June 26, 1962 EIICHI HOSOKAWA ETAL 3,040,888

CLASSIFIER FOR PULVERIZED SUBSTANCES

Filed March 22, 1960 2 Sheets-Sheet 1

Fig. 1

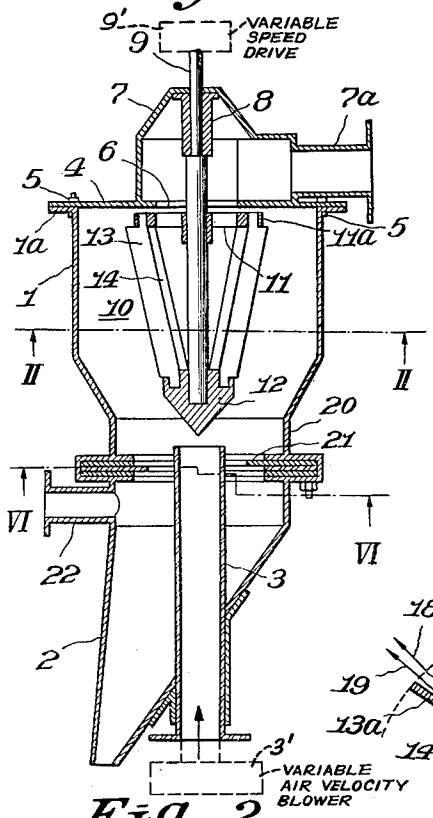



Fig. 4

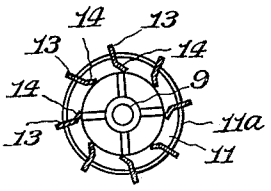



Fig. 5

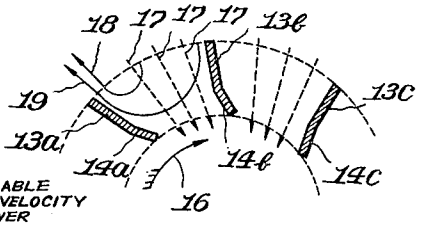



Fig. 2

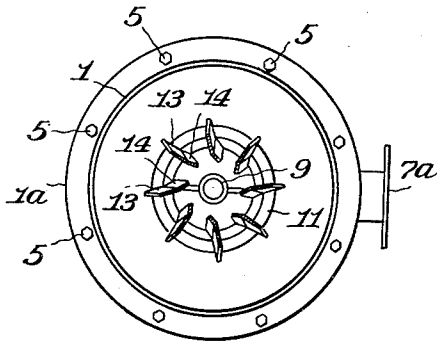
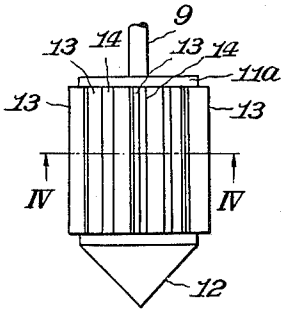



Fig. 3




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Filed March 22, 1960 2 Sheets-Sheet 2

Fig. 6

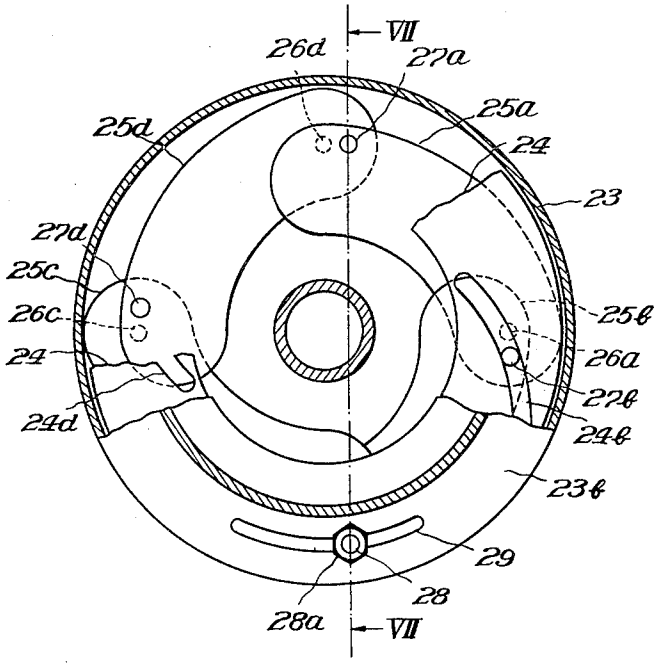
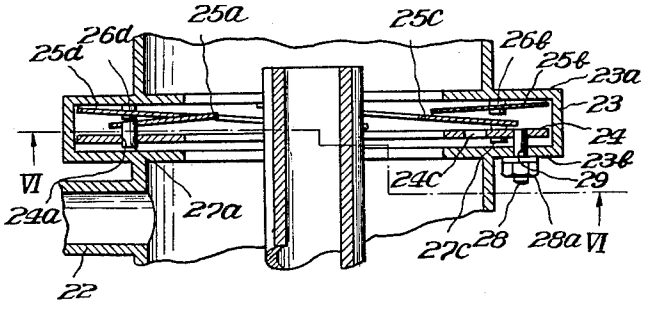



Fig. 7




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# CLASSIFIER FOR PULVERIZED SUBSTANCES

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7 Claims. (Cl. 209—144)

This invention relates to classifiers for pulverized substances, and more particularly it relates to a new device for classifying pulverized substances which has low pressure loss with respect to the rate of gas flow; has high handling capacity; yet has high classifying precision; is capable of being adjusted to classify fine particles of extremely small grain size; is capable of completely eliminating coarse particles of irregularly large diameter; and is compact in voulmetric size and requires relatively small installation space.

Heretofore, so-called cyclones, sifters having wire screens, and other types of dust-removing devices have been used for the purpose of separating out the pulverized substance from an intermediate point in a mixed gas flow of a gas and a pulverized substance mixed and suspended therein, or for the purpose of separating out only particles of the pulverized substance having a desired grain size from such a gas flow.

Among these devices, the cyclones have been and are being used the most, but they have had such disadvantages as having high pressure loss relative to the gas flow and entailing difficulties in carrying out sensitive classification. Furthermore, the conventional cyclones have had the disadvantage in that such accessories as bag filters have required large filtration areas with respect to the rate of gas flow and, as a result, have required large installation space.

A substantially large number of sifters having wire screens have also been or are being used. However, since the wire screen meshes are easily clogged, thereby lowering their operational capacity, the operational capacity decreases with the grain size; particularly in the case of fine particles of 325-mesh size or finer, separation has been practically impossible.

The other kinds of dust-removing devices also have had various disadvantages similar to those mentioned above, and it is the present state of the art that said devices are not being used extensively.

With the conventional devices of this type, the simultaneous improvement of all of the various disadvantages mentioned above would be considerably difficult. Moreover, in the case of these devices, it is possible for coarse particles of irregularly large diameters to become mixed, sometimes, in the finely pulverized substance, and the complete elimination of this possibility would be extremely difficult.

It is an essential object of the present invention to provide a new device for classifying pulverized substances which does not have such disadvantages as those found in the conventional devices of this type.

More specifically, it is an essential object of this invention to provide a new device for classifying pulverized substances which has low pressure loss with respect to the rate of gas flow; has high handling capacity; requires only a small installation space; accomplishes classification sensitively and with great precision; is capable of classifying also fine particles of extremely small grain size; and, moreover, is capable of completely eliminating coarse particles of irregularly large diameter.

Said object and other objects and advantages as will become apparent hereinafter have been achieved by the device of this invention, which has been conceived and developed through consideration of the following discoveries made by the present inventors:



(1) The inventors have discovered that, if a rotating body in the form of a sieve is caused to rotate in a flow of a mixture of a pulverized substance and a fluid, and the said fluid is caused to flow from the exterior of the rotating body toward the interior thereof, good classifying action will be accomplished with almost no entailment of pressure loss. Reduction of pressure loss has an important relation, conjointly with good classifying action, to the increasing of classifying capacity, to the reduction of size of the entire apparatus, and, thereby, to the economy of installation space.

(2) The inventors have discovered that, if the peripheral surface of the aforesaid rotating body is provided with vanes, the precision of classifying will be improved. The reason for this improvement is that the time required by the flow of gas mixture to pass through the spaces, where the classifying action takes place, between the vanes is increased by the installation of said vanes. It has been found also that, if the vanes are inclined somewhat relative to the radial direction, their effect will be increased further.

(3) The inventors have discovered that, if the inner portions of the aforesaid vanes on the peripheral surface of the rotating body are provided with auxiliary vanes at suitable angles of inclination relative to the radial direction, acceleration in the outward direction will be imparted on the coarse particles of large grain size which will thus be flung outwardly from the rotating body and be prevented from passing. The installation of these auxiliary vanes has been found to cause no measurable loss in pressure, nor any detrimental effect on the classifying capacity or precision; on the contrary, it slightly improves the classifying capacity and precision.

(4) The inventors have discovered that, by providing a hub-cap body, or fairing, of conical form on the lower part of the aforesaid rotating body, it is possible to reduce the pressure loss. Said hub-cap body prevents the flow of the gas mixture from becoming turbulent, thereby reducing the pressure loss. It has been found that, as another result of the prevention of turbulence, the precision of classifying, also, is favourably affected.

(5) The inventors have discovered that, by constructing the aforesaid rotating body in the form of an inverted cone, it is possible to obtain high sensitivity in the classifying precision. The classifying action with respect to the flow of the gas mixture fed from below is accomplished while said gas flow is passing through the classifying spaces of the rotating body. However, the velocity of the flow of gas mixture passing through the said spaces at the upper portion thereof differs from the velocity at the lower portion. As a result, if the rotating body is of conical form, the grain size of the pulverized particles which have been classified at the upper portion of said spaces will differ from that at the lower portion. Since the classifying action is obtained from the balancing of the velocity of the flow of gas mixture in the classifying spaces with the centrifugal force imparted on the pulverized particles, if the relations between the centrifugal force and flow velocity imparted on the particles in the classifying spaces are made equal for the top and bottom of the rotating body by constructing the rotating body so that the radii at its upper and lower portions are different, the entire rotating body will classify particles of equal grain size, and the classifying precision will be improved.

(6) The inventors have discovered that, by varying the number of aforesaid vanes on the rotating body in accordance with the properties of the pulverized particles to be

classified, the distribution of grain size, and the required precision of classifying, it is possible to make adjustments so as to obtain high classifying capacity and precision. More specifically, if the pulverized substance contains a substantially large number of fine particles and a small quantity of coarse particles, it is possible to increase the classifying capacity, without lowering the classifying precision, by suitably reducing the number of the vanes. The reason why the above adjustment is possible is that, since the number of vanes is reduced, the probability of the groups of fine particles being flung out of the rotating body is reduced. For the same reason, in cases where low classifying precision is permissible, it is possible to increase the classifying capacity by a substantial amount by suitably reducing the number of vanes on the rotating body.

(7) The inventors have discovered that, by constructing the vanes of the rotating body so that their widths, or chords, are variable, it is possible to make adjustments so as to obtain high classifying capacity and precision. More specifically, if the content of fine particles in the pulverized material to be classified is low, the classifying precision can be raised by increasing the chord width of the vanes of the rotating body. The reason for this possibility is that the time during which the various particles are retained in the spaces between the vanes is increased, and it is possible to impart centrifugal force thoroughly on the coarse particles, thereby increasing the probability of their being flung outwardly from the rotating body. For the same reason, in cases where low classifying precision is permissible, the classifying capacity can be increased by a substantial amount by decreasing the chord width of the vanes of the rotating body.

(8) The inventors have discovered that, if an air current at high speed is caused to be drawn in around the exit end of the intake pipe for the pulverized raw material, in a direction parallel to the feed direction of the said pulverized material, the classifying precision will be improved and, at the same time, the classifying capacity will also be increased. In general, from the pulverized material to be classified, only the fine particles below a certain grain size are caused to pass through the spaces between the vanes of the rotating body. However, some of the fine particles which should be passed are sometimes accidently flung out from the rotating body together with the coarse particles. Especially, when the pulverized raw material has the property of easily cohering and forming lumps, these lumps are also flung out from the rotating body. All of these particles and lumps flung out from the rotating body drop toward the discharge section for coarse particles. However, the aforesaid auxiliary air flow has an air sifting function in that it returns the fine particles toward the rotating body and, disintegrating the lumps into fine particles, returns them to the rotating body, permitting only the coarse particles to drop toward the discharge section. Consequently, together with the substantial improvement in the classifying precision, the classifying capacity is also increased because of the increase in the yield of classified particles.

(9) The inventors have discovered that, by installing an iris type diaphragm around the raw material intake pipe, it is possible to adjust the flow velocity of the aforesaid, auxiliary air flow, thereby suitably regulating the air sifting action. Obviously, the grain size sorted out by the air sifting action has a relation to the flow velocity of the auxiliary air flow; and, for the purpose of controlling the said flow velocity, the iris diaphragm is the simplest and easiest to use.

The details of the present invention, which has been conceived and developed through consideration of the above-described discoveries, will be more clearly apparent by reference to the following detailed description of representative embodiments of the invention when taken in connection with the accompanying illustrations, in which the same members are designated by the same numerals and, in which:



FIG. 1 is an elevational view, in longitudinal section, showing one example device embodying the invention;

FIG. 2 is a plan sectional view, taken along the line II—II in FIG. 1;

FIG. 3 is an elevational view, showing a modification of the rotor, or rotating body of the embodiment of FIG. 1;

FIG. 4 is a plan sectional view, taken along the line IV—IV of FIG. 3;

FIG. 5 is a diagram, in plan sectional view, for describing the functioning of the auxiliary vanes which are to be used in the device of this invention;

FIG. 6 is an enlarged, plan view, partly in section, taken along line VI—VI of FIG. 1, with parts cut away;

FIG. 7 is an elevational view, in section, taken along line VII—VII of FIG. 6.

Referring to FIGS. 1 and 2, the classifier comprises a casing **1** which is provided with a connecting flange **1***a* at its upper end and a funnel-shaped, discharge section **2** for coarse particles, through which an intake pipe **3** is passed and installed. A variable speed blower **3'** for varying the velocity of air or other gas mixed with the pulverized material is connected to the pipe **3**. The top of the casing **1** is closed by a cover plate **4**, said cover plate **4** and the flange **1***a* thereof being fastened by bolts **5**. A round discharge aperture **6** is provided in the center of the cover plate **4**. A discharge chamber **7** is installed to cover the said aperture **6** and is connected to a discharge pipe **7***a*. A gas-tight, shaft bearing **8** of suitable construction is installed on the upper part of the discharge chamber **7**, and a rotating shaft **9** extends through said bearing **8** into the interior of the casing **1**, where said shaft **9** supports and drives a rotating body **10** (hereinafter referred to as a rotor) by means of a suitable variable speed drive **9'**. The rotor **10** is composed of: a large-diameter wheel **11** installed on the shaft **9** in the vicinity of the discharge aperture **6**; a conical hub cap **12** of small diameter installed on the lower end of the shaft **9** and facing the intake pipe **3**; a plurality of vanes **13** disposed between said wheel **11** and hub cap **12**; and auxiliary vanes **14** connected contiguously to the inner edges of the vanes **13** and having an angle of inclination. Said vanes **13** and auxiliary vanes **14** are so adapted that, by loosening the metal band **11***a*, which is clamping the outer periphery of the wheel **11**, they can be easily removed or installed. Accordingly, in accordance with such operational conditions as the properties of the pulverized material to be classified, the required classifying precision, and the required handling capacity, it is possible to vary suitably the number of said vanes **13** and auxiliary vanes **14**, or to replace said vanes by others of different chord width.

FIGS. 3 and 4 show a rotor of a form which is different from that described above. The diameters of the wheel **11** and the conical hub cap **12** are equal. A plurality of vanes **13** and auxiliary vanes **14** are disposed between the said wheel **11** and cap **12**. In this case also, the vanes **13** and auxiliary vanes **14** can be varied in number, or replaced by others of different chord width, by loosening the metal band **11***a*.

The theoretical grounds upon which the unique characteristics of the invention are based will be best understood from a consideration of the following disclosure.

In the above-described devices, let the following quantities be represented by their respective symbols as shown:

Particle diameter:_____ $d$
Density of material composing the particle:_____ $\rho_s$
Density of the gas_____ $\rho_o$
Radius of rotor **10**_____ $r$
Rotational velocity of rotor **10**_____ $\omega$

Then, the centrifugal force F imparted on the particle is:

$$F=\frac{\pi}{6}d^3(\rho_s-\rho_o)\omega^2 r \qquad (1)$$

On the other hand, if we let:

$v$ be the velocity in the direction toward the center, of the mixed gas flow at the outer periphery of the rotor,

$\mu$ be the viscosity of the gas, the fluid resistance C to which the particle is subjected is given by Stokes law as

$$C=3\pi\mu dv \tag{2}$$

The particle, theoretically, should have no motion when the centrifugal force F given by the Equation 1 exactly equals the fluid resistance C given by the Equation 2.

If this condition is represented mathematically, the following equation is obtained by the Equations 1 and 2;

$$d\text{th}=\frac{1}{\omega r}\sqrt{\frac{18\mu v r}{\rho_s-\rho_o}} \tag{3}$$

where $d$th represents the diameter of the particle which stops. In the case of a coarse particle of larger diameter than this, since the centrifugal force F is greater than the fluid resistance C, said particle is flung outwardly from the rotor **10** and falls toward the discharge section for coarse particles **2**; and only particles of smaller diameter than $d$th are delivered from the discharge pipe **7***a*. Then, it is apparent that, by varying the velocity $v$ of the mixed gas flow, or the rotational velocity $\omega$ of the rotor **10**, it is possible to adjust this critical particle diameter in a simple manner.

According to the results of experiments, it was possible to separate 400 pounds per hour of powdered material when a rotor of 8-inch diameter, 8-inch height, approximately as shown in FIGS. 3 and 4, was used; and the air flow rate was 150 to 300 cubic feet per minute. For example, the maximum diameters of particles during classification of a mixture of powdered, calcium bicarbonate and the corresponding rotational speeds of the rotor were: 0.2 millimetre (mm.) at 3,600 revolutions per minute (r.p.m.); 0.65 mm. at 1,800 r.p.m.; 1.2 mm. at 900 r.p.m.; and 4 mm. at 380 r.p.m. In all these cases, recovery rates between 80 and 95 percent were obtained. Also in the case of large machines treating from 600 pounds to 3,000 pounds per hour of pulverized material, high performance, equal to that of the above-described small machine, was obtained.

A classifier in which is used a rotor such as that shown in FIGS. 3 and 4 operates according to the above principle. As a practical problem, however, the velocity $v$ of the air flow passing through the rotor is different for the upper and lower parts of the rotor, and the magnitude of the critical particle diameter $d$th mentioned above differs. Accordingly, the sensitivity of classifying is insufficient.

When the rotor shown in FIGS. 1 and 2 is used, since it is obvious that the air flow velocity $v$ is high at the upper part of the rotor, in the vicinity of the discharge pipe **7***a*, where suction is taking place, and becomes lower toward the lower part, it may be considered to be a function of the radius $r$ of the rotor. Thence, since the Equation 2 is represented by

$$C=3\pi\mu d\cdot f(r) \tag{4}$$

the Equation 3 is changed in form to

$$d\text{th}=\frac{1}{\omega r}\sqrt{\frac{18\mu r\cdot f(r)}{\rho_s-\rho_o}} \tag{5}$$

Since the direction of variation of the flow velocity $v$ is the same as that of the variation of the radius $r$, they may be assumed to be proportional, as an approximation. Then, if K is taken as the proportionality coefficient,

$$f(r)=K\cdot r$$

Hence, the Equation 4 becomes

$$d\text{th}\doteqdot\frac{4.25}{\omega}\sqrt{\frac{k\mu}{\rho_s-\rho_o}} \tag{6}$$

That is, if the radius $r$ of the rotor **10** is adapted to have a suitable variation and is so selected as to be proportional to the local air flow velocity $v$ at the corresponding point, it will be possible to obtain classifying action with a critical diameter of particle of constant value over the entire surface of the rotor **10**; and the precision thereof will become substantially high.



When such a device as described above was actually operated, 80 percent of the pulverized particles which passed through the rotor **10** were of the critical grain size or finer, and coarse particles having diameters several times or several tens of times the critical particle diameter were sometimes found to be mixed in with the classified material. The auxiliary vanes **14** of this invention effectively remedy this disadvantage.

In FIG. 5, reference numerals **13***a*, **13***b*, and **13***c* designate vanes, and **14***a*, **14***b*, and **14***c* designate auxiliary vanes. The rotor is rotating in the direction indicated by the arrow **16**, and, with respect to this rotation, the mixed gas is flowing along the paths indicated by the broken lines **17**. Of the pulverized particles suspended in the mixed gas flow, coarse particles of relatively large diameter are subjected to sufficient centrifugal force immediately upon entering the classifying area between two vanes and are readily flung outwardly as indicated by the path line **18**, but particles of diameters approaching the critical particle diameter enter deeply into the classifying area as indicated by the path line **19**, during which interval, centrifugal force is gradually imparted on said particles, which then move in a curved path and, travelling along the surface of a vane **13***a*, are flung outwardly. However, there are some coarse particles which, in the meanwhile, are swept along by the gas current and are conveyed into the interior of the rotor. In order to prevent this infiltration of coarse particles, auxiliary vanes **14** are provided so as to impart, by the motion indicated by the arrow **15**, an acceleration having a large component in the outward direction to the coarse particles. As a result, the force due to said component acts, conjointly with the centrifugal force imparted by the vanes **13**, to fling the coarse particles outwardly.

As the result of actual operation with the auxiliary vanes **14** installed, 90 to 95% of the particles passing through the rotor **10** had diameters equal to or less than the critical particle diameter, and there were no coarse particles having diameters two or more times the critical diameter. Moreover, no increase whatsoever, due to the installation of the auxiliary vanes, in the pressure loss occurred.

The above-described classifier of this invention was used on substances other than the aforementioned calcium bicarbonate, such as graphite, activated carbon, agricultural chemicals, ilmenite, and zinc oxide, and was found to accomplish good classification in each case.

Referring again to FIG. 1, an air-sifting section **20** is disposed between the casing **1** and the discharge section **2** for coarse particles. Said air-sifting section is composed, essentially, of an iris diaphragm **21**, which is installed so as to encompass the intake pipe **3**, and an air suction pipe **22**, which is connected to the lower part.

As one illustrative example of the construction of the air-sifting section **20**, certain details are presented in FIGS. 6 and 7 in enlarged scale, in which within the iris diaphragm housing **23** are installed a ring-shaped control plate **24** and four blades **25***a*, **25***b*, **25***c*, and **25***d*. The said blades are supported pivotally, at one end each, by pins **26***a*, **26***b*, **26***c*, and **26***d*, respectively, on the upper plate **23***a* of the said diaphragm housing **23**, and the other ends of the said blades are provided with pins **27***a*, **27***b*, **27***c*, and **27***d*, respectively, which fit, respectively, into guide slots **24***a*, **24***b*, **24***c*, and **24***d* provided with inclined orientation in the control plate **24**. An adjusting screw **28**, which is fixed to the said control plate **24**, is made to extend to the outside through an arcuate slot **29** formed through the lower plate **23***b* of the outer wall **23** and is tightened by a nut **28***a*.

The degree of opening of the diaphragm as described above can be adjusted at will by loosening the nut **28***a*

and shifting the position of the adjusting screw **28** along the slot **29**. Accordingly, the flow velocity of the air flowing from the air suction pipe **22**, through the iris diaphragm **21**, into the casing **1** can be adjusted at will.

Results of experiments are as follows: in the case where the sifting section **20** was not installed, the degree of classifying precision in classifying talc at 0.2 millimetre size was 35 to 40 percent in terms of Newton's classification efficiency. When the air sifting section **20** was installed, the classification efficiency was improved to between 55 and 65 percent, and the yield passing through the rotor was increased approximately 15 percent.

Since it is obvious that many changes and modifications can be made in the above-described details without departing from the nature and spirit of the invention, it is to be understood that the invention is not to be limited to the details described herein except as set forth in the appended claims.

We claim:

1. A classifier for a pulverized substance comprising an essentially cylindrical housing with the axis thereof being substantially vertical, a cage-like rotor within said housing and mounted for rotation on an axis substantially parallel to the first said axis, said rotor having upper and lower blade supporting members and a plurality of elongated blades extending between and carried by said members, each of said blades being formed of inner and outer elongated portions with the inner portion having at least its leading surface inclined relative to a radial plane and in a direction opposite to the direction of rotation and with the outer portion having its leading surface inclined in the same direction as the inner portion but to a lesser degree, means for rotating said rotor, a cone-shaped cap carried by the bottom end of said rotor, an inlet feed pipe for said substance being classified positioned below said housing and having a discharge opening aligned with and directed toward said cone-like cap, a closure having a central opening carried by the top of said housing, the last said opening being smaller than the diameter of the rotor and aligned with and in close proximity to the upper end of said rotor, and large particle outlet means carried by the lower end of said housing and surrounding at least part of said inlet feed pipe, whereby said substance upon being fed into said housing by a compressed gas is acted upon by said rotor to classify the substance according to particle size with particles smaller than a predetermined size being discharged through said central opening and larger particles being discharged through said large particle outlet means.

2. A classifier for a pulverized substance comprising an essentially cylindrical housing with the axis thereof being substantially vertical, a cage-like rotor within said housing and mounted for rotation on an axis substantially parallel to the first said axis, said rotor having upper and lower blade supporting members and a plurality of elongated blades extending between and carried by said members, each of said blades being formed of inner and outer elongated portions with the inner portion having at least its leading surface inclined relative to a radial plane and in a direction opposite to the direction of rotation and with the outer portion having its leading surface inclined in the same direction as the inner portion but to a lesser degree, means for rotating said rotor, an inlet feed pipe for said substance being classified positioned below said housing and having a discharge opening, a closure having a central opening carried by the top of said housing, the last said opening being smaller than the diameter of the rotor and aligned with and in close proximity to the upper end of said rotor, and large particle outlet means carried by the lower end of said housing and surrounding at least part of said inlet feed pipe, whereby said substance upon being fed into said housing by a compressed gas is acted upon by said rotor to classify the substance according to particle size with particles smaller than a predetermined size being discharged through said central opening and larger particles being discharged through said large particle outlet means.

3. A classifier according to claim 2 including means for varying the rotational speed of said rotor to modify the maximum particle size discharged through said central opening.

4. A classifier according to claim 2 including means for modifying the gas velocity carrying said substance to said classifier to control the maximum particle size delivered through said central opening.

5. A classifier according to claim 2 wherein the outer edges of said rotor blades define a section of a cone.

6. A classifier according to claim 2 wherein said large particle outlet is conical in shape and includes an air inlet pipe connected therewith to air sift said particles.

7. A classifier according to claim 6 including an adjustable closure carried by the bottom of said housing and surrounding said inlet feed pipe to control the air flow from said air inlet pipe to said housing.

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