Feb. 14, 1950 H. G. LYKKEN ET AL 2,497,088

VORTICAL CLASSIFYING MACHINE

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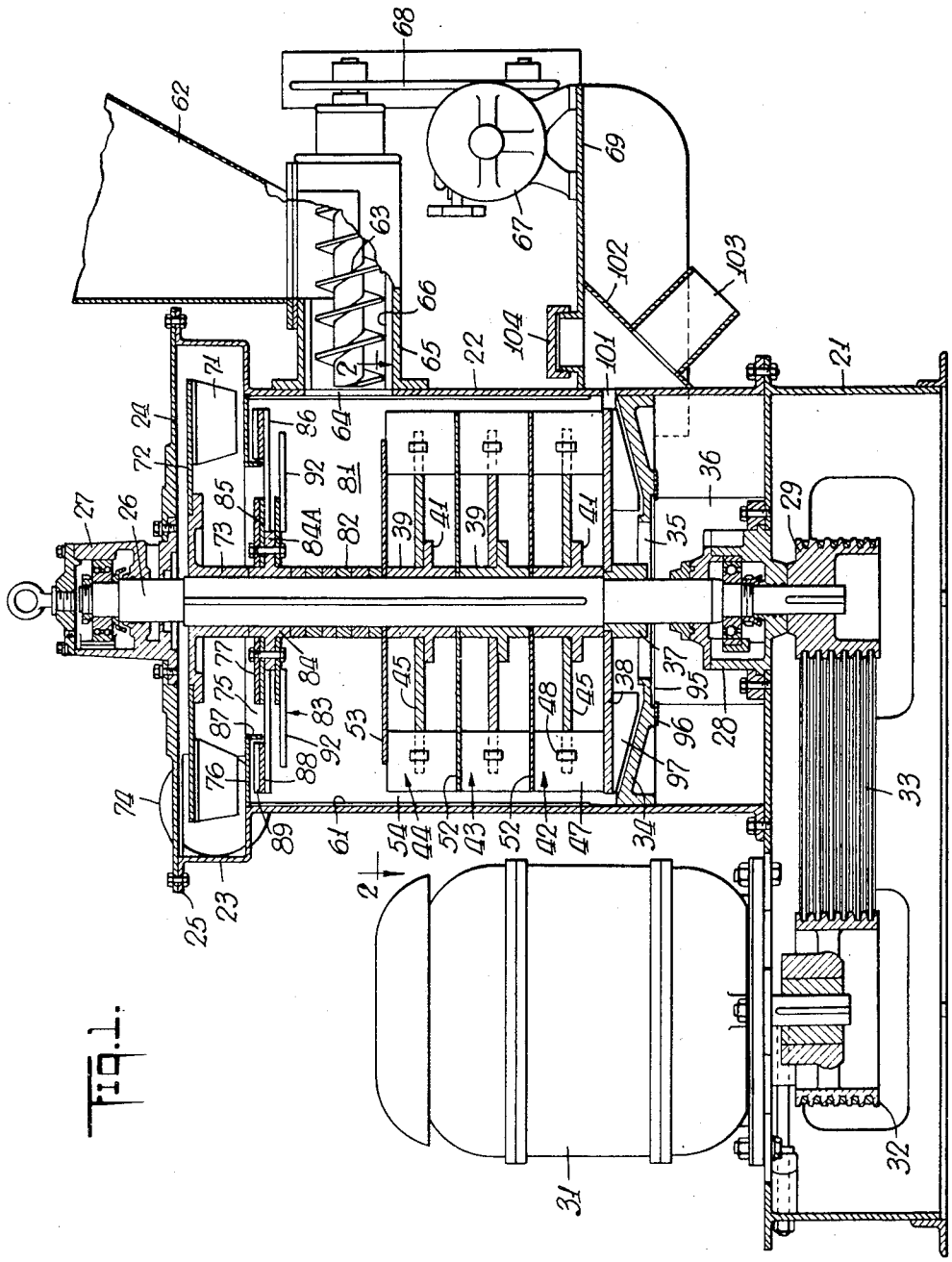


Fig. 1.

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FIG. 2.

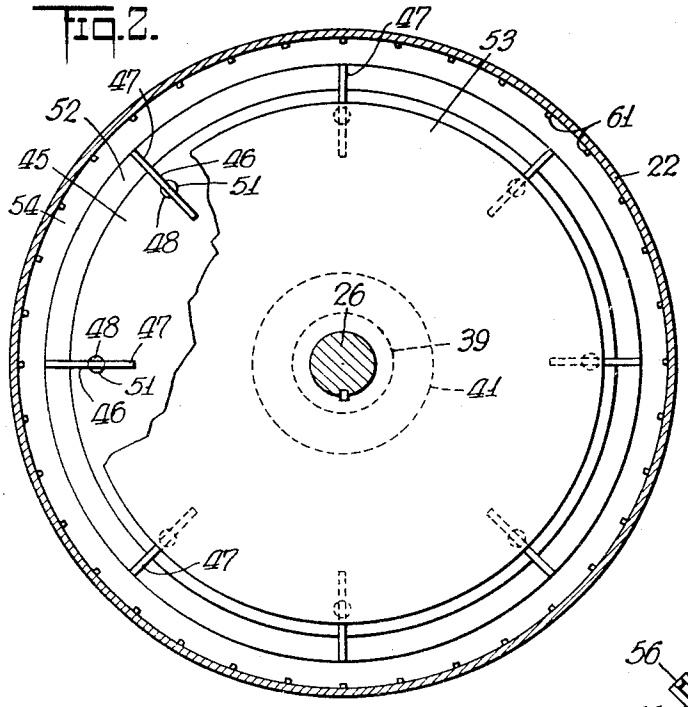


FIG. 3.

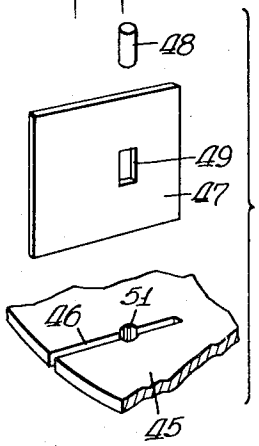


FIG. 4.

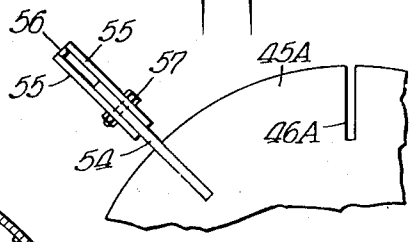


FIG. 5.

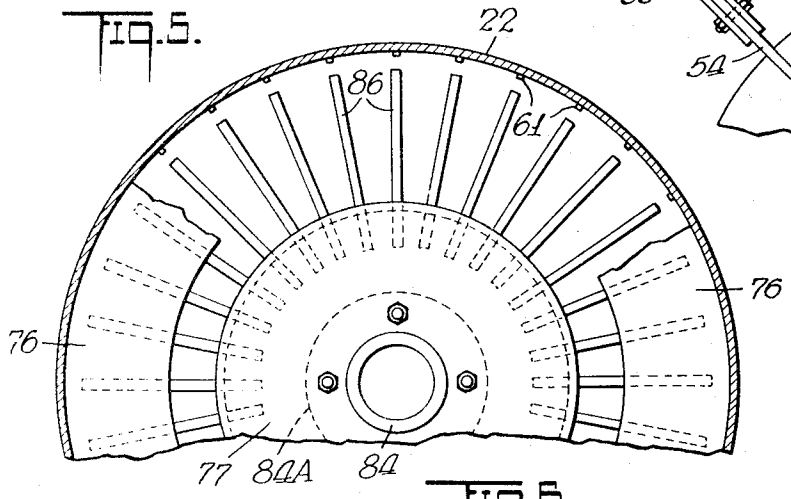
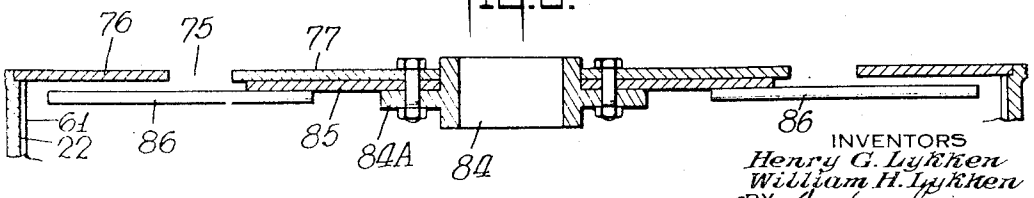


FIG. 6.



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Fig. 7.

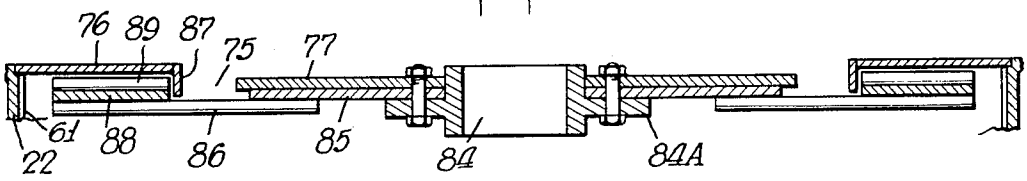


Fig. 8.

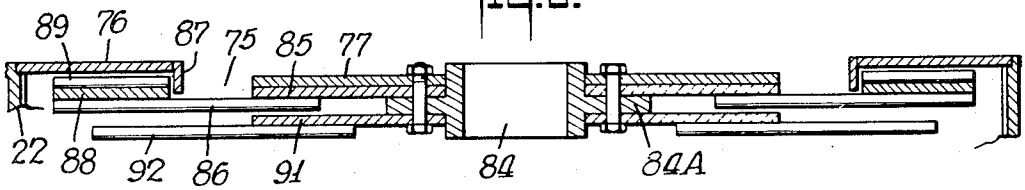


Fig. 9.

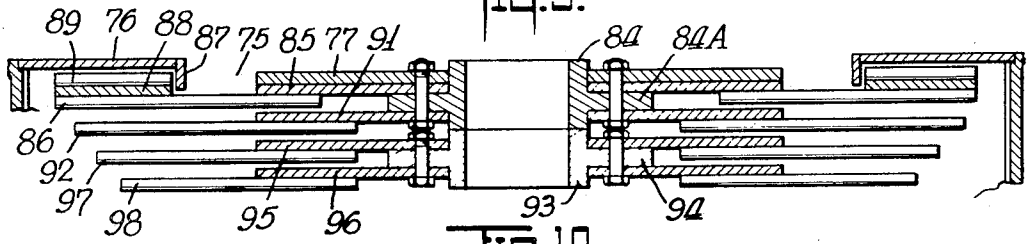
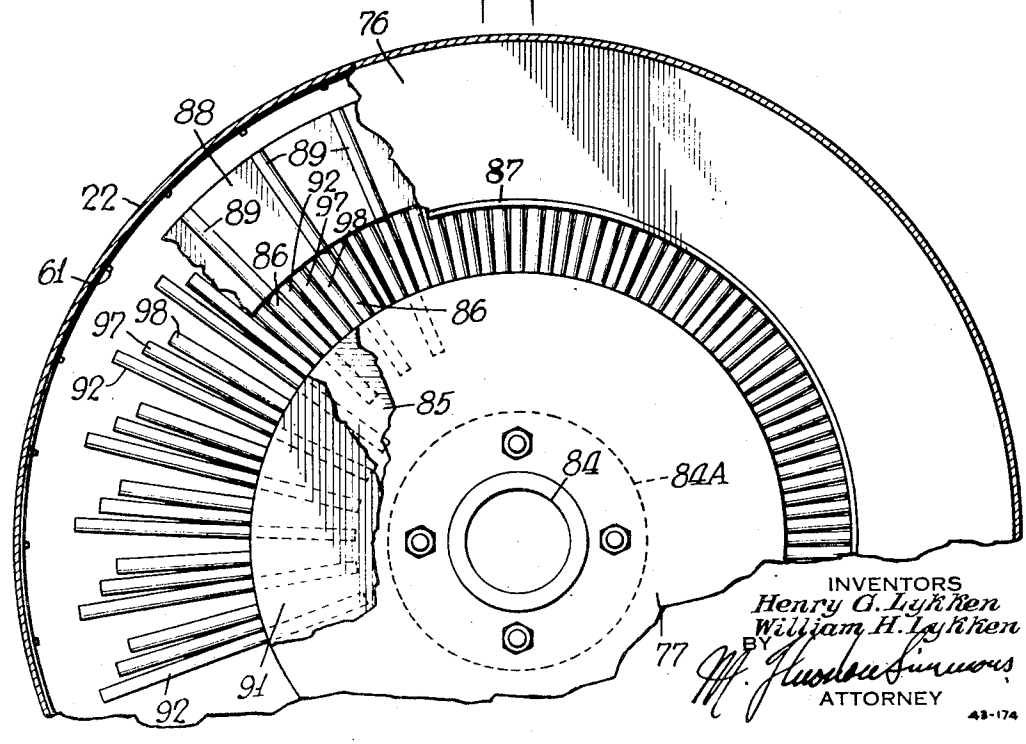


Fig. 10.



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Fig. 11.

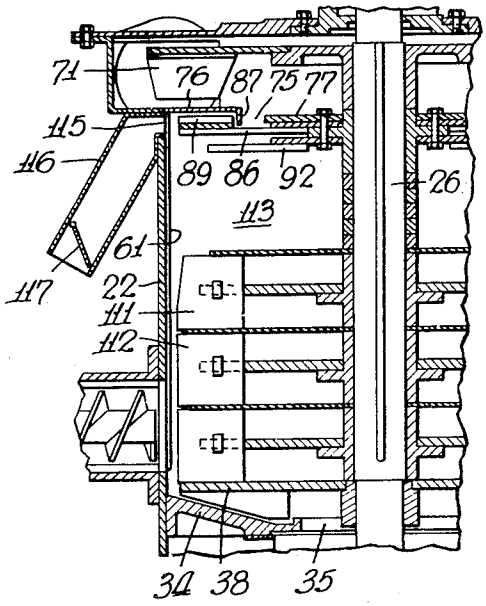


Fig. 12.

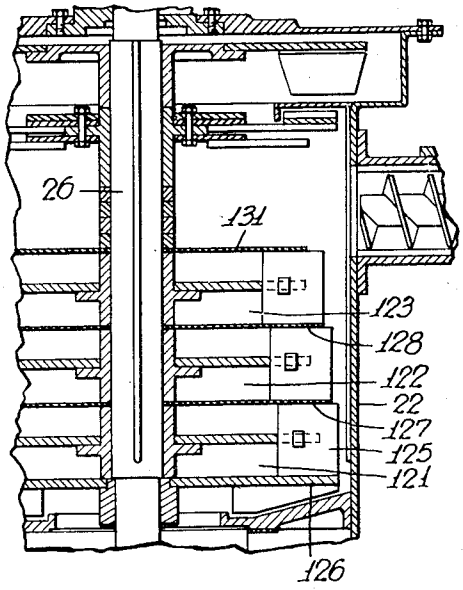
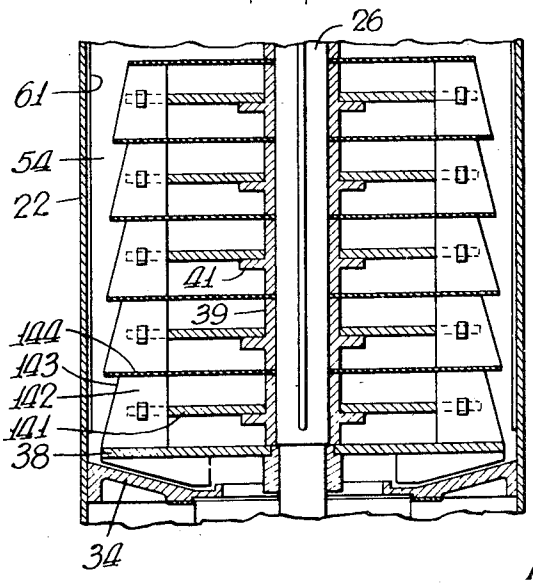


Fig. 13.



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Patented Feb. 14, 1950 2,497,088

UNITED STATES PATENT OFFICE

2,497,088

VORTICAL CLASSIFYING MACHINE

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Application August 17, 1943, Serial No. 498,988

4 Claims. (Cl. 209—144)

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Our invention relates to new and improved constructions of pulverizing machines, and also of classifier units for use with the same or other constructions of pulverizing machines.

In our co-pending application Ser. No. 484,898, now Patent 2,440,285 of April 27, 1948, there is described and claimed a sectionalized pulverizing rotor which sets up a pulverizing vortex of air or gaseous suspended friable material in the annular space around the rotor and between it and the walls of the enclosing casing. Sectionalizing the rotor may be done by dividing the same vertically by the use of one or more horizontal discs, or separate rotor sections may be mounted on the same shaft and separated by the horizontal discs. In either event the sections are usually from four to six inches in height, and the separating discs may vary in diameter in accordance with the nature of the material being pulverized and the desired fineness of the delivered particle size. The sectioned rotor serves to substantially reduce the tendency toward upward movement of the oversize material into the upper part of the casing, in which the classification or selection of the material takes place, i. e., a more even distribution of the load is secured. After the selection of the desired material, the oversize falls back to the pulverizing vortex for further reduction in particle size.

It has now been discovered that if the material to be pulverized is introduced at the top of the pulverizing vortex, the rotor sections can be so proportioned and the feed so regulated that a wide variety of results can be obtained which renders this construction adaptable for numerous pulverizing operations and industrial processes.

For example, in one rotor arrangement and by regulation of the automatic feed mechanism for the material, all pulverization of the desired material is completed before any material reaches the floor of the rotor chamber. And in another arrangement, differential grinding can be effected, so that a material of greater or less specific gravity can be separated from the other materials.

In our machine, air is admitted to the rotor chamber from beneath the rotor and flows counter to or across the path of the pulverizing vortex. The volume of this air is proportioned so as to lift the sufficiently pulverized material out of the pulverizing vortex as continuously and as rapidly as it is produced. Thus, one advantage of this construction is that an increased grinding capacity is obtained without an increase in size of machine over what has heretofore been found to be necessary; a second advantage is more uniformity of

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results in quicker time; and a third advantage is simplification of the classification problems.

As to the other classes of pulverization, providing a bleeder outlet at the level of the floor of the rotor, impurities of higher specific gravity than the desired material will pass through the pulverizing zone without being reduced, will be separated from the desired material in the course of the pulverization, and be continuously eliminated from the machine.

On the other hand, the desired material may be of greater specific gravity than the substance in which it is found; and in those cases, the arrangement of the rotor can be such as to pulverize and separate the lighter, undesired material, removing the same from the top of the casing, and collecting the desired material through the bottom bleed-off. If thereafter it is desired to pulverize the collected material, the rotor and feed can be so proportioned and arranged to do so because we have successfully pulverized such easily reducible materials as talc (separating silica impurities therefrom) on the one hand, and pulverized such difficult friable materials as silica and steel, on the other hand, as well as many other materials that are more or less friable.

Again, in the event of an accidental over-feeding of the material, the excess will reach the floor of the rotor and be taken off through the bleeder; but with some materials it has been found advantageous to deliberately overfeed the same, as the normal operation of the machine, allowing such excess to pass off through the lower outlet.

In other cases, where the undesired material is not of greater specific gravity than the desired material, a top bleedoff device can be arranged to remove the impurity, and this, insofar as our present experience goes, operates in conjunction with our improved classifier.

Certain details of the pulverizing mechanism are adaptable to other forms of pulverizing machines, and as was noted above, the use of our improved classifier is not confined to the construction of pulverizing machine described in detail in this application.

Referring now to the classifier unit, several constructions have been proposed heretofore, and each of which has shown an improvement in operation in the matter of eliminating oversize particles from the desired materials delivered from the machine. These have worked on the general principles of attempting to eliminate the oversize by means of a classifying vortex; and various arrangements of outlets and dispositions and sizes thereof, have been used with advantage.

But in all these cases there have been elements disturbing the classifier action, so that good, but not perfect, classification has resulted.

By the constructions and arrangements described in this application, we are able to set up and maintain a classifying vortex of air or gas suspended material that is sufficiently free from influences which disturb the continuity and smoothness thereof that a definite balance can be maintained at all times between an induced withdrawing current opposing the centrifugal force of the vortex, whereby the withdrawing current will remove the sufficiently pulverized material without removing oversize particles. At the same time, the elimination of the oversize is very materially aided, first, by the special construction of classifier rotor element which sets up and maintains the vortex, second, by the relationship thereof to the particular outlet arrangement, and third, by the size and disposition of the outlet.

In addition, a sealing arrangement operating in conjunction with the outlet insures against oversize by-passing the rotor.

Like the pulverizing rotor, the classifier rotor will be varied in construction in accordance with the nature of the material, the fineness of the particle size, and so on. That is to say, a different arrangement of classifier rotor unit outlet and sealing ring will be used if the maximum delivered particle size is 5 microns, over the arrangements for the delivery of 200 screen mesh material; and also will vary for talc or sugar, or cocoa, or the more friable materials.

Hard and fast rules constituting laws for the construction of this apparatus are not possible, but in the specification we will set forth sufficient examples that the principles for both the pulverizing and classifying operations will be understood, and variations of the same for other uses will be evident. Furthermore, the entire construction is such that the machine may be readily assembled from pre-fabricated units in the adaptation of the machine to the variety of uses and processes, and this may be done as readily both in the manufacture of the machine originally and in re-arrangements thereof by the customer or user to suit his varying needs.

Broadly stated, therefore, the main objects of our invention may be stated as the improvement of the construction and methods of operation of pulverizing apparatus to improve the output thereof and to make the apparatus more widely and readily applicable to the pulverization of a greater variety of friable materials; and to provide a classifier arrangement which will obviate the inclusion of oversize particles in the delivered material whether the selected material is to be of a particle size of 2 microns or relatively large particles such as 50 mesh material.

It is another object of our invention to provide in combination in one casing means for setting up and maintaining a pulverizing vortex of air suspended material in which the vertical circulating load of insufficiently pulverized material is greatly minimized together with an independently acting means in the same casing for setting up and maintaining a classifying vortex of air suspended material, which as a practical matter, is free of influences disturbing the classifying vortex.

It is a further object of our invention to provide a construction of pulverizing apparatus which is susceptible of operation so as to concurrently eliminate impurities from the selected material whether that material be of higher or lower specific gravity than the selected material.

Other and further objects of our invention will be apparent from this specification, taken in conjunction with the accompanying drawings, in which—

Figure 1 is a central vertical section of a unitary pulverizing and classifying machine according to our invention.

Fig. 2 is a cross section taken on the line 2—2 of Fig. 1.

Fig. 3 is an exploded view in enlarged detail of one method of mounting the blades of the pulverizing rotor.

Fig. 4 is a fragmentary view of a modified construction of pulverizing rotor.

Fig. 5 is a fragmentary plan view of the outlet and a classifying rotor according to this invention, parts being broken away to facilitate the illustration.

Fig. 6 is a view in enlarged detail and in section showing one construction and arrangement of classifier for the pulverized material according to this invention.

Fig. 7 is a view similar to Fig. 6 showing the addition of a sealing arrangement at the material outlet.

Fig. 8 is an enlarged detail in section showing a modified construction of classifier rotor.

Fig. 9 is an enlarged detail in section showing a further modified construction of classifier rotor.

Fig. 10 is a fragmentary plan view of the arrangement of Fig. 9, parts being broken away to facilitate the illustration.

Fig. 11 is a fragmentary sectional view illustrating certain modified arrangements in material feed, pulverizing and auxiliary material outlet.

Fig. 12 is a fragmentary sectional view illustrating a modified construction of pulverizing rotor.

Fig. 13 is a fragmentary sectional view illustrating still another modified construction of pulverizing rotor.

While we have shown and will describe the best forms of our inventions now known to us to illustrate the principles of construction involved, it will be apparent that one or more of the individual features may be used separately from the others and that modifications may be made in the construction, combination and arrangement of parts within the spirit and scope of the invention as described in this specification and as set forth in the appended claims.

In general, the pulverizer comprises a cylinder having a vertically mounted rotor therein composed of superimposed closed end sections which set up and maintain a pulverizing vortex of air-suspended material, or a series of such vortices, in the space around the rotor, the material to be pulverized being fed into the casing at the top of the pulverizing rotor and moving downwardly in the vortex while a current of air is induced transversely of the vortex and counter to the downward path of the material to withdraw the sufficient pulverized material as rapidly as it is produced.

Where material of heavier specific gravity is to be separated from the pulverized material, or excess material due to accidental or deliberate over-feeding is to be eliminated, the casing is provided with an opening near the bottom of the rotor.

In the preferred form of mechanism, the material is classified by the elimination of over-size

particles in the same chamber in which pulverization occurs, but this is not a necessary arrangement. In such cases, the withdrawn material expands from the pulverizing vortex into a free space, above which operates a classifying rotor, consisting of one or more discs with radial spokes thereon, the uppermot disc being located adjacent an annular outlet through which the induced air current is drawn. A sealing ring is provided at the outlet, functioning in conjunction with elements carried by the classifying rotor to prevent accidental entry of stray over-size particles into the outlet.

Figs. 1 and 2 illustrate a construction of pulverizing and classifying apparatus which is suitable for the general run of friable materials, such as sulphur, talc, chemicals, etc. The same construction with modifications is adaptable for use with many other materials, including cocoa and sugar mixtures.

The base 21 has a cylinder 22 vertically mounted thereon. The cylinder has an enlarged portion 23 at the upper end thereof, and it is closed by means of a cover plate 24 which is bolted to the peripheral flange 25 of the cylinder. A rotor shaft 26 is centrally mounted in the cylindrical casing 22 so as to rotate in the upper bearing 27 and the lower bearing 28, respectively carried by the cover and base. The lower end of the shaft extends into the hollow base 21 and there carries a sheave 29 through which the shaft is driven from the motor 31 that is mounted on the base, with its shaft extending thereinto, where there is mounted the sheave 32, connected to the sheave 31 by driving belts 33. Spaced above the base 21, the cylinder has mounted therein a dish shaped member 34, having a central aperture 35, and constituting the floor of the pulverizing chamber. The opening 35 is for the admission of air into the pulverizing chamber from the opening 36 in the side of the casing 22 which communicates with the space between the base 21 and floor 34.

The shaft 26 carries a collar 37 on which is mounted the bottom rotor disc 38. It will be noted that this disc extends horizontally but is of less diameter than the internal diameter of the cylinder 22. Shaft 26 also has keyed thereto a series of hubs 39 each having an intermediate flange 41. There is one hub for each of the rotor sections 42, 43 and 44, illustrated, but as noted above, a rotor may consist of one or more such sections usually of a height of from four to six inches. Each of these rotor sections is similar in construction so that it will only be necessary to describe one section in detail.

Bolted or otherwise secured to the flange 41 is a horizontal disc 45 that is provided with a plurality of radial slots 46 extending inwardly from the outer edge thereof and corresponding in number to the number of blades in the rotor section. It may be pointed out here that the rotor may have eight or more radial blades, thirty-two have been used in some cases, the number varying with the particular pulverizing conditions; and furthermore, the number of radial blades in all rotor sections may be the same, or they may differ. Also, as will be pointed out hereinafter, the rotor sections may be of the same or different diameters, and the outer edges of the blades may be tapered to introduce a desired pressure component in the pulverizing vortex produced by the rotor.

In the illustration in Figs. 2 and 3, the radial blades 47 are plates which fit into the slots 46 and extend outwardly the desired distance for the particular diameter of rotor and vertically the height of the particular rotor section. The blades 47 are held in the slot by means of a round key 48 which is of a size to fit in a hole 49 in the blade 47, and the sides of the slots 46 also are cut away, as indicated at 51, to receive the key 48. In the assembly, the key 48 is positioned in the hole 49 and the blade with its key is pressed into the slot 46 and the key way 51 thereof. In this manner, the plates 47 may be readily removed and replaced when necessary by simply tapping out the old blade until the key is free, and then the new blades may be inserted by the reverse operation. The key 48 functions to prevent the radial displacement of the blade as the rotor spins, and by reason of the construction of the rotor, including the fact that the blades are the full height of each rotor section, it does not require a driving fit to retain the blades in their vertical location.

Each of the rotor sections are separated by a horizontal plate 52 which in this illustration extends to the outer edge of the radial blades 47. However, the diameter of the intermediate or dividing plates 52 may be less than the diameter of the rotor with certain materials, and the diameter of each plate may be different from the others. As will be noted from Fig. 1, the rotor is built up by keying to the shaft 26 a hub 39 with its blade assembly, a dividing or intermediate plate 52 resting on the hub 39, then another hub 39 and plate 52, and this assembly is repeated for each of the rotor sections, except that the top rotor disc 53 is usually of less diameter than the plate 52. Thus, the rotor is made up of a plurality of closed end rotor sections, each of which is capable of and does produce a high speed vortex of air in the annular space 54 between the perimeter of the rotor and the cylinder 22, into which space and vortex the material to be pulverized is fed.

Before proceeding to a further description of the machine, we call attention to an alternate construction of rotor illustrated in Fig. 4. In this case, the disc 45A (for mounting on a hub flange 41) has the radial slots 46A in which are welded mounting plates 54 that extend radially outwardly beyond the edge of the disc 45A and may have bolted thereto, the blade assembly shown comprising the pair of blades 55 arranged on either side of the mounting plate 54 and joined together at their outer ends by the vertical bar 56. Alternately, a single blade also may be bolted to either side of the plate 54. To replace the blades in this case, it is merely necessary to unbolt the same from the mounting plate and bolt in place the new blade.

Referring again now to Figs. 1 and 2, the interior of the casing 22 is provided with a corrugated liner 61. In this construction of pulverizing vortex machine, the shape of these corrugations may vary, and they are generally very shallow, and in some cases are omitted entirely. One of the principal effects of the use of the corrugations is to retard the outer portion of the pulverizing vortex and the material suspended therein so as to provide a greater differential of movement between the higher-speed inner part of the vortex (at the periphery of the rotor) and the outer portion thereof. We have found this arrangement to be beneficial in speeding up the pulverizing action in some cases. In other cases, the influence of the liner is such as to retard the pulverizing, thereby reducing the capacity

of the apparatus, and the retarding effect of the smooth inner wall of the cylinder 22 is sufficient.

These corrugations are shown as extended into the portion of the cylinder above the pulverizing rotor wherein the classification operation is carried out, and here the retardation of the outer portion of the classifying vortex serves to facilitate the return of the oversize particles by gravity into the pulverizing zone.

The material to be pulverized is fed into the cylinder 22 from the hopper 62 by means of the feed screw 63 which communicates at its inner end with the opening 64 in the wall of the cylinder. As will be noted, this feed opening is at the top of the pulverizing rotor and chamber, the purpose of which will be explained shortly. The feed screw 63 operates in a barrel 65 having a corrugated liner 66, which increases the capacity of the feed for a given size screw, and avoids stalling due to oversize getting into the cut-off. The screw is driven by the motor 67 through the sprocket and chain connection 68, the motor being mounted on the sub base 69 secured to the cylinder 22. The speed of the feed screw determines the rate of feed of the material to be pulverized, which speed may be governed in any desired manner, such as a speed regulation of the motor 67, or changing the size of the sprockets, and so on.

The material enters the vortex around the rotor and the rate of feed is such that the material is picked up and kept suspended in the vortex during pulverization. In the vortex, the suspended material is subjected to the centrifugal force thereof, which is proportional to the mass of the particles so that the particles are constantly moving about in the vortex, rubbing each other and effecting innumerable collisions with each other which result in the reduction in particle size.

The enlarged chamber 23 at the upper end of the cylinder constitutes a housing for the fan 71 which has a plurality of radial blades carried by the disc 72 that is secured to the flange of the hub 73, which latter is mounted on the rotor shaft 26. The purpose of the fan is to induce an air current vertically through the cylinder 22 to (1) carry the sufficiently pulverized material out of the pulverizing vortex, and (2) to set up a current of air counter to the classifying vortex to withdraw the sufficiently pulverized material into the fan chamber, and deliver the same through the delivery opening 74 on one side of the fan chamber 23. This delivery opening may connect with suitable collection apparatus, or to a place of use for the pulverized material delivered from the machine. With the variations in specific gravity of materials and different particle sizes, it will be appreciated that it will be necessary from time to time to change the fan in respect to its power to induce the air current through the pulverizing and classifying apparatus. Of course, the fan need not be located in the same casing as the pulverizing and classifying apparatus. The path of the induced air current will be described shortly.

Connection between fan chamber 23 and the upper end of the cylinder 22 is through an annular outlet 75 which is defined by the ring 76 and by the concentric disc 77. In our co-pending application Serial No. 367,314, filed November 27, 1940, now Patent 2,392,331 of January 8, 1946, we have described in considerable detail how variations may be made in the area of this annular opening and also in its radial disposition, and that these variations are dictated by such factors as the nature of the material being pulverized, and the particle size being delivered from the machine, and so on. We will not go further into such matters in this application, because only indirectly part of the present invention. However, the use of the variable sizes and locations of the annular outlet 75 is to be used in the pulverizing and classifying apparatus of this case, with this addition, viz. it is possible to locate the outlet a greater distance radially from the rotor shaft for the coarser grinding; and also it is sometimes feasible to use the same size and the same location of annular outlet for different materials and different particle sizes, and rely upon the construction of the classifier about to be described to in and of itself control the fineness of the delivered particles.

Classification, or the elimination of oversize particles is accomplished in the portion of the casing above the pulverizing rotor. As stated above, this may be a separate chamber to which pulverized material is fed from any pulverizing apparatus, but in either case it is desirable that the pulverized material enter an unobstructed chamber 81, the height of which varies, again according to the nature of the material and the fineness of the delivered particle. In most cases this free chamber will have a height of from four to six inches, but in other cases a height of ten to twelve inches gives the best result, as with certain lighter materials. In this apparatus a series of spacing collars 82 rest on top of the top disc 53 of the pulverizing rotor, to whatever is determined to be the height of this free space.

At the top of the classification chamber, and operating immediately adjacent the annular outlet 75, is the classification rotor 83, the details of the construction of which are shown in Figs. 5 to 10. The rotor comprises a hub 84, which is keyed to the rotor shaft 26, and has an intermediate flange 84A, to which is bolted the disc 85. In this illustration, the disc 77, which is one of the elements defining the annular outlet 75, and the disc 85 are the same size, but this is not always the case. Welded to the underside of the disc 85 are a plurality of radial rods or spokes 86 which, for most purposes, will be round rods. Radially these rods extend substantially to the line of the corrugated liner 61, or adjacent the inner wall of the cylinder 22. They thus extend beyond the annular outlet 75 a distance which varies with the radial location of that outlet. The rods most generally will have a diameter of one-quarter inch, but they may vary in diameter and we have used rods up to five-eighths inch diameter, in larger mills. Also, the number of rods may vary from sixteen to sixty-four equally spaced around the disc 85, thirty-two spokes being the number most generally used.

The effects of this spoke classifier rotor are several. First, it sets up and maintains a vortex of the air suspended pulverized material in the region adjacent the outlet 75. At the same time, the round rods will not produce any effects in the vortex which will disturb the smoothness of the action thereof, which is in contradistinction to the action of flat bladed rotors, even if narrow. The flat blades have a substantial intra-blade action, either a purely undulating effect, or an intra-blade vortex action, in neither of which cases is a smooth, unidirectional classifying vortex produced. Furthermore, this intra-

blade action brings substantial quantities of the oversize material into the rotor in more or less irregular amounts thus imposing conditions requiring the most careful adjustments. It is true that very slight eddies are produced in rear of the spokes of the rotor, but these are insignificant, and if it is desired to eliminate such eddy effects, the spokes can be streamlined, after the manner of airplane practices.

Secondly, the classifying rotor moves faster than the vortex which it produces, so that the spokes of the rotor are continually combing through the air-suspended material. The result is that the oversize particles, which are retarded in their passage to the outlet 75 by the classifying vortex, are encountered by these spokes and are either deflected downwardly and away from the outlet, or they are further retarded in their progress toward the outlet so that the vortex action of the classifier rotor has sufficient time to act upon the oversize to eject it to the wall of the cylinder 22 from whence it falls by gravity back into the pulverizing zone for further reduction in particle size. Since the number of spokes will be increased as the delivered particle size is smaller, the action of the classifier rotor may be compared to that of a rotary screen, and serves as one control of particle size to be delivered.

For some purposes it is sufficient to have the classifier rotor as described above, a single row of spokes operating adjacent to the annular outlet 75, as seen in detail in Figs. 5 and 6, but in most cases we prefer to add a sealing arrangement to prevent the possibility of stray particles getting into the outlet, especially along the underside of the ring 76. One such construction is shown in Fig. 7 and comprises a sealing ring 87 which is welded to the inner edge of the ring 76 and depends therefrom into close running clearance with the spokes 86. A flat ring 88 is welded to the tops of the spokes 86 so as to be located between the sealing ring and the casing 22, and a series of wiper blades 89 are welded on top of the ring 88 so as to operate in close running clearance with the underside of the ring 76. The blades 89 are generally of the same stock as the spokes 86. The action of these wiper blades 89 is to set up a more intense vortex action between the sealing ring and the wall of the casing, and immediately under the ring 76 so as to keep all material, including the oversize, from entering the outlet 75 over the top of the rotor. Furthermore, the depending sealing ring, located as it is at the outer edge of the outlet opening 75, causes the induced air current to flow more directly through the spokes rather than radially thereof. Inasmuch as some materials, especially the lighter materials, have a tendency to crowd to the top of the casing, the wiper blades 89 also may be used for the purpose of forcing the material below the classifying rotor, in which case these wiper blades may be increased in diameter. When this is done, the sealing ring 87 will be longer so as to extend into running clearance with the spokes 86 of the rotor. In our present experience we have used wiper elements 89 varying in diameter between one-quarter inch and one inch, with a corresponding depth of the sealing or retarding ring 87.

For many purposes, this construction of classifier rotor is sufficient, but in some cases, especially where very fine particle sizes are to be delivered from the machine, it is desirable to add a second or sub-classifier rotor below the rotor disc 85. In one such construction, shown in detail in Fig. 8, a second disc 91 is bolted to the underside of the hub flange 84A, which disc also carries a plurality of equally spaced radial round rods or spokes 92, which extend outwardly beyond the annular outlet 75, but do not extend outwardly as far as the spokes 86 of the primary classifier rotor unit. The ends of this second rotor are generally open.

The numbers of the spokes in each disc will be varied in accordance with the particular requirements, the example of the machine of Figs. 1 and 8, using thirty-two rods or spokes 86 mounted upon the disc 84A, and sixty-four spokes mounted upon the sub-classifier disc 91. We have operated the sub-classifier with from thirty-two to seventy-two spokes.

The functioning of the sub-classifier is, in principle, generally the same as that described above for the primary classifier rotor. The addition of the sub-classifier increases the depth and the intensity of the classifying vortex, and the sub-classifier rotor either physically rejects the oversize, or slows down the movement thereof toward the outlet 75, so that in the space between the primary and sub-classifier rotors there is sufficient time for the centrifugal force of the vortex to be effective to eject the oversize. We have found that a quarter inch spacing between the primary and sub-classifier rotors is sufficient, but this may be increased.

Additional discs carrying radial spokes may be added to the classifier unit, but we have not found any case, as yet, where more than four discs are required, such an arrangement being shown in Figs. 9 and 10. In this figure, a hub 93 having a flange 94 is keyed to the rotor shaft immediately below the hub 84. The flange has bolted thereto horizontal discs 95 and 96 respectively carrying a plurality of equally spaced radial round rods or spokes 97 and 98. As noted above with respect to the primary and sub-classifier rotor units, the numbers of these spokes may be similarly varied so that each of the classifier rotor discs has a different number of spokes. We have also found it advantageous to have all the classifier rotor discs carry the same number of spokes but arranging the spokes of one rotor unit offset with respect to those of the next rotor unit to present a staggered pattern when viewed from the top. If the rods are offset in the direction of rotation, an advancing component of pressure is introduced into the classification action, while offsetting the rods in the opposite direction introduces a retarding component of pressure. Furthermore, it is preferred to have the rotor units of increasing diameters from the bottom to the top.

To summarize the operation of the entire mechanism of Fig. 1, the material to be pulverized is fed into the cylinder 22 through the opening 64. The pulverizing rotor has already been set into operation, and since this opening 64 is at the top of the pulverizing rotor, the material as it is picked up in the vortex in the annular space 54, gravitates toward the floor 34 of the pulverizing chamber, in the course of which travel it is subjected to innumerable impacts, collisions and rubbings to effect the reduction in particle size. Inasmuch as the particles of material are suspended in the air of the vortex, these collisions, etc. occur between the particles themselves, and not between the particles and

the blades, and the particles and the wall of the cylinder.

The proportion of the feed is such that all the material will be pulverized to the desired particle size before it reaches the floor of the pulverizing chamber, and this can be controlled by the intensity of the effect of each of the pulverizing rotor sections.

The removal of the sufficiently pulverized material is caused by the current of air induced by the fan 71, which draws the air through the lower opening 36 in the casing 22, the central opening 35 in the floor 34 of the pulverizing chamber, vertically through the pulverizing vortex and the free space 81 above the pulverizing rotor, and finally through the classifier rotor and the annular outlet 75. The current of air is proportioned according to the size of the particle to be delivered, and the nature of the material being pulverized. The volume of air so drawn in is controlled in any suitable manner. We have indicated and used for this purpose a slide 95 operated from outside the cylinder 22 and sliding on the guideways 96 to regulate the effective area of the opening 35. The underside of the bottom rotor disc 38 is provided with a plurality of radial fan blades 97, the purpose of which is to effect an even distribution of the air entering the annular zone 54 from beneath the rotor disc 38, and also to effect an air seal between the outer edge of the disc 38 and the floor 34 to prevent the escape of material beneath the rotor.

The induced air current moving through the pulverizing vortex counter to the material as it spirals downwardly, more quickly removes the sufficiently pulverized material from the vortex, so that such material does not impede or retard the pulverization of the remaining material. It is obvious that the induced air current also carries some oversize material out of the pulverizing vortex, and it is that which it is necessary to remove and return for further pulverization.

The withdrawn material enters the free space 81 of the classifying zone, and inasmuch as it is whirling in a vortex when it enters this space, most of the oversize material will be thrown outwardly in this free space toward the wall of the cylinder 22, and falls by gravity back into the pulverizing vortex. The remaining material is lifted through the free space 81 toward the annular outlet 75.

The classifying rotor sets up and maintains its own vortex which is free from any undulations and eddy currents which disturb the uniformity of the classifying vortex. Accordingly, the induced air current can be carefully proportioned and balanced against the constant centrifugal force of this classifying vortex with more accuracy to carry off only that material which is sufficiently pulverized. At the same time, the depth and intensity of the classifying vortex is variable, usually being increased for the very fine delivered particle sizes, and the radial spokes of the classifying rotor serve the further purpose of rejecting the oversize particles that remain after the material has passed through the free space 81.

The function of the sealing ring 87 and its cooperating ring 88 and wiper elements 89 is to prevent the creeping of oversize particles upwardly along the wall of the cylinder 22 and inwardly along the underside of the ring 76. This arrangement now becomes entirely successful in preventing "spatter" particles from entering the annular outlet 75.

Considered as a whole, the more complete pulverization in the downward or counter-current flow of the material in the pulverizing vortex, the expansion of the material into the free space 81 to quickly remove oversize, the setting up of the smooth and undisturbed classifying vortex, the consequent ability to balance the centrifugal force of this smooth classifying vortex and the counter current of air to withdraw the sufficiently pulverized material, together with the sealing ring arrangement at the annular outlet, all combine to provide a very efficient pulverizing machine delivering material of a maximum particle size and free of oversize material.

As was explained above, at times the material being pulverized contains foreign materials which are of greater specific gravity, or harder, than the desired material, and it is desired to eliminate the same during the pulverizing operation. Or, as in the case of some ores, the material which it is desired to recover is heavier than the remaining material, and it is desired to effect a separation, and retain a continuous operation. In such cases, the pulverizing mechanism is arranged and operated as indicated above, as a result of which the material of greater specific gravity will settle to the floor 34 of the pulverizing chamber. To remove such material, the cylinder 22 is slotted, as indicated at 101, about the level of the floor 34. A partition 102 is mounted beneath the sub-platform 69 to define a box to receive the material of greater specific gravity, which will be ejected through the slot 101. The box may have an outlet 103 communicating with any suitable place of collection for the material reaching the box. A capped cleanout opening 104 is provided for the box 102. As will be apparent, in the operation of the mechanism where this differential grinding or material separation operation occurs, the heavier material will pass off continuously through the opening 101 and the delivery opening 103 from the box 102. This same continuous bleed-off will occur for any excess material being pulverized, as might occur in case of an accidental or intentional overfeed. The size of the slot 101 need be only approximately three-quarters of an inch in height and from six to eight inches in length, and more than one such bleed-off outlet 101 may be provided. Also, a screw conveyor may be connected with this bleed-off outlet, one arrangement for which is shown in our co-pending application Serial No. 484,898.

In other cases, the undesired substance is light in weight, as with some fibrous materials. With a pulverizing and classifying machine of the general construction of the apparatus shown in this case, this substance can be separated from the desired material during the classification operation. One arrangement for doing this is illustrated in Fig. 11, the rotor 111 of which is constructed and driven as previously described herein. However, in this case it will be noted that the radial blades 112 of the rotor extend outwardly so as to operate much more closely to the corrugations 61 on the interior of the cylinder casing 22, in all the rotor sections except the upper one. This is done in the case of fibrous materials so that the pulverization is by a shearing action between the rotor blades and the corrugations. The material being pulverized may be fed to the annular space between the rotor blades and the corrugations either from the top of the rotor, as illustrated in Fig. 1, or from near the bottom thereof, as shown in this figure, but in either case the fan 71 induces an air current in the same manner through this pulverizing space so as to re-

move the sufficiently pulverized material into the free space 113 above the rotor 111.

A classifying rotor similar in construction to that shown and described in Fig. 1 is illustrated in this figure, but any of the other constructions of classifier rotors may be used. In any event, the mechanism preferably has the annular outlet 75 defined by the ring 76 and disc 77, as well as the depending sealing ring 87 attached to the inner edge of the ring 76, and depending into close running clearance with the spokes 86 of the primary classifier rotor. Also, the classifier rotor carries the wiper blades 89 operating beneath the ring 76. The cylinder 22 is provided with a slot 115 at the top thereof, immediately below the place of mounting of the ring 76. This slot apparently needs to be only from one-half to three-quarters of an inch high and about three inches in length for the bleeding off of the lighter weight material, which will find its way beneath the ring 76 and would otherwise accumulate there. The slot 115 may connect with an outlet trap 116 having the spring closed door 117 thereon, or it may be connected to any other arrangement for collecting the material passing through the slot 115. It usually will be desirable to have a closure for the collection device so as to avoid disturbing the balance of pressures in the pulverizing and classifying casing 22. It is inevitable that some of the desired material will also be ejected through the slot 115, but since the desired material is heavier than the undesired material, this may be separated out in any centrifugal collection device, as is well known.

It should be noted that this top bleed-off arrangement also may be used as a material outlet where there is an overfeeding of material. In cases of light weight materials, this excess tends to accumulate beneath the ring 76, but with this bleed-off arrangement such accumulation is prevented.

Fig. 12 illustrates a modified arrangement of sectionalized pulverizing rotor in which the rotor may be driven as indicated in Fig. 1, or in any other suitable manner. The rotor comprises a plurality of sections 121, 122, and 123, the rotor elements of which may be constructed as indicated in detail in Figs. 3 and 4, so as to have radial blades 125, respectively. However, it will be noted that the diameter of each of the rotor sections as defined by the outer edges of the rotor blades, is progressively narrower for each of the sections from the bottom to the top of the rotor assembly. Likewise, the bottom rotor disc 126 and the intermediate rotor discs 127, and 128, as well as the top rotor disc 131 are progressively smaller in diameter.

The operation of the assembled mechanism is the same as described for Fig. 1, that is, each rotor section sets up a pulverizing vortex in the annular space therearound, but the intensity is different opposite each section proportional to the width of the respective annular spaces. The whole effect may be said to be that of a tapered rotor, and this form of rotor is used to advantage with certain materials and in a uniform distribution of the material in the pulverizing vortex. However, a truly tapered rotor may be had by beveling the outer edges of the rotor blades 125 along a line intersecting the top of the uppermost rotor blades of section 123 and the bottom rotor disc 126. Such a tapered rotor construction produces an upward component of pressure in the pulverizing vortex which with certain materials is helpful in delaying the downward spiralling of the material in the pulverizing vortex.

Still another arrangement of sectionalized pulverizing rotor is shown in Fig. 13. The casing 22 has the corrugations 61 on the interior thereof, and there is the annular space 54 in which is set up the pulverizing vortex, all as described in connection with Fig. 1. In this case, the rotor shaft 26 also has the bottom rotor disc 38 with the plurality of hubs 39 keyed to the shaft and each having an intermediate flange 41. Secured to each of the flanges 41 is a horizontal disc 141 in the periphery of which is set the plurality of radial rotor blades 142, which may be mounted in any desired manner, such as illustrated in Figs. 3 and 4. In this case, it will be noted that the outer edge 143 of each of the rotor blades of each rotor section is tapered inwardly and upwardly. Each of the rotor sections may be of the same diameters at the top and bottom thereof, or as seen in Fig. 13 the sections may be of progressively smaller diameters from bottom to top so that the annular space 54 is wider at the top than at the bottom. These sections are separated from each other by intermediate discs 144 which in this illustration have the same diameter as the maximum diameter of the respective rotor sections, although this need not necessarily be so. The pulverizing vortex in the annular space 54 will be most intense opposite the places of widest diameter of the rotor section, and least intense opposite the places of narrowest diameter, so that in each section there is an upward component of pressure, as well as in the rotor as a whole, and this also is utilized to obtain a more uniform distribution of the circulating load of material in the pulverizing vortex, or to express it another way, the downward progress of the material in the pulverizing vortex is retarded so as to insure that all of the material is pulverized before it reaches the floor 34 of the pulverizing chamber. Again, some of the material may be more difficult to reduce, while other portions of the material may reduce more quickly, particularly in cases of the pulverizing of mixtures of materials. By having the areas of more intense vortex action, the differences in friability are compensated for.

We have indicated various constructions of mechanisms, and it will be apparent that the assembly of a machine to suit a particular set of conditions can be accomplished readily by bringing together units having features especially adapting the mechanism for the most efficient pulverization and classification of the materials being processed. Hence, the features may be used independently of each other, namely, they may be applied to other machines than those illustrated.

We claim:

1. In a classifier for air suspended pulverized material, a cylindrical casing, an annular outlet in the top of said casing for selected material, a sealing ring depending from one side of said outlet, a rotor mounted in said casing and operating adjacent said sealing ring, said rotor comprising a hub, a plurality of equi-distant round spokes radially mounted in said hub, the spokes extending across the outlet, an opening in the lower part of said casing for admitting air suspended pulverized material, means for setting up an air current to withdraw sufficiently pulverized material through said outlet, and fan-like means operating adjacent the top of the casing and between the casing and the sealing ring to aid in

keeping oversize material from entering said outlet.

2. In a classifier for air suspended pulverized material, a cylindrical casing, an annular outlet in the top of said casing for selected material, a sealing ring depending from one side of said outlet, a rotor mounted in said casing and operating adjacent said sealing ring, said rotor comprising a hub, a plurality of equi-distant round spokes radially mounted in said hub, the spokes extending across the outlet, an opening in the lower part of said casing for admitting air suspended pulverized material, means for setting up an air current to withdraw sufficiently pulverized material through said outlet, a ring-shaped plate carried by the spokes adjacent the outer ends thereof, and fan-like elements mounted on the plate and operating adjacent the top of the casing and between the casing and the sealing ring to aid in keeping oversize material from entering said outlet.

3. In a classifier for air suspended pulverized material, a cylindrical casing, an annular outlet in the top of said casing for selected material, a sealing ring depending from one side of said outlet, a plurality of rotor elements mounted in said casing, one of which operates adjacent said sealing ring, said elements being mounted upon a shaft and each element comprising a hub, a plurality of equi-distant, round spokes radially mounted in said hub and extending across the outlet, a ring shaped plate mounted on the spokes of the rotor element adjacent the outlet, fan-like elements carried by said plate and operating beneath the top of the casing and between the casing and the sealing ring to aid in keeping oversize material from entering said outlet, an opening in the lower part of said casing for admitting air suspended pulverized material, and means for setting up an air current to withdraw sufficiently pulverized material through said outlet, the rotor maintaining a substantially uniform vortex of the air-suspended material in said casing from which the sufficiently pulverized material is withdrawn through said outlet and rotor and by which the oversize material is rejected.

4. In a classifier for air suspended pulverized material, a cylindrical casing, an annular outlet in the top of said casing for selected material, a sealing ring depending from one side of said outlet, a plurality of rotor elements mounted in said

casing, one of which operates adjacent said sealing ring, said elements being mounted upon a shaft and each element comprising a hub, a plurality of equi-distant, round spokes radially mounted in said hub and extending across the outlet, a ring shaped plate mounted on the spokes of the rotor element adjacent the outlet, fan-like elements carried by said plate and operating beneath the top of the casing and between the casing and the sealing ring to aid in keeping oversize material from entering said outlet, an opening in the lower part of said casing for admitting air suspended pulverized material, and means for setting up an air current to withdraw sufficiently pulverized material through said outlet, the rotor maintaining a substantially uniform vortex of the air-suspended material in said casing from which the sufficiently pulverized material is withdrawn through said outlet and rotor and by which the oversize material is rejected, a relief material outlet slot in the side of said casing adjacent the top thereof, and a collection device connected to said slot.

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