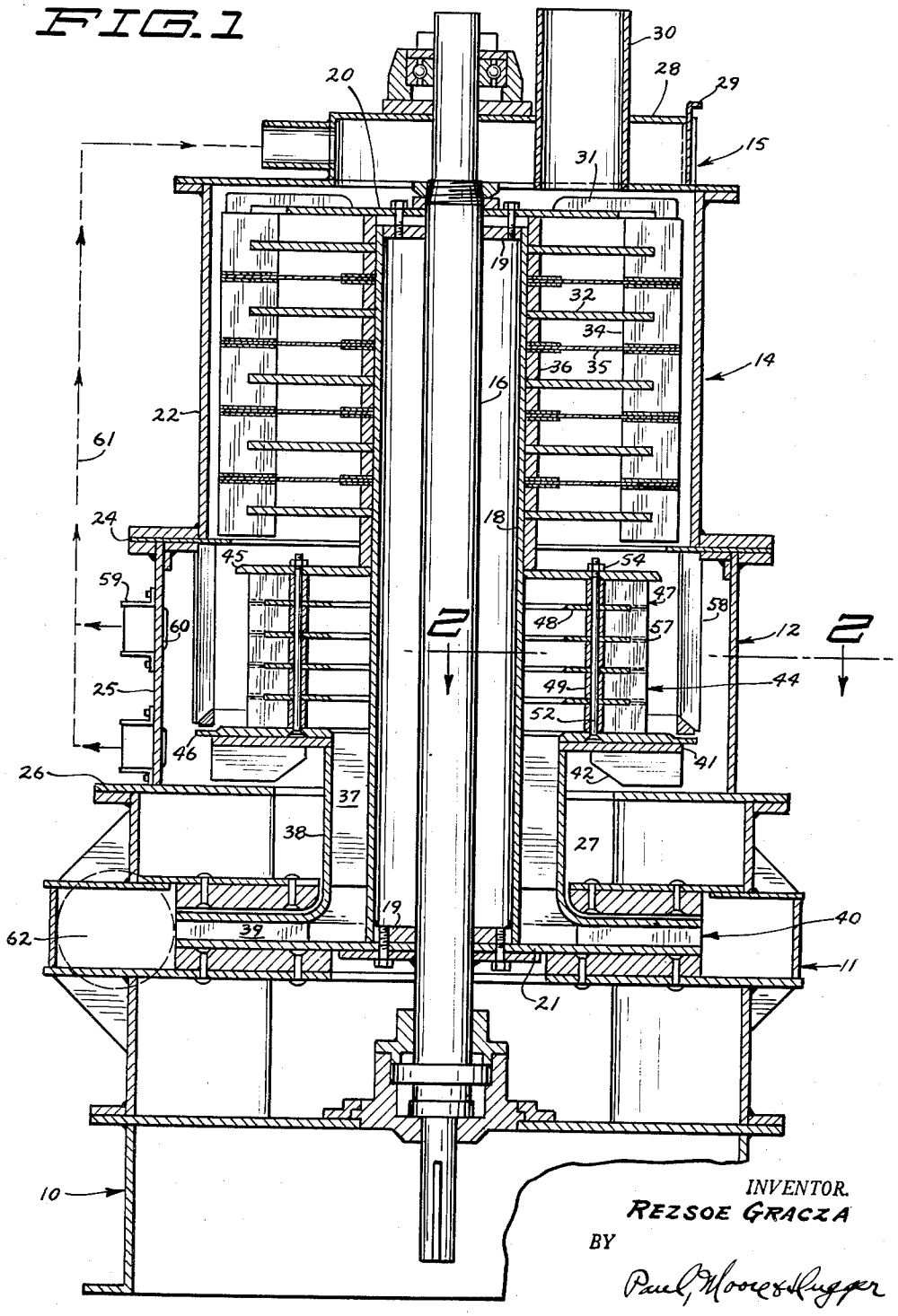
June 13, 1961 R. GRACZA 2,988,220

TURBO-CLASSIFIER

Filed Oct. 10, 1955 4 Sheets-Sheet 1

FIG. 1



INVENTOR.
REZSOE GRACZA
BY
Paul, Moore & Rugger
ATTORNEYS

June 13, 1961 R. GRACZA 2,988,220

TURBO-CLASSIFIER

Filed Oct. 10, 1955 4 Sheets-Sheet 2

FIG. 2

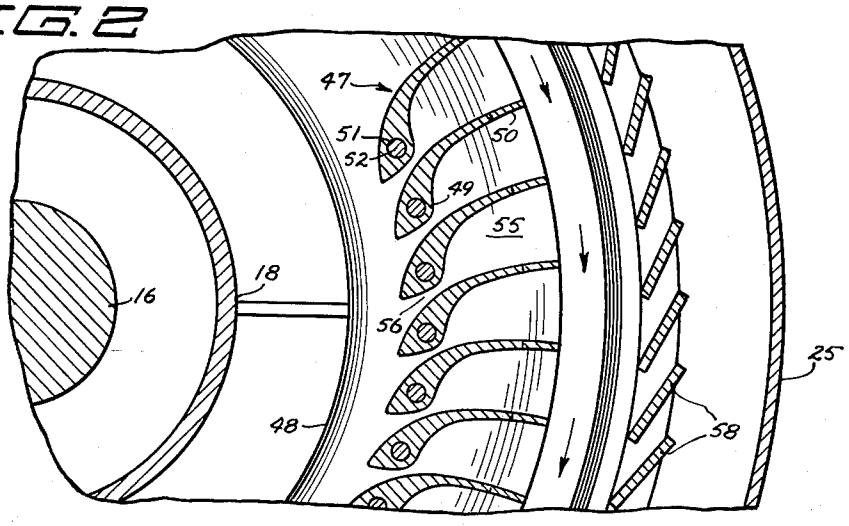
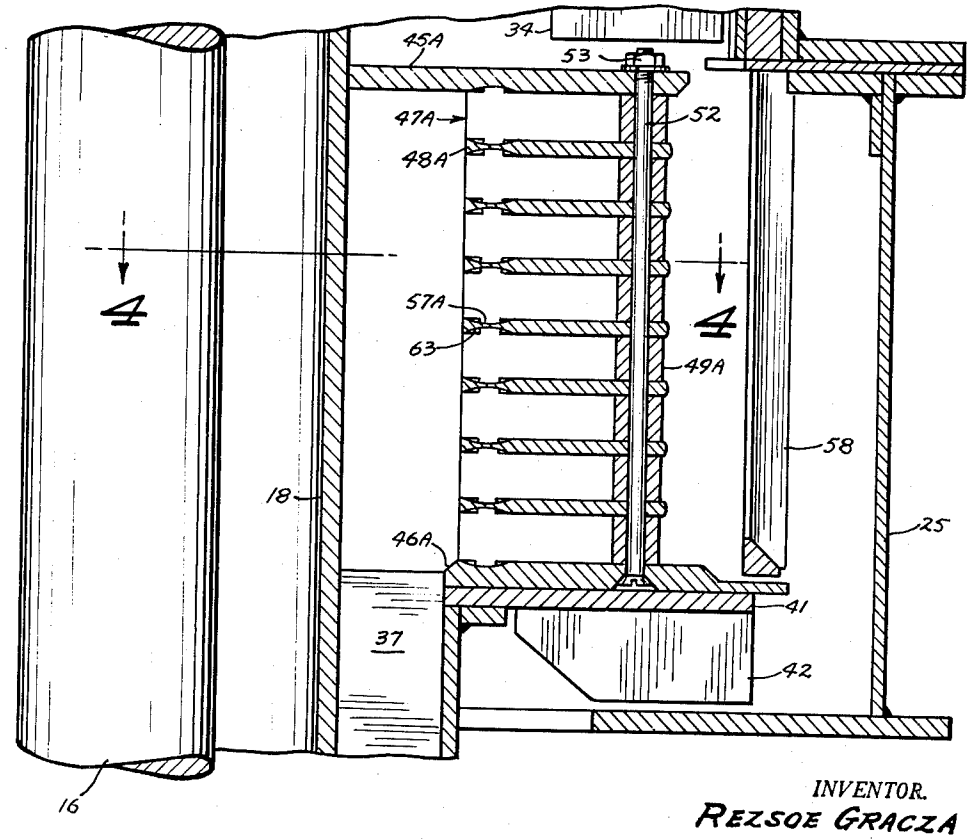


FIG. 3



INVENTOR.
REZSOE GRACZA
BY
Paul, Moore & Rugger
ATTORNEYS

June 13, 1961 R. GRACZA 2,988,220

TURBO-CLASSIFIER

Filed Oct. 10, 1955 4 Sheets-Sheet 3

FIG. 4

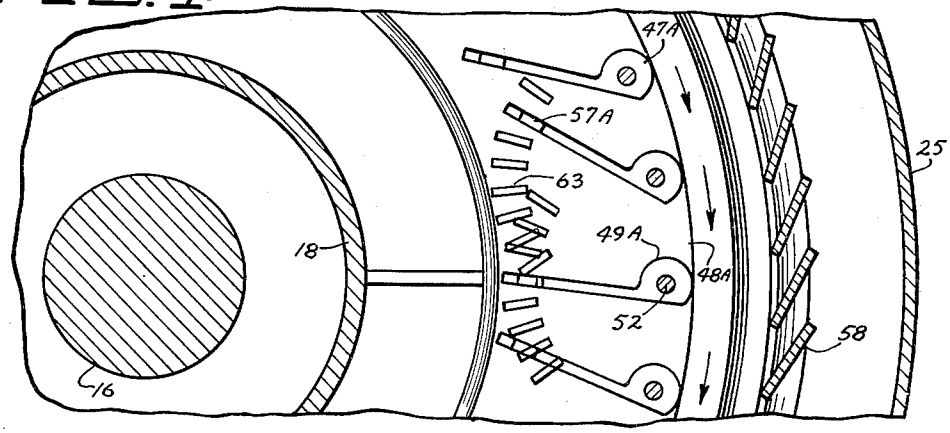


FIG. 5A

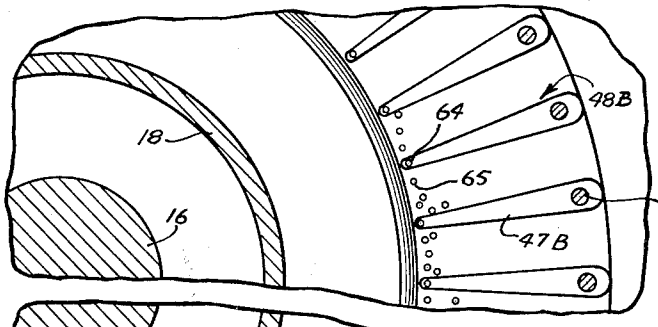
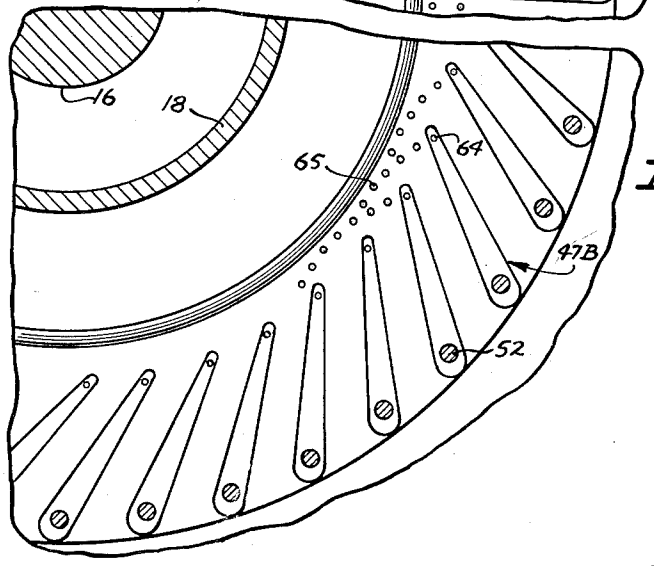


FIG. 5B



INVENTOR.
REZSOE GRACZA
BY
Paul, Moore & Rugger
ATTORNEYS

June 13, 1961 R. GRACZA 2,988,220

TURBO-CLASSIFIER

Filed Oct. 10, 1955 4 Sheets-Sheet 4

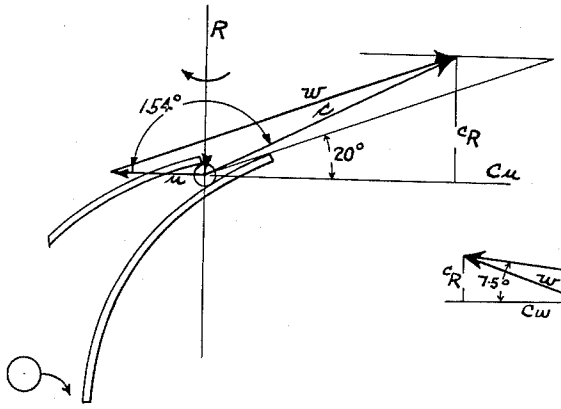


FIG. 7

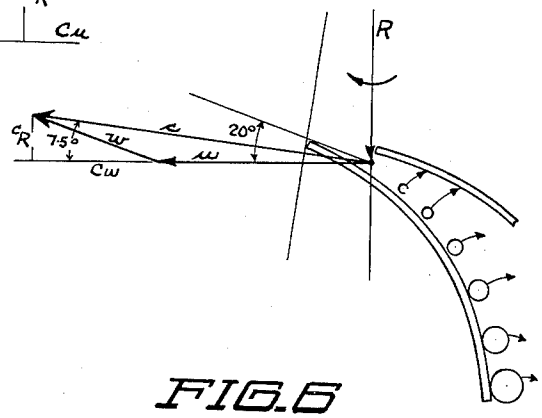


FIG. 6

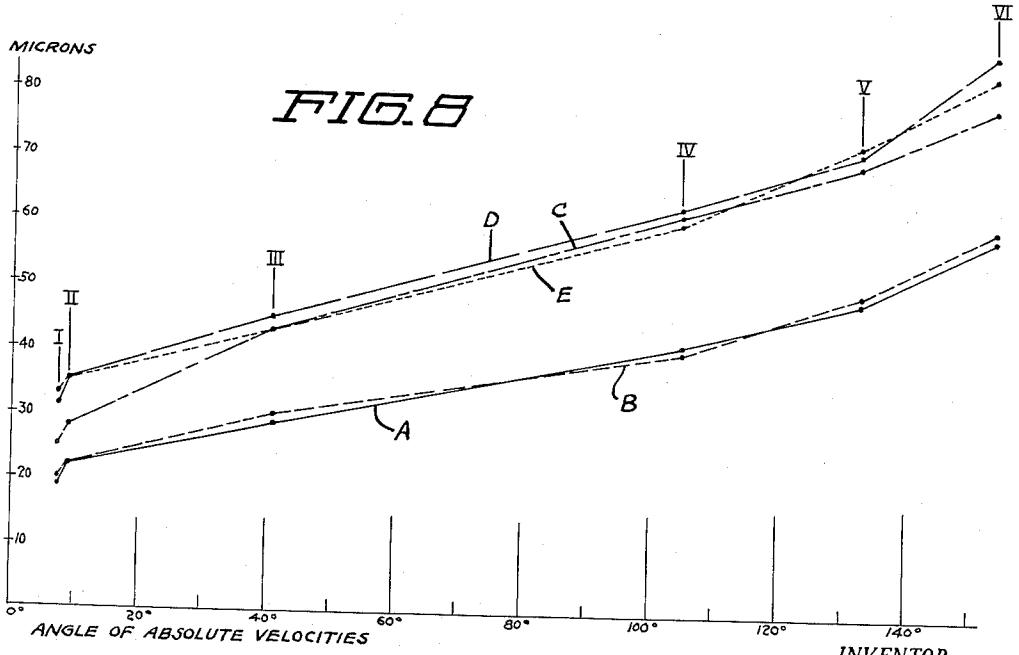


FIG. 8

INVENTOR.
REZSOE GRACZA
BY
Paul, Moore & Rugger
ATTORNEYS

United States Patent Office

2,988,220

Patented June 13, 1961

2,988,220

TURBO-CLASSIFIER

Rezsoe Gracza, Minneapolis, Minn., assignor to The Microcyclomat Co., Minneapolis, Minn., a corporation of Delaware

Filed Oct. 10, 1955, Ser. No. 539,638
13 Claims. (Cl. 209—144)

This invention relates to new and improved means and method for classifying dry pulverulent material. More particularly, this invention relates to a new and improved rotary centripetal classifier means having provision for changing the pitch or angle of the classifier blades and for thereby changing the effective cross-sectional areas of the classifier rotor channels and a method of controlling the critical classifier cut by regulating and controlling the angle of absolute velocity of the stream of suspended particles at the discharge ports within the classifier system.

Heretofore, centripetal classifiers have functioned as a result of the operation of units subject to variable conditions as to the rotational speed at which they were run, the volume of air through the classifier and the cross-sectional areas of the rotor passages. The yield of the product varies with a rotor having passages of given cross-section area depending upon the rate of rotation and air flow and varies with a given rate of rotation and air flow, depending upon the cross-sectional areas. Although it has been a relatively simple matter to construct rotors having any desired cross-sectional area so as to produce maximum yields of a given product at a given speed, these rotors have been limited in utility to the specific circumstances and product for which they were built. That is, for another product presenting different requirements, such a rotor operated at less than maximum efficiency. The result has been the necessity of designing classifiers for specific desired results with specific materials, thereby greatly reducing their overall utility, or of designing classifiers for general use adaptable to the treatment of a variety of materials, but with the result that less than maximum efficiency could be obtained. At the same time, unless the magnitude and direction of absolute velocity at the fine discharge port are taken into account, the critical cut is not sharply defined.

It is the principal object of this invention to provide a rotary centripetal classifier capable of producing separation of heretofore unknown sharpness with relatively high feed rate based upon the use of the combination of rotation at high speed of a rotary classifying element with means for imparting a changeable predetermined pitch to slanted rotor blades and for changing the cross-sectional area of the rotor passages to produce a classifier capable of accommodation to a variety of materials and the production of a large number of wanted critical cuts by means of relatively simple adjustment between runs.

A further object of this invention is to provide a method of centripetal classification of dry solid particles wherein the critical particle size cut is controlled by regulating the angle of absolute velocity of the moving stream of solid particles at the discharge ports of the classifier rotor.

Other objects of the invention will become apparent as the description proceeds.

To the accomplishment of the foregoing and related ends, this invention then comprises the features hereinafter fully described and particularly pointed out in the claims; the following description setting forth in detail certain illustrative embodiments of the invention; these being indicative, however, of but a few of the various ways in which the principles of the invention may be employed.

The invention is illustrated by the drawings wherein the same numerals are used to designate corresponding parts and in which:

FIGURE 1 is a vertical elevation, in section, of one machine embodying the classifier of this invention;

FIGURE 2 is a fragmentary horizontal section taken on the line 2—2 of FIGURE 1 and in the direction of the arrows showing particularly one form of curved blading useful in the practice of the invention;

FIGURE 3 is a fragmentary vertical section showing another form of the improved classifier of this invention;

FIGURE 4 is a horizontal section taken generally along the line 4—4 and in the direction of the arrows of FIGURE 3;

FIGURES 5A and 5B are horizontal sectional views showing still another form of blading which can be used in the classifier of this invention;

FIGURE 6 is a diagrammatic presentation of the discharge port of the classifier rotor according to this invention including in vector diagram form the velocities present when operating under the conditions outlined in Example I;

FIGURE 7 is a similar diagrammatic presentation, but showing the rotor blades curved in the opposite direction and operating under the conditions outlined in Example VI; and

FIGURE 8 is a graphic presentation showing the critical cut of classification of five different materials as related to the angle of absolute velocity.

Broadly stated, this invention comprises a method of centripetal classification including the steps of whirling a mass of dry solid particles suspended in a gas in a stream at high speed around a generally cylindrical classifying area, separating the finer particles from the coarser particles by whirling a plurality of smaller fluidal streams of particles at high speed around the inner periphery of said cylindrical classifying area setting up a plurality of inner vortex actions, continuously withdrawing the desired fine particles from the inner vortices by distorting the paths of the inner vortices carrying the fine particles inwardly by suction and removing the fine particles from the classifying area. The invention is characterized by the improvement which consists in controlling the critical particle size cut by regulating the angle of absolute velocity of the streams of particles at the discharge ports around the innermost periphery of the cylindrical classifying area.

The invention also includes a rotary centripetal classifier having adjustable blading so that the blades may be moved to change their directions and their relative locations to change the angle of absolute velocity of the moving streams of particles at the discharge ports within the classifier to adapt the classifier to specific needs. The classifier rotor blades are so positioned that adjacent blades define a discharge port of variable cross-sectional area facing upon the inner annular axial passage of the rotor and those ports are disposed generally tangential to the annular passage.

Coriolis force in the interblade flow pattern is responsible for the classification along the suction or trailing side of the blade when the rotor is in motion. Classification in this classifier occurs along the blades in the space between the blades in contrast to other classifiers in which classification is said to take place at a critical radius on a potential surface, as held by some writers in the field. The peculiar character of the interblade flow pattern provides a positive means, that is, the pressure side of the blade, for the elimination of oversize particles from the classification zone without interfering with the entering mixture. The classifier of this invention provides means for carrying fine particles into the fine-removal opening and at the same time provides positive means for carry-

ing coarse particles out into the coarse-removal opening from the classification zone without interfering with each other. This two-way provision of fine and coarse particle removal is generally responsible for the sharper classification obtained with the classifier of this invention.

Coriolis force may be defined as the force corresponding to an acceleration which must be vectorially added to the sum of the acceleration of a moving particle with respect to a body of reference and the absolute acceleration of the body of reference to give the absolute acceleration of the particle. It is equal to twice the vector product of the annular velocity of the body of reference and the linear velocity of the particle with respect to it.

Referring now to the drawings, and particularly to FIGURES 1 and 2, there is shown one exemplary form of apparatus embodying the improved classifier of this invention. The apparatus as shown in these figures consists of a unitary vertical milling and classifying device together with a mounting base of the type described in detail in a copending United States application Serial No. 328,016, filed December 26, 1952 by Henry G. Lykken and Tibor A. Roza, now Patent No. 2,762,572, issued September 11, 1956. The machine there described is merely exemplary of one type of device into which the improved classifier of this invention may be incorporated and is used for convenience in describing the operation of the improved classifying means and for illustrating the setting for this invention. For this reason, the accessory elements which are not essentials of the instant invention are described in generalities. For detailed description, reference may be had to the copending application. It must be emphasized, however, that this improved classifier unit may be used alone or in conjunction with other mills and pulverizers utilizing rotary centripetal classifiers. The apparatus is divided generally into a platform structure **10**, a base and fan housing structure **11**, a classifying section **12**, a milling section **14** and a top cover and feed housing **15**. The machine is enclosed at both ends between an annular top plate and an annular bottom plate, both having central openings for the passage of a shaft **16**. The vertical shaft **16** is supported in suitable bearing structures at the top and bottom of the apparatus and extends through the milling and classifying sections and the fan housing.

Shaft **16** is adapted to be driven by any suitable motor means, not shown. The shaft is enlarged and reinforced through the part of its length that extends through the milling, classifying and fan housings by a tube **18**, supported by annular rings **19** secured to the shaft. Rotor end disks **20** and **21** are mounted at either end of tube **18** within the top and bottom plates respectively. All of the rotative elements are mounted on and between the end disks for rotation by the shaft **16**.

The milling section **14** is contained within a cylindrical housing **22** between the top plate and an annular plate **24** having a large central annular opening positioned between the milling and classifying sections. The classifying section **12** is contained within a somewhat larger diameter cylindrical housing **25** and an annular plate **26** spaced apart slightly from the fan housing **11** to provide an auxiliary air inlet space **27**. The annular opening in plate **26** is preferably provided with dampers to permit regulation of auxiliary air flow.

Mounted on the top plate over the aperture therein is an inlet box **28**. Inlet box **28** is provided with a slide gate **29** for the admission of atmospheric air. A tubular inlet **30** for the admission of solid material to be disintegrated in the mill projects through the inlet box. A plurality of blades **31** is provided on the top surface of rotor end plate **20** to assist in distributing the dry material fed through tubular inlet **30**.

The milling section is made up of a plurality of units on stages, each comprising a slotted annular disk **32** carrying at its periphery a plurality of spaced radial vertical blades **34**. Between successive milling stages are mounted annular plates **35**. These plates may be mounted so as to be free to vibrate or they may be rigid. The annular disks **32** and annular plates **35** are supported on the shaft tube **18** held spaced apart by suitable spacer rings **36**.

Secured near the opposite end of tube **18** is a plurality of radial splines **37**. Around these splines is a flanged tube section **38** which rests upon fan blades **39**, which in turn, rest upon end plate **21** and comprise the blades of an impeller fan indicated generally at **40**. Tube **38** extends through the opening in annular plate **26** constituting the bottom wall of the classifier housing. The space between the flange of tube **38** and end plate **21** includes the impeller fan **40** and acts as discharge passage for the desired fine fraction of particles. The space between flanged tube **38** and shaft tube **16** defines an annular passage from the classifier unit to the discharge passage.

Mounted at the upper end of tube **38** within the classifier housing is an annular plate **41** carrying on its lower surface a plurality of blades **42** and constituting an auxiliary fan for drawing air through the annular opening in plate **26** from space **27** as needed.

Mounted on shaft tube **18** between annular plate **41** and the lowermost milling unit is the classification rotor of this invention indicated generally at **44**. The classifier rotor comprises an upper annular plate **45** mounted on shaft tube **18** and a lower annular plate **46** having a somewhat larger annular opening corresponding to the annular passage in flanged tube **38**. Supported between these annular plates are a plurality of classifying units or decks, each comprising a plurality of spaced apart vertical blades **47** disposed around the perimeter of the rotor, separated vertically by horizontal annular disks **48**. In the form illustrated in FIGURES 1 and 2, the blades **47** are curved elements in the form of an air foil section having a thickened inner hub portion **49** and a gradually tapering vane element **50** curving to the edge of disk **48**. The hub **49** of each blade is provided with a hole **51** through which a bolt **52** is passed. Bolts **52** extend through annular plate **46**, through each annular disk **48** and blade **47** to annular plate **45** and are tightened and secured by means of nuts **54** to hold the classifier rotor together and to hold blades **47** in their desired positions.

Adjacent blades **47** define fine classification zones **55** in which the desired fine particles are separated and removed from the near fines and larger particles and discharged through throat or port **56**. Bolt **52** acts as a pivot for rotating blades **47** in order to change the dimensions, cross-sectional area, direction and shape of the individual classifying zones and discharge ports to meet varying conditions and materials. This is accomplished simply by loosening nuts **54**, changing the positions of the blades and then retightening the nuts. To facilitate adjustment and uniform positioning of the blades, each blade may be provided with slight projections **57** adjacent their outer edges and disks **48** may be provided with notches or depressions corresponding to a plurality of predetermined especially useful positions.

An annular pendant wall or louver curtain **58** is attached to the under surface of annular plate **24** and is suspended in the annular space between the classifier rotor **44** and the classifier housing wall **25** extending almost to lower rotor plate **46**. The individual louver elements are disposed generally tangential to the circular aspect of the wall and slant in the direction of rotation of the rotary units of the apparatus.

The classifier housing is provided with one or more skimmer boxes **59** which may be constructed as shown in the copending United States application, Serial No. 278,239, filed March 24, 1952 by Henry G. Lykken, now Patent No. 2,754,967, issued July 17, 1956. Each of the skimmers has one or more adjustable wire lips **60** on the inner side of the cylindrical shell of the classifying

section, the edge of the lips being directed against the spiral flow of solid particles. The coarse particles skimmed off may be returned by means of any suitable conduit means, indicated at 61, to the feed inlet.

A discharge outlet 62 is provided for removal of the wanted fine fraction from the classifier. Outlet 62 is connected to any suitable entrainment separator means to collect the fine particles from the carrying gas.

In Figures 3 and 4 there is shown a modified form of rotor construction. According to this form, the blades 47A are formed with generally flat surfaces but with enlarged hubs 49A conforming generally to the air flow pattern between the blades. In the form here illustrated, rotor end plates 45A and 46A are somewhat modified to receive bolts 52 nearer to their outer peripheries. Thus, the narrowed throats are presented on the outer face of the classifier rotor and the blades are pivoted from the outer periphery of disks 48A.

As in the case of the curved blade form, the edges of the blades 47A are preferably provided with projections or lugs 57A so that they may be locked in position in grooves 63 formed in the rotor disks. A plurality of grooves 63 are provided for facilitating adjustment and uniform positioning of the blades. The individual blades pivot upon bolts 52 when the nuts 54 are loosened, permitting easy movement of the blades. The grooves 63 are formed to correspond to predetermined desirable blade positions. When the lugs or projections are seated in the grooves and the rotor is tightened down, the blades are locked against movement.

In FIGURES 5A and 5B, there is shown a further modified form of blade and disk construction. In this form the blades 47B are generally straight but tapering slightly toward the center of the rotor. The blades are pivoted on bolts 52 from their thicker heels adjacent the outer periphery of disks 48B. Each blade is provided with a slight projection, such as a hemispherical protuberance 64 at the top and bottom of the blade and disks 48B are provided with a plurality of perforations or dimples 65 arrayed in an arcuate path to receive the projections 64 and hold the blades in their pre-set positions. As shown in FIGURE 5A, all of the blades are disposed generally radially; in FIGURE 5B the corresponding blades are shown shifted to a position generally tangential to the inner periphery of the classifier rotor disks.

The blades may be formed in a variety of shapes as desired and as dictated by the particular requirements of the materials and conditions encountered in use. They may be curved or straight, flat or tapered and may slant or curve forwardly or backwardly. A convenient manner of reversing the slant of the blades is merely to invert the entire classifier rotor upon shaft tube 18. The blades may be pivoted for movement from either the inner or outer peripheries of the annular rotor disks or, in some instances, from some intermediate point. The blades may be cast or forged from metal, such as steel, or they may desirably be molded from a wear-resistant synthetic resinous material, such as nylon, for example.

In the operation of the device of this invention, as illustrated, solid material is introduced in a continuous stream through inlet 30 from any suitable feeder mechanism. The solid material falls down upon spinning end plate 20, having vanes 31 on its upper surface and is evenly distributed, is thrown centrifugally outwardly and falls from around the periphery of the plate to the milling stages. In falling downward, it is subjected to reducing action produced as a result of attrition induced by the rapidly rotating milling section of the rotor in a manner well understood in this art. As the material falls, it is progressively reduced in size. A relatively small flow of air or other gaseous fluid is fed as needed by opening damper 29.

All of the disintegrated material passing downwardly through the milling section is delivered in a uniformly distributed suspension through the annular orifice in plate 24 to the classifying zone, immediately inside the pendant wall 58.

The downflow of gaseous fluid and pulverized granular material of mixed sizes at 58 is balanced by the inflow of gaseous fluid through the opening in plate 26 at the bottom of the classifying section. The desired fine ground particles and most of the gaseous fluid is withdrawn through the classifier rotor 44, through the spaces defined by the blades 47 and the rotor disks to the annular passage around shaft tube 18, thence through the annular passage within flanged tube 38 and out through the impeller fan 40 to the discharge outlet 62.

Within the classifying section 12, there is a complex multiple phase classifying action. The fan blades 42 produce a tight spiral or vortex of air in the space just inside the classifier housing wall 25 and outside of the pendant wall 58. The spiral is generally upward. The gaseous fluid is maintained in a generally vorticular condition within this space and the coarser solids thrown out centrifugally below the bottom of the pendant wall are continuously suspended in this vortex. Those coarse particles are generally maintained as a circulating layer against the wall 25 where they may be picked off as desired by the skimming weirs 60 of the skimmer boxes 59 and, if wanted, returned for further grinding.

Any fines that may get into the space between the pendant wall and the classifier housing wall, and most of the gaseous fluid in that space, in order to leave the classifying section, must pass inwardly through the pendant wall 58 and then through the centripetal classifier rotor 44. In progressing thusly through the wall 58 and towards the rotor 44, the gaseous fluid and its load of fines and any near fines that may be present is drawn inwardly through the louvers of the pendant wall. At the same time, within the pendant wall, there is a generally spiral downflow superimposed upon the general eddy flow pattern created by the blades of the rotor unit. This composite downward spiraling flow starts at the feeding annulus in plate 24 and ends at the bottom of the pendant wall.

The inwardly directed air under pressure from the air inlet fan blades 42 passing through the louvers blasts through the composite spiralling downflow containing coarse as well as fine solid materials, which is inside of the pendant wall and is continuously entering through the feeding annulus from the milling section. A vorticose cross flow action of great intensity is thus established inside the pendant wall.

At the same time, the blades 47 of the centripetal classifier rotor produce small vortices somewhat within the peripheral limits of the radial blades and the intervening disks. In addition, there is a general velocity into the narrowing space, such as throat or port 56, between adjacent blades. Depending upon the speed of operation, spatial relationships between the blades and physical constants of the solid material a certain range of finer particles are moved inwardly under these actions into the axial annular space in the interior of the classifier rotor and discharged through the impeller fan.

The coarser particles are meanwhile thrown outwardly against the pendant wall where they gradually move spirally downward to the bottom of the pendant wall 58 and are thrown out centrifugally into the space adjacent the classifier housing wall by the action of spinning plate 46. There the coarse particles and any fines that may have adhered to them are met by the outer vortex and the spirally upflow in this space, as described previously. In this manner the larger particles are cleaned off and the fines are carried up and again given a chance to be pulled in through the louvers of pendant wall and into the classifier rotor.

Thus, in the illustrated form of construction, there is provided a three-fold classifying effect: the classifying effect due to the action of the centripetal classifier, the effect due to the pendant wall construction and the clas-

sification resulting from the combined effect of the fan blading 42 and the spatial arrangements. The coarse particles are freed from intermixed fines and the coarse particles are then removed from the vorticose layer moving on the inside of wall 25, by the skimmer boxes as they are separated and may be discarded, collected or recirculated as desired in the operation.

Referring now to the fine classifying action of the classifier rotor, the stream through the spaces defined by the rotor blades and the rotor disks and induced by the impeller fan is assumed to have generally constant velocity distribution pattern along its cross-section, but the velocity changes at different points along the path of the stream. Along the path of the stream, particles and air move in a free system. As a practical matter, some forced movement exists due to the difference between air and particle velocities, that is, terminal velocities at any given point in the free path of the stream, although this forced movement is practically negligible considering the order of magnitude in the particle and air velocities. Gravity is similarly neglected as being an unimportant variable. This consideration would generalize the direction of the axis of the classifier in the space quite arbitrarily. That is, the axis need not be aligned in any particular direction.

A particle moving in the paths of the stream into the rotor on the suction side of the blade, but out of contact with the blade surfaces, is subject to drag and to centrifugal force, but practically not to Coriolis force. A particle moving in the paths of the stream against the blade surface is subjected to flowdynamical drag, centrifugal force, friction force (friction of particle on blade surface) and Coriolis force since forced movement exists along these paths, forced by the blades and drag in radial direction.

The vectorial sum of the acting forces, that is, centrifugal force, flowdynamical drag, Coriolis force and friction, is the resultant force. The direction of the resultant determines possible movement of a particle in the rotating system.

For a particle moving inwardly in the path of the stream into the rotor out of contact with the blade surfaces, there is no friction; and no Coriolis force exists since there is no forced movement in the radial direction. The resultant force on any arbitrarily selected particle will be determined by drag and centrifugal force. Centrifugal force has radial direction outward. Drag follows generally direction of air flow. The resultant force causes the particle to move inwardly obliquely in the direction of the blade.

For a particle moving on inwardly in the path of the stream along the suction side of the blade, the particle is affected by the Coriolis force since forced movement exists in radial direction. Coriolis force points toward the blade and causes the friction force. The direction of the friction force is radial and points opposite to the direction of particle movement.

For a particle of definite size in this path, there will exist a point of equilibrium where a balance of forces occur and the resultant force is zero. There will be no movement of the particle in the radial direction, only movement of air. There will be no forced movement in radial direction, and accordingly, no Coriolis force and no friction. Forces in the radial direction are in balance, and no acting force exists in tangential direction.

Up to this point, Coriolis force keeps the particle pressing against the blade surface, but at the equilibrium point, this suddenly ceases. The particle is set free in the tangential direction and in the absence of air flow would act as it would if released from central motion. In the absence of air flow its inertia would keep it on the line of its absolute velocity, similarly to any body which, if released from central motion, leaves a rotating system on a tangential path.

In a given infinitesimal time period, the rotation of the system changes the location of the equilibrium point on the blade surface. This different site on the blade is characterized by a different velocity of the rotating system. During the same time period, however, the absolute velocity of the particle is kept constant. The particle starts to move and accelerates in the rotating system, due to its inertia. At the same time, this inertia force affects the particle in the rotating system. While the particle moves away from the blade in tangential direction, the radial and larger component of the inertia force has to be balanced and even overcome while the particle is in the vicinity of the blade. The inertia force in the radial direction is balanced by the drag of air flow parallel to the blade.

As the particle departs in tangential direction from the blade, it loses peripheral velocity, and consequently, centrifugal force. In the vicinity of the blade surface, air drag being relatively greater than centrifugal force, the particle does not leave the blade surface in tangential direction, that is, perpendicular to the blade surface, if radial blades, but in an oblique direction inwardly. As the particle advances, leaving the blade, it reaches airflow layers with progressively lesser radial velocities representing progressively less inertia force controlling drag.

At the point where the particle reaches deepest penetration between the blades, the radial component of inertia force and air drag and centrifugal force are in balance. Consecutive air flow layers have large velocity gradient, which enables the particle to rapidly change its radial velocity. At the same time, there is a steady loss in the peripheral velocity of the particle, resulting in less centrifugal force. The particle finally reaches the pressure side of the opposite blade and is carried back out into the spiralling flow around the rotor.

Larger and larger particles spin out at larger radii eliminating in this way oversize particles from the air stream along the suction side of the blade. These particles are carried out by the air stream along the pressure side of the opposite blade to be removed with the coarse fraction.

In the inward direction of the stream, the gaseous dispersion carries finer and finer particles, the finest of which are finally removed at the heel of the blade centerward. This point is called the critical radius, since it is critical for the theoretical largest particle in the fine fraction.

As described above, the balance of forces on decreasing particle sizes occurs at decreasing radii along the suction side of the blade and represents the physical means to size out oversize particles from the inwardly moving stream and to carry these oversize particles out of the interblade area to the coarse removal opening in the periphery of the classifier rotor in an orderly undisturbed flow pattern of the intrablade eddies.

The above discussion has been based upon the assumption that velocity distribution pattern in the radial direction is constant. In actuality, velocity distribution over any cross-section of the space defined by radial rotor blades and the rotor disks are not constant, but are drastically different. Because of this, different size particles can cross the critical radius circle, depending upon their location passing the port, and end up in the fine fraction, thereby greatly reducing the sharpness of classification and the efficiency of the classifier.

To remedy this situation, it is necessary to maintain radial velocity distribution generally constant, as well as to control the magnitude and direction of velocity especially at the critical radius. This result is achieved regulating the air flow through the classifier, the rate of rotation and the positioning of the rotor blades at the critical radius. In this way velocity distribution over the cross section of the space defined by the rotor blades and disks becomes practically constant and critical particle size is strictly controlled, covering practically the entire subsieve size range to yield sharper classification

than heretofore. The critical particle size is controlled by changing the magnitude and direction of the absolute velocity of the moving stream of suspended particles at the port communicating with the annular discharge passage of the rotor, where due to limited space between blades, the blades acting as directing vanes, little, if any, unit of critical cut is expressed in these examples in flow-dynamic units of effective diameters in physical units of microns.

The conditions under which the classifier was operated during each of the exemplary experiments are tabulated below:

Example	I	II	III	IV	V	VI
Operating Conditions:						
C.f.m. without load	3,440	4,300	4,550	3,000	3,100	2,680
R.p.m. (nominal)	2,260	2,260	2,260	960	960	960
Angular velocity in radians/sec.	235	235	235	100.5	100.5	100.5
Critical radius (R) centimeters	18.3	18.3	18.3	18.3	18.3	18.3
Decks used	8	8	8	8	5	2
Ports per deck	40	40	40	40	40	40
Systems' velocity (U) at critical radius in cm./sec.	+4,300	+4,300	+4,300	+1,840	+1,840	+1,840
Relative velocity (W) at critical radius in cm./sec. (observer in rotary system)	2,510	3,140	3,200	2,170	3,500	7,750
Absolute velocity (C) at critical radius in cm./sec. (observer in stationary system)	6,900	7,400	1,600	800	1,800	5,500
Cu in cm./sec. for centrifugal force	+6,750	+7,200	+1,200	−250	−960	−5,000
CR in cm./sec. for flowdynamical drag in radial direction	850	1,080	1,000	750	1,000	2,400
Angle of blades in degrees	20	20	20	20	20	20
Angle of absolute velocity in degrees	7.5	9	41	105	133	154
Relative position of blade heels	Forward Curved.		Backward Curved.		Backward Curved.	

turbulence exists (approximation of laminar flow) providing ideal conditions for classification in the vicinity of the critical radius.

With a constant air flow through the classifier the magnitude of the absolute velocity at the port can be controlled by using different numbers of classifier decks. The angle of the blade at the port, directing velocity in a generally tangential direction can be built into the classifier in which case critical particle size change is obtained by changing the direction of rotation or by inverting the rotor. Or according to this invention, the blade angle is made adjustable to enlarge the efficient utilization of the classifier over a wide range of conditions and materials.

The method of this invention is illustrated by the following examples. Each of the Examples I to VI describe operating conditions for increasing critical cut from the first to the last example. In each of the examples five different materials designated A to E were used. All five experimental materials have a specific gravity of 1.44 gr./cm.^{3}, but, as reasonably repeatable bulk density tests show, they have increasing bulk densities from A to E and generally less irregular shape characteristics from A to E. Thus, the shape factor of the powder particle decreases in the direction from A to E.

Air flow in cubic feet per minute (c.f.m.) was measured in the discharge duct attached to the classifier. Relative velocities W (to an observer in the rotary system) at the classifier rotor discharge ports, i.e., throats 56, were calculated from c.f.m. and the measurable size of the ports. The direction of relative velocities W is determined by the positioning of the classifier rotor blades. The velocity of the system U at the rotor ports is calculated from the known r.p.m. of the rotor unit and structural measurements, i.e., critical radius R. The direction of the systems' velocity is determined by the direction of rotor rotation. The vectorial sum of relative velocities W and the systems' velocity U is the absolute velocity C (relative to an observer in the stationary system of the housing).

The angle of absolute velocity as measured from the direction of the systems' velocity at critical radius, as shown in FIGURES 6 and 7, is an important variable for producing separations at different critical cuts. Critical cut is the critical particle size measured in any unit under which size every particle goes into the fine fraction and over which size every particle goes into the coarse fraction, assuming perfect classification. Since perfect classification is impossible of achievement the

For Examples I and II the blade heels curved forward in the direction of rotation as shown in FIGURE 6. For Examples III and VI the rotor was turned upside down with the result that the blade heels then curved backwards as shown in FIGURE 7. In all examples the critical radius, the blade angle and the number of ports was the same. The angle of absolute velocity increased from the first to the last example.

The characteristics of the product, that is, the critical cut of material delivered from the classifier in each experiment, are tabulated below:

Example I

Materials	A	B	C	D	E
Bulk densities	.502 / .479	.477 / .456	.607 / .574	.601 / .580	.613 / .582
Effective diameters in microns	19	20	25	31	32

Example II

Materials	A	B	C	D	E
Bulk densities	.487 / .537	.485 / .511	.595 / .671	.643 / .677	.625 / .666
Effective diameters in microns	22	22	28	35	35

Example III

Materials	A	B	C	D	E
Bulk densities	.503 / .619	.505 / .531	.657 / .708	.681 / .733	.654 / .693
Effective diameters in microns	29	30	43	45	43

Example IV

Materials	A	B	C	D	E
Bulk densities	.608 / .646	.557 / .584	.695 / .743	.689 / .736	.679 / .723
Effective diameters in microns	41	40	61	62	60

Example V

Materials	A	B	C	D	E
Bulk densities	.647 / .703	.603 / .640	.711 / .785	.714 / .751	.713 / .741
Effective diameters in microns	48	49	69	71	72

Example VI

Materials	A	B	C	D	E
Bulk densities	.647 / .703	.600 / .645	.723 / .760	.729 / .758	.715 / .755
Effective diameters in microns	58	59	78	86	83

As is apparent from these examples, and illustrated graphically in FIGURE 8 where the particle sizes are plotted against angle of absolute velocities, there is definite and close correlation between critical cut particle size and angle of absolute velocities. The effect of inverting the classifier rotor to change the blade direction is seen by comparison of Examples II and III. By varying the pitch of the classifier rotor blades, the dimensions of the outlet port, the critical radius, the speed of rotation of the rotor, the air flow, or any of them, the angle of absolute velocities can be varied and controlled, thereby permitting control of the critical cut particle size for any material.

It is apparent that many modifications and variations of this invention as hereinbefore set forth may be made without departing from the spirit and scope thereof. The specific embodiments described are given by way of example only and the invention is limited only by the terms of the appended claims.

What is claimed:

1. In a centripetal classifier comprising a cylindrical classifier housing, a peripheral inlet-axial outlet classifier rotor journalled for rotation within said housing, said rotor comprising an inner annular axial passage surrounded by a plurality of spaced apart annular disks and a plurality of blades spaced about and extending longitudinally of the axis of the rotor between said disks and defining a plurality of passages communicating with said annular passage and the periphery of the rotor, means communicating with said inner annular passage for inducing a flow of gas through said classifier rotor and means for feeding a uniformly distributed mixture of varied size particles in gaseous suspension to said classifier, the improvement which consists in said rotor blades being pivotally mounted and contoured to define a discharge port of variable cross-sectional area facing upon said inner annular rotor passage upon pivotal adjustment of said blades, said port being generally tangential to said annular passage.

2. A centripetal classifier, according to claim 1, further characterized in that said rotor comprises a plurality of elongated rod members extending longitudinally through said rotor disks and blades uniformly spaced around the periphery of said disks, each of said blades having a hole through which said rod members pass to serve as pivots for said blades and means for tightening and loosening said rod members.

3. A centripetal classifier, according to claim 1, characterized in that said blades are provided with projections extending from the edges thereof, and the rotor disks are provided with corresponding depressions to receive said projections.

4. A centripetal classifier, according to claim 1, further characterized in that said rotor blades are curved.

5. A centripetal classifier, according to claim 4, further characterized in that said rotor blades are formed from a wear-resistant synthetic resinous material.

6. A centripetal classifier, according to claim 5, further characterized in that said rotor blades are formed from nylon.

7. A centripetal classifier comprising a cylindrical classifier housing, a peripheral inlet-axial outlet classifier rotor journalled for rotation within said housing, said rotor including an inner annular axial passage surrounded by a plurality of spaced apart annular rotor disks and a plurality of blades spaced about and extending longitudinally of the axis of the rotor between said disks and defining a plurality of passages communicating with said annular passage and the periphery of said rotor, a plurality of elongated rod members extending longitudinally through said rotor disks and blades uniformly spaced around the periphery of said disks, a hole in each of said blades through which the rod member passes to serve as a pivot for said blades, means communicating with said inner annular passage for inducing a flow of gas through said classifier rotor, means for feeding a mixture of varied size solid particles in gaseous suspension to said classifier and means for withdrawing oversize from said classifier.

8. A centripetal classifier, according to claim 7, further characterized in that said blades have projections extending from the edges thereof and the rotor disks are provided with corresponding depressions to receive said projections.

9. A centripetal classifier, according to claim 7, further characterized in that said pivotal blades are curved.

10. In the method of centripetal classification utilizing a rotating bladed centripetal classifier rotor wherein a suspension of particles to be classified in a gaseous fluid is whirled in a stream at high speed around the outer periphery of a generally cylindrical rotating classifying area, the finer particles are separated from the coarser particles by whirling a plurality of smaller fluidal streams of particles at high speed around the inner periphery of said cylindrical classifying area setting up a plurality of inner vortex actions and the desired fine particles are continuously withdrawn inwardly from the inner vortices and discharged axially by suction, the improvement which consists in exercising control over the critical particle size cut by adjustment of the angle of absolute velocity of the moving streams of particles within the classifying area by variation of the pitch of the classifier blades relative to the inner periphery of said cylindrical classifying area.

11. In the method of centripetal classification of fine solid particles in a fluid suspension circulating about a generally cylindrical rotating classifying area utilizing a rotating bladed centrifugal classifier rotor the step of exercising control over the critical particle size cut by adjustment of the angle of absolute velocity of the moving stream of particles by variation of the pitch of the classifier blades relative to the periphery of said cylindrical classifying area.

12. The method according to claim 11 further characterized in that the angle of absolute velocity is further regulated by varying the volume of air flow through the classifying area.

13. An improved method of centripetal classification utilizing a rotating bladed centripetal classifier rotor comprising the steps of whirling a suspension of dry solid particles in a gaseous fluid at high speed in a stream around a cylindrical classifying area, separating the finer particles from the coarser particles by whirling a plurality of smaller fluidal streams of particles at high speed around the inner periphery of said cylindrical classifying area setting up a plurality of inner vortex actions, exercising control over the desired critical particle size cut by adjustment of the angle of absolute velocity of the

inner vortical streams at the innermost periphery of the generally cylindrical classifying area by variation of the pitch of the classifier blades relative to the innermost periphery of said cylindrical classifying area and continuously withdrawing the desired fine particles inwardly from the inner vortices and discharging them axially by suction.

References Cited in the file of this patent

UNITED STATES PATENTS

2,484,255	Thomas	Oct. 11, 1949
2,739,709	Kaiser	Mar. 27, 1956
2,753,996	Kaiser	July 10, 1956
2,754,967	Lykken	July 17, 1956