleration through a classification means.

It is yet another object of the present invention to provide novel comminuting apparatus having means to separate a portion of the supporting fluid away from material being comminuted before such material enters a final part of the classifying section.

It is another object of the present invention to provide a comminuting apparatus having two cooperating chambers, one of which is a hammer mill which directs material to be comminuted into a fluid jet, and the other chamber having vanes to accelerate material through a classifying means.

Other objects will appear here and after.

For the purpose of illustrating the invention, there are shown in the drawings forms which are presently preferred; it being understood, however, that this invention is not limited to the precise arrangements and instrumentalities shown.

FIGURE 1 is vertical sectional view of one of the embodiments of the present invention.

FIG. 2 is a transverse sectional view of the embodiment shown in FIG. 1 taken along the line 2—2.

FIG. 3 is a partial sectional view of a second embodiment of the present invention, illustrating that portion which differs from the embodiment shown in FIG. 1.

FIG. 4 is a sectional view of a third embodiment of the present invention.

FIG. 5 is a partial transverse sectional view of the embodiment shown in FIG. 4 taken along the line 5—5.

FIG. 6 is a sectional view of a fourth embodiment of the present invention.

Referring now to the drawings in detail, wherein like numerals indicate like elements, there is shown in FIGURE 1 a grinding apparatus in accordance with the present invention designated generally as **10**.

As shown, the grinding apparatus **10** comprises a generally circular chamber **12** defined by the cylindrical casing **14**. A duct **16** extends tangetially away from the casing **14**. A cross-duct **18** having an outlet **20** depending from its inner periphery connects the duct **16** to a return-duct **22**. The ducts **16**, **18** and **22** generally form a continuous duct which may be referred to as the grinding apparatus classifying section. As best shown in FIGURE 2, the duct **22** communicates with the casing **14** through its planar side **24**. As will be more fully explained below, the product laden gas is discharged through the outlet **20**.

An opening **26** is provided in the circular peripheral wall **28** of the casing **14**. The opening **26** permits the interior of casing **14** to communicate with an accelerating tube **30**. The tube **30** communicates at one end with an impact chamber **32**, having an impact block **24** disposed on the wall immediately opposite the open end of tube **30**. The tube **30** is disposed at an angle to the horizontal to aid the return of material and gas through opening **26**. A duct **36** openly communicates with impact chamber **32** and with the interior of casing **14** through wall **28**. The duct **36** is directed into casing **14** at a position on wall **28** and in a direction which allowing the vanes **40** to accelerate material being ground before it enters the classifying section through duct **16**. Thus, duct **36** is spaced from duct **16** on wall **28**.

A rotatable shaft **42** mounted on bearings **44** and **46** extends through the casing **14** and chamber **12**. The shaft **42** is coaxial of the casing **14**. Cooling fins **48** and **50** are mounted on the shaft **42**. A pair of stuffing boxes **52** and **54** serve to permit the shaft **42** to pass through the chamber **12** in gas-tight rotatable relationship therewith. The shaft **42** may be rotated by means of a pulley **56** driven by a belt **58** and motor (not shown).

Within the chamber **12**, a disk **60** is mounted on the shaft **42** intermediate the walls **24** and **38**. The disk **60** is fixedly mounted to the shaft **42** and rotates therewith. As best shown in FIGURE 1, the vanes **40** are mounted at uniformly spaced points about the periphery of disk **60**. The vanes **40** extend from the disk **60** to a position close to the periphery **28** of casing **14**.

As shown in FIGURE 2, an injector feed assembly **62** consisting of a hopper **64** and gas-fed venturi **66** is provided to feed material into the casing **12**. The operation of the injector feed assembly **62** to entrain feed material in a gas stream is known in the art and need not be described in detail. The injector feed assembly **62** communicates with the lower portion of duct **22** in a manner that permits material to be fed through the planar wall **24** into impact with the disk **60**. It is to be understood that other feed means could be used to accomplish the purposes of this invention.

The injector feed assembly **62** feeds the material into impact with disk **60** whereupon it is dispersed and engaged by the vanes **40**. The vanes **40** are rotating when the injection of feed material is made. The vanes **40** engage the feed material gas to drive it against the inner periphery of peripheral wall **28**. Because of their proximity to the peripheral wall **28**, the vanes **40** will direct a circulating mixture of gas and feed material into opening **26**. The spacing between the ends of vanes **40** and wall **28** is adjusted to provide the optimum between efficient grinding and vane wear.

A nozzle **68** which communicates with a high pressure source of gas (not shown) is located adjacent the opening **26** opposite to the tube **30**.

When high pressure gas applied to the nozzle **68**, feed material which is forcibly directed through opening **26** by vanes **40** is projected into the jet of gas issuing from nozzle **68** and becomes entrained therein. The point of entry into the jet is close to the nozzle **68**. Hence the material is more highly accelerated. The material so entrained in the jet of gas issuing from nozzle **68** is directed into and through accelerating tube **30** into impact with the impact block **34** which forms the end of chamber **32**. The force of impact of the material upon the block **34** sometimes referred to as an anvil, will comminute the material.

Within the chamber **32**, the velocity of the gas is converted into a pressure head causing the material entrained therein to flow through the duct **36** and back into the chamber **12**. As the material enters the chamber **12** from the duct **36**, it is engaged again by the vanes **40** which accelerate it together with the material carrying gases into the duct **16**. The thus-accelerated material and gases pass through the duct **16** into the classifying zone, which is the duct **18** extending between ducts **16** and **22**. A portion of the gas leaves the duct **18** through outlet **20** carrying with it those fractions of material representing a finished product. The operation of a classifying zone in duct **18** is known. Various shapes and cross sections are described in the prior art as well as the shape and location of duct **20**. Consequently, the classifying section need not be described in further detail.

The greater portion of the gas in duct **18** carries the insufficiently reduced material past the outlet **20**, through the duct **22** and into the chamber **12** at the same point where it originally entered chamber **12** as feed material. The material which has been partially ground is mixed with feed material and again accelerated by the vanes **40** after dispersion by impact with disk **60**. The vanes **40** also concentrate the partially ground material adjacent the inner periphery of wall **28** where it is projected into opening **26**. A large portion of the circulating gases freely circulate past the outlet **26** and do not enter the tube **30** through opening **26**. Consequently, the grinding jet created by nozzle **68** does not have to accelerate the recirculating gases as well as the partially ground material. Therefore, the jet created by nozzle **68** is free to perform its work primarily upon the material being ground. The gases returning from the duct **22** and moving past the opening **26** merge with the gas coming from the impact chamber **32** through the duct **36** and exit from chamber **12** by means of duct **16** as previously described.

FIGURE 3 represents a modification of the embodiment shown in FIGURES 1 and 2. Like elements have the same number used in describing FIGURE 1, except a prime is added.

As shown, the embodiment represented by FIGURE 3 includes a casing **14'** communicating with a tube **30'** through an opening **26'**. A nozzle **68'** is connected to a high pressure source of gas (not shown) and is disposed opposite the end of tube **30'** which is adjacent opening **26'**. The other end of tube **30'** communicates with an impact chamber **72'**. A return duct **36'** also communicates with the impact chamber **72'**.

The side of impact chamber **72'** opposite the tube **30'** communicates with an injector feed assembly **74'**. The injector feed assembly **74'** includes a funnel **76'**, a venturi **78'**, and a nozzle **83'** connected to a source of high pressure gas (not shown).

The gas issuing from nozzle **83'** is in the form of a jet which entrains feed material supplied to it from funnel **76'** and carries it into chamber **72'**. In this manner, the raw feed material is impacted against the insufficiently ground material being projected from the end of accelerating tube **30'**.

Throughout the description of the embodiments shown in FIGURES 1 and 3, mention has been made of accelerating tubes **30** and **30'**. It should be pointed out that considerable grinding is actually accomplished in these tubes. The grinding action within tubes **30** and **30'** occurs in somewhat the same manner demonstrated in the so-called flash pulverizer in Perry's fourth edition of Chemical Engineers Handbook. Thus, the handbook states that, "It was later demonstrated that the size reduction was actually accomplished by impact of the particles upon the nozzle walls and by attrition among the particles as they passed at high velocity and in a very turbulent flow through the nozzle." It has been determined that by more highly concentrating material relative to the volume of gas flowing with it, there is a large increase in the opportunity for inner action among the particles. The apparatus shown in FIGURES 1 and 3, as well as others shown herein, enables the material to be more highly concentrated.

It has been determined that there are optimum lengths for the tubes **30** and **30'**. The optimum lengths are determined by trial and error. However, it has been recognized that the length of the tube will vary in accordance with at least the following factors:

(1) The specific gravity of the material being ground.
(2) The grindability of the material being ground.
(3) The ultimate particle size to which the material being ground is to be reduced.
(4) The size of the initial feed material.
(5) The size of the mill.

With respect to the fifth parameter, the size of the mill will also be a factor in determining the size of the main jet supply nozzles **68** and **68'**. Accordingly, the length of accelerator tubes **30** and **30'** will be much longer for a main supply nozzle **68** or **68'** that has an increased size over nozzles used for smaller mills.

By way of example, it has been found that an accelerating tube of ten inches is satisfactory for a one-quarter

inch nozzle operating at one hundred pounds pressure for many materials.

In the embodiment shown in FIGURE 3, it has been found desirable to surround both feed tubes with impact blocks 80' and 82'. Thus, material not comminuted by impact with particles travelling in the opposite direction may be comminuted by impact with an impact block.

Referring now to FIGURES 4 and 5, there is shown another embodiment of the invention designated generally as 300.

As shown, the mill 300 comprises a classifying chamber 302 of substantially circular cross section. The chamber 302 is defined by the casing 304 which comprises side plates 306 and 308 mounted upon a peripheral wall 310. The peripheral wall 310 includes a pair of spaced apart openings 312 and 314 which permit the chamber 302 to communicate with the jet grinding assemblies 316 and 318.

The jet grinding assemblies 316 and 318 include nozzles 320 and 322, accelerating tubes 324 and 326, impact chambers 328 and 330, and impact blocks 332 and 334. The nozzles 320 and 322 are connected to a common source of high pressure gas (not shown). Ducts 336 and 338 provide open communication from the impact chambers 328 and 330 to the chamber 302 through side plate 306. The operation of the assemblies 316 and 318 is similar to those which have previously been described and therefore need not be repeated in detail.

A duct 340 is centrally mounted in plate 308. The opening 342 created by duct 340 is of sufficient size to allow the discharge of pulverized products together with circulating gas from the chamber 302. A collector means (not shown) may be connected to the duct 340.

Material to be pulverized is introduced into the chamber 302 by means of a feed assembly 344. The feed assembly 344 comprises a nozzle 346 connected to a source of high pressure gas (not shown), a venturi 348, and a funnel 350. In accordance with principles previously described, the jet of gas issuing from nozzle 346 passes through venturi 348 carrying material from funnel 350 into the chamber 302. Material is discharged against disk 352.

A shaft 354 is rotatably mounted on bearings 356 and 358 and extends through plate 306 into the classifying chamber 302. The stuffing box 360 seals the chamber at the point where shaft 354 passes through plate 306. Fins 362 are attached to shaft 354, and serve to dissipate heat that may be transmitted from chamber 302 towards bearing 358. A pulley 364 and belt 368 are adapted to cause shaft 354 to rotate when driven by a motor (not shown).

The disk 352 is fixedly mounted on the ends of shaft 354 and rotates therewith. A plurality of vanes 368 are attached at equally spaced points about the periphery of disk 352.

As material is forced into the chamber 302, it impinges upon rotating disk 352 and is dispersed. As it is dispersed, the vanes 368 pick up the material and accelerate it radially into impact with peripheral wall 310. The relationship of the vanes 368 to the peripheral wall 310 causes a forced circulation of the gas and material adjacent thereto and general movement or flow towards and into the openings 312 and 314. The material is directed into the jets created by nozzles 320 and 322 and projected through the accelerating tubes 324 and 326 into the impact chambers 328 and 330. Further, the vanes 368 extend to a position which is closely adjacent to the peripheral wall 310. It should also be noted that the inside diameter of peripheral wall 310 increases in an axial direction extending from plate 306 towards openings 312 and 314. This aids the movement of material toward openings 312 and 314.

In accordance with principles already discussed, material exits from impact chambers 328 and 330 through ducts 336 and 338, and is carried by the circulating gas back into the chamber 302 on the side of disk 352 closest to feeding means 344. As best shown in FIGURE 4, a portion 368' of the vanes 368 extends outwardly through the disk 352 on the side closest to duct 340. The portion 368' aids the circulating stream of gases and increases the centrifugal force on the re-entrant materials which are to be directed back into outlets 312 and 314. Thus, the vane portions 368' intercept and accelerate a coniderable portion of the material which is only partially ground and must be returned for further grinding.

Another function of the portions 368' is to aid the circulating gases in creating the classification vortex which carries the ground product to the center of disk 352 and out of the classifying chamber 302 through duct 340.

Although the operation and function of openings 312 and 314 together with jet grinding assemblies 316 and 318 have been described together, it is not necessarily intended that they both operate at the same time. Referring to FIGURE 5, it will be noted that openings 312 and 314 have opposed angular relationships with their respective nozzles 320 and 322. Thus, for clockwise rotation of disk 352 and vanes 368, material be directed through opening 312 and into the jet stream created by nozzle 320 in a direction which is opposed to the force of the said jet stream. On the other hand, material accelerated through opening 314, with the disk 352 turning in a clockwise direction, will have a directional component which is the same as that of the jet stream created by nozzle 322. Accordingly, different grinding results will be produced by the assemblies 316 and 318. For this reason, it is possible that the assemblies may be used simultaneously or alternatively. For alternative use, plugs (not shown) may be provided to close either of the openings 312 and 314.

The choice of which grinding assembly to use depends upon several factors. Among the factors to be considered are the type of material being ground including its specific gravity and grindability, the size of particle desired, and the size of the mill.

Referring now to FIGURE 6, there is shown another embodiment of the present invention. The embodiment shown in FIGURE 6 represents a modification of the embodiment shown in FIGURES 4 and 5. Accordingly, only such details as are necessary to explain the distinctions are illustrated. Further, like elements have been provided with like numbers, except as distinguished by a double prime.

As shown, the disk 352" has a plurality of vanes 368" spaced about its periphery. Only four of the vanes 368" are shown, however, it is to be understood that as many as desired may be provided. The disk 352" is fixedly mounted on a shaft 354" and rotates therewith. The disk 352" and vanes 368" are mounted within a casing 304" having a circular peripheral wall 310". The vanes 368" are shaped like the vanes 368 of FIGURE 4 and extend from both sides of the disk 352".

As shown, the peripheral wall 310" is provided with two outlets 370" and 372". A combination of unground and partially ground material is fed through the openings 370" and 372" into the jets created by the nozzles 374" and 376" which are fed by a source of high pressure gas (not shown). As shown, the grinding nozzles 374" and 376" are in opposed axial alignment, and the material projected by them is impacted against itself in impact chamber 378".

The opening 370" may be smaller than the opening 372" because coarser material will be discharged first out of opening 370". A duct 380" is provided in impact chamber 378" to return the material to chamber 302".

Based upon the principles previously recited, the operation of the mill shown in FIGURE 6 should be readily apparent. Therefore, no detailed description of this operation will be given.

Throughout the specification where the term "gas" has been used, it can be any one of several fluids which are known in the art. For example, high temperature superheated steam may be employed as the gaseous medium. If this is the case, high-temperature packing should be

used in the stuffing boxes, and as shown, the bearings closest to the mill should be shielded from the transfer of heat along the shaft.

It should also be borne in mind that, in general, a greater number of vanes in any of these devices will assist in the circulation and turning them at higher velocities should result in a finer product.

In connection with FIGURES 20 and 21, as well as others, it might be desirable to have more than one nozzle cooperating with those illustrated in the drawings, or more distributed at other points around the periphery of the various devices.

The present invention may be embodied in other specific forms without departing from the spirit or essential attributes thereof and, accordingly, reference should be made to the appended claims, rather than to the foregoing specification as indicating the scope of the invention.

I claim:

1. Apparatus for the reduction of material comprising a classifying chamber having an intermediate curvilinear portion outlet means disposed on the inward periphery of said curvilinear portion for the discharge of fluid and reduced material, said classifying chamber being connected to a substantially circular casing having a rotatable element therein, said element including vanes adapted to cause a circulation of fluid and material through said classifying chamber and at least a portion of said casing, means for introducing material to be ground into said casing, second outlet means adjacent the periphery of said casing for the discharge of material circulating therein, a nozzle mounted adjacent said second outlet, said nozzle being adapted to create a high velocity jet of fluid for accelerating material discharged through said second outlet into an impact chamber, and means for conducting fluid and material back to said casing for acceleration by said rotatable element.

2. An apparatus for the reduction of material comprising a substantially circular chamber having a rotatable element therein, said rotatable element including vanes adapted to cause rapid circulation of fluid and material within said chamber, said chamber being connected with a curvilinear duct for circulating material and fluid through the curvilinear duct and at least a portion of the circular chamber, first outlet means disposed inwardly of the periphery of said curvilinear duct for the discharge of fluid and finished material, second outlet means adjacent the outer periphery of said chamber for the discharge of material under treatment, a nozzle adapted to create a jet of fluid adjacent said second outlet and thereby accelerate material discharged from said second outlet into impact with an impact means, conducting means for the return of fluid and impacted material back into said circular casing, and means for feeding material to be ground into said casing.

3. Apparatus for the reduction of material comprising a substantially circular chamber, a rotatable element within said chamber, said element including vanes adapted to cause the rapid circulation of fluid and material within said chamber, said chamber being joined with a curvilinear duct for circulating material and gas through the curvilinear duct and at least a portion of the chamber, first outlet means disposed inwardly of the periphery of said curvilinear duct for the discharge of gas and finished material, second outlet means adjacent the outer periphery of the chamber for the discharge of material under treatment, first nozzle means adapted to create a jet of gas adjacent said second outlet for accelerating material discharged therethrough, feed means including a feed nozzle for creating a high velocity jet for accelerating feed material, said first nozzle and said feed nozzle being adapted to accelerate material and feed material in axially opposed directions whereby material under treatment is impacted upon feed material, and conducting means for returning fluid and impacted material into said casing.

4. Apparatus for comminuting material comprising means for forming a high velocity jet adjacent an outlet in the periphery of a substantially circular casing, rotatable vanes within said casing adapted to circulate material under treatment adjacent the inner periphery of said casing, said vanes also being adapted to accelerate said material under treatment through said outlet at a high velocity, an impact block, an accelerating tube between said nozzle and said impact block, said accelerating tube cooperating in the reduction of material, and means for conducting material from said impact block back into said casing, second material and fluid conducting means for providing open communication between said casing and the entrance portion of a classification means, a return conducting means for providing open communication between an exit portion of said classification means and said casing, said classification means including outlet means for discharge of fluid and finished material.

5. Apparatus for comminuting material including means for forming a high velocity jet adjacent an outlet in the periphery of a circular casing, said outlet providing open communication between the inside of said casing and said jet forming means, a plurality of vanes adapted to rotate adjacent the inner periphery of said casing, said vanes also being adapted to project material at a high velocity through said outlet in the periphery of said circular casing and into a jet created by said jet forming means, an accelerating tube in axial alignment with a feed means, said feed means including means for accelerating feed material in a direction opposite to the direction of said material acceleration, whereby feed material and material under treatment will be projected at high velocities in opposite directions and into impact, a partially curved duct extending from and returning to said casing in open communication therewith, said curved duct and a portion of said casing forming a circulating means for the material under treatment, second outlet means disposed inwardly of the periphery of the curved duct for the discharge of fluid and finished material.

6. Apparatus in accordance with claim 5 wherein at least the end of said accelerating tube closest to said feed means is provided with a wear-resistant material.

7. An apparatus for the reduction of material comprising a substantially circular chamber having a rotatable element therein, said rotatable element including means to cause rapid circulation of fluid and material within said chamber, said chamber being connected with finished material classifying means, first outlet means on said classifying means for the discharge of fluid and finished material, second outlet means adjacent the outer periphery of said chamber for the discharge of material under treatment, a nozzle adapted to create a jet of fluid and accelerate material discharged from said second outlet into impact with an impact means, conducting means for the return of fluid and impacted material to be reduced into said apparatus.

8. Apparatus in accordance with claim 7 wherein said classifying means is a curvilinear duct.

9. Apparatus for the reduction of material, a generally circular casing, rotatable vanes within said casing for forcibly circulating material under reduction adjacent the inner periphery of said casing, an outlet in the periphery of said casing for the discharge of material under reduction, means for creating a high velocity jet adjacent said outlet and for accelerating material discharged through said outlet, said means accelerating the material into impact with an impacting means, means for conducting the impacted material back into said casing, and fluid and finished product discharge means disposes centrally of said casing.

10. Apparatus for the reduction of material comprising a substantially circular chamber, a rotatable element

within said chamber, said element including vanes adapted to cause rapid circulation of fluid and material within said chamber means providing fluid and material communication between said chamber and a finished product classifying means, outlet means associated with the classifying means for discharge of the finished product, means for generating a jet of fluid and impacting partially reducted material against an impact reduction means, means for conducting said impacted material back into said circular chamber, and means for feeding raw material into said apparatus.

11. Apparatus for the reduction of material comprising classifying means, said classifying means being connected to a substantially circular casing having a rotatable element therein, said element including vanes adapted to cause a circulation of fluid and material through said classifying chamber and at least a portion of said casing, means for introducing material to be ground into said casing, outlet means adjacent the periphery of said casing for the discharge of material circulating therein, a nozzle mounted adjacent said outlet means, said nozzle being adapted to create a high velocity jet of fluid for accelerating material discharged through said outlet means into an impact chamber, and conduit means for conducting fluid and material from said impact chamber back to said casing for acceleration by said rotatable element.

12. Apparatus in accordance with claim **11** wherein there are two outlet means adjacent the periphery of said casing, and a nozzle mounted adjacent each of said two outlet means for creating a high velocity jet of fluid for accelerating material discharged through both said outlet means into impact chambers.

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