

April 29, 1969

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3,441,133

VANE CONTROL FOR AIR CLASSIFIER

Filed May 4, 1966

Sheet 1 of 3

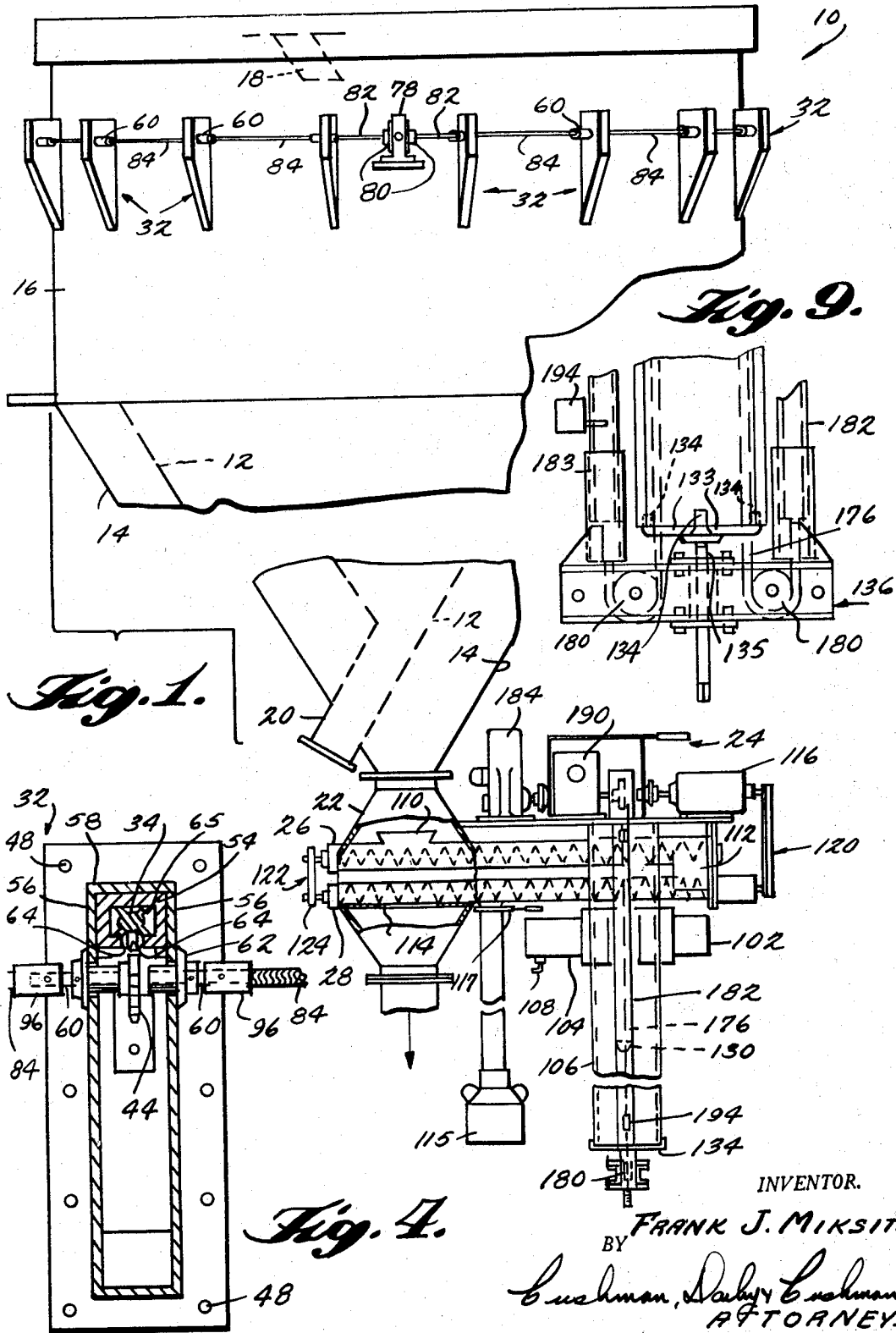


Fig. 9.

Fig. 1.

Fig. 4.

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Fig. 3.

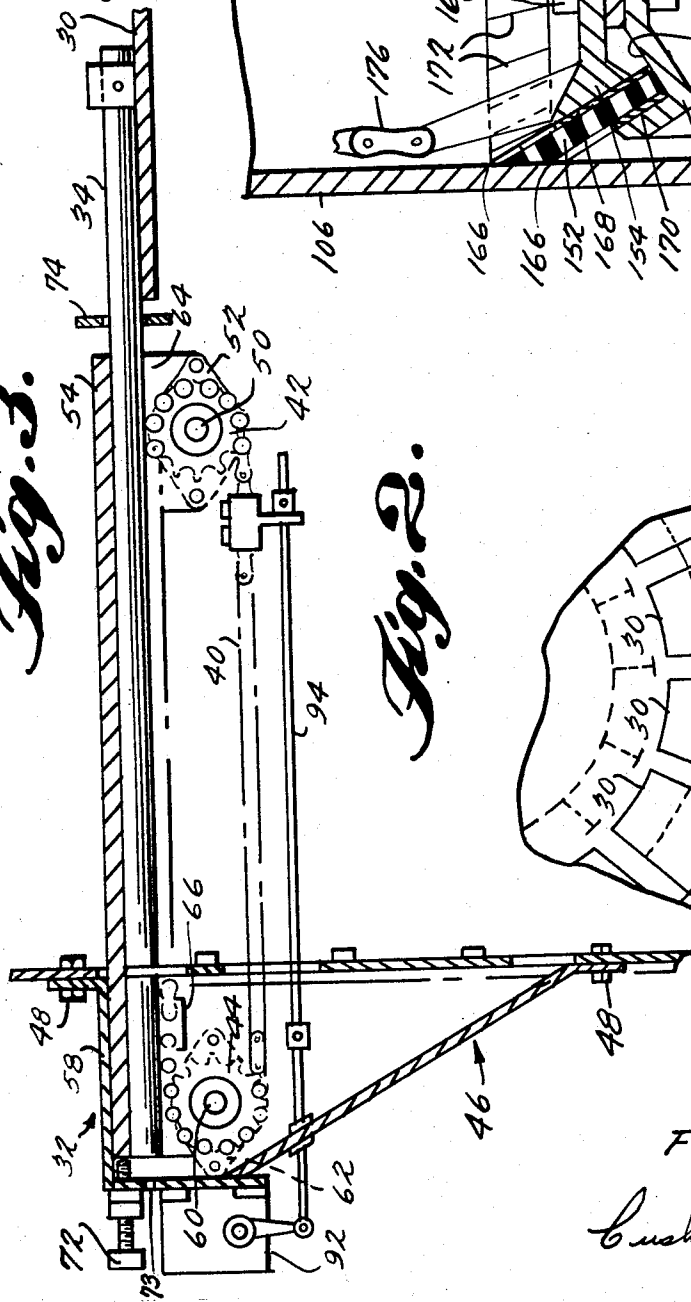
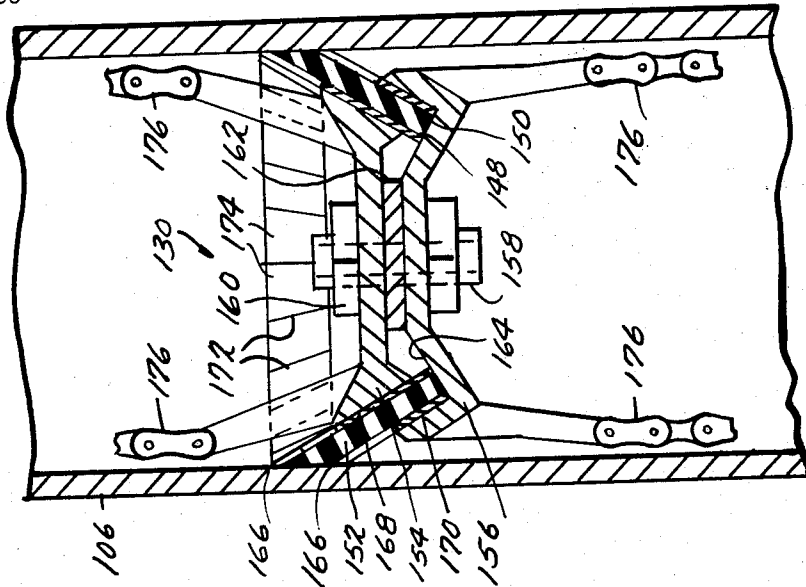
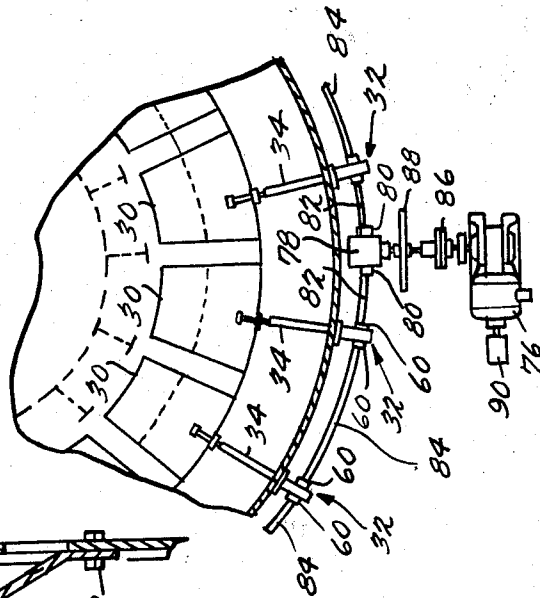


Fig. 2.



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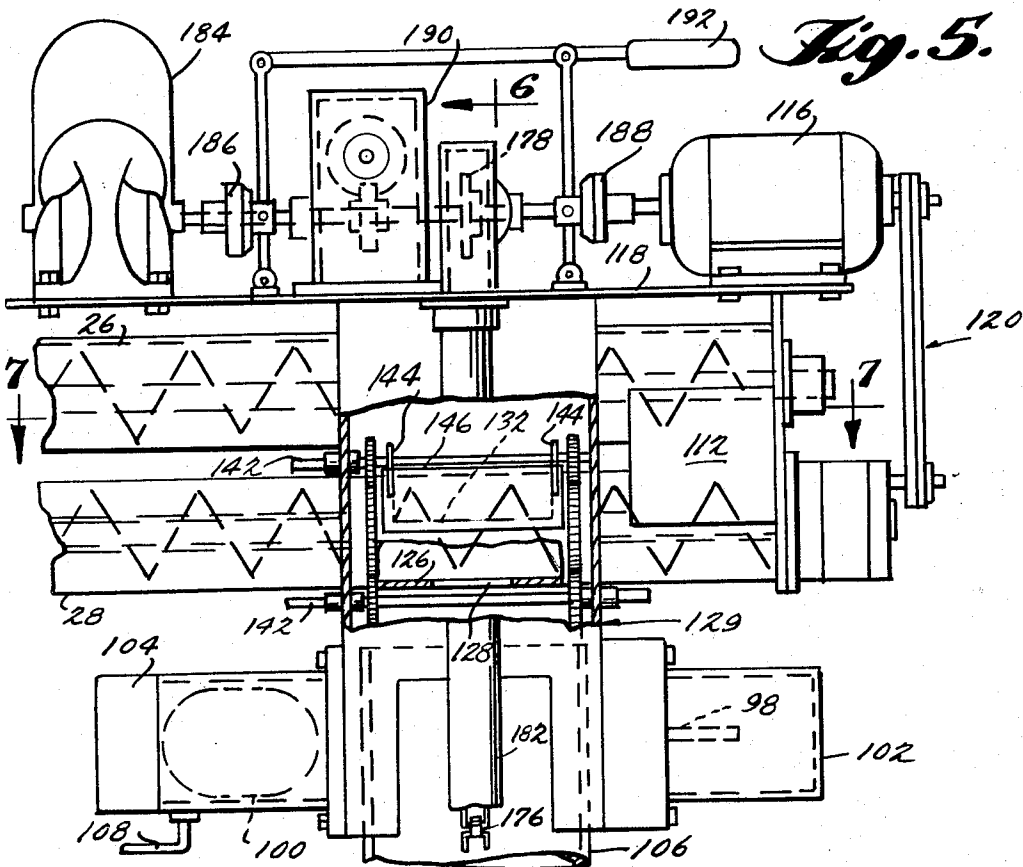


Fig. 5.

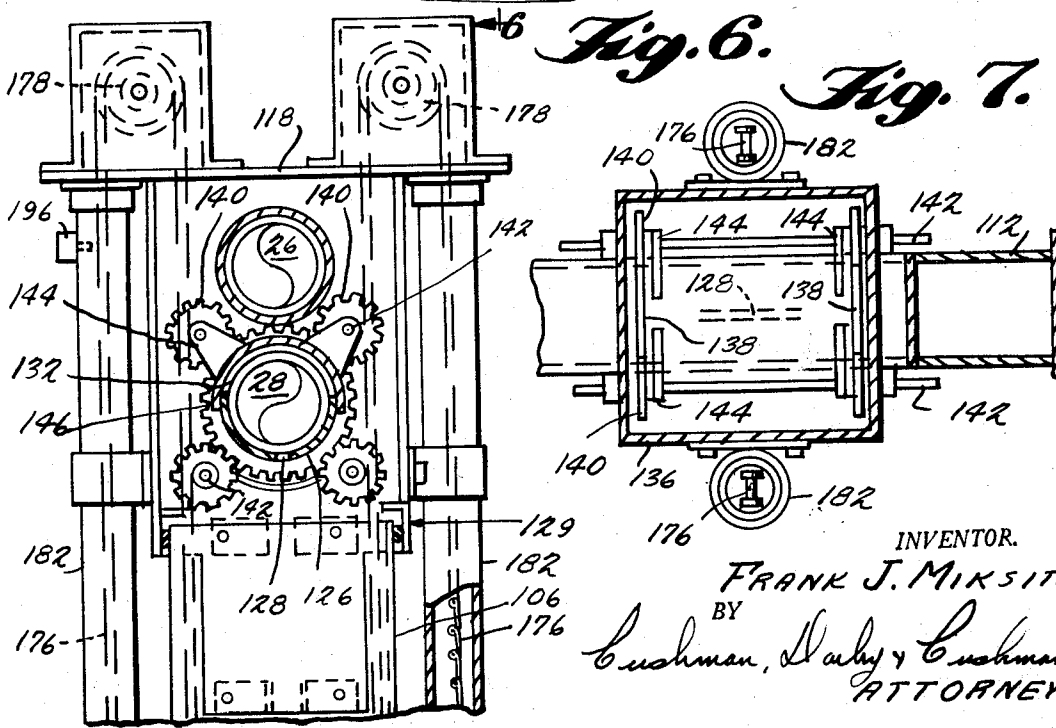


Fig. 6.

Fig. 7.

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VANE CONTROL FOR AIR CLASSIFIER

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5 Claims

ABSTRACT OF THE DISCLOSURE

In an air classifier, an improved drive for the movable control vanes which are disposed in a circular pattern includes a mechanical transmission associated with each vane and flexible drive shafts connecting the transmissions together so that a single motor can be employed to adjust all the vanes simultaneously. Each transmission moves its respective vane in or out of the classifier by means of a chain drive which is so constructed as to minimize dust packing and freezing problems.

The particle size of the comminuted particles issuing from the classifier is measured by withdrawing a portion of the stream with a screw conveyor, delivering the solids to the top of a sample tube as a uniformly loosely compacted mass, urging the solids in the form of an unagitated column through the tube with the aid of a plunger and chains, and measuring the density of the moving column with a gamma ray density meter.

This invention relates to centrifugal air classifiers for treating dry comminuted solids and in particular to the control of this type of classifier. It also relates to the continuous measurement of the particle size of a stream of dry comminuted material and to the accurate metering of dry comminuted material.

As is known, the term air classifier refers to a pneumatic device which separates a dry comminuted material into two or more fractions each more closely sized than the feed material. These devices are employed, for example, to obtain from a finely ground material, such as cement or ore, a sized fraction and to return the coarser particles to the grinding equipment. It is often necessary to obtain a product of closely controlled particle size, and to this end it is conventional to periodically measure the particle size in the discharge stream of the classifier and to make adjustments to the control features of the latter so as to increase or decrease the particle size being separated from the feed. The present invention provides an improved mechanical drive for the control devices commonly employed in one type of classifier and also provides an improved testing device for automatically measuring the particle size in the classifier discharge or in other streams of dry comminuted material.

Referring more specifically to the feature of the invention which relates to the control of a classifier to obtain a desired grading of particle size, it will be understood that the type of classifier being considered is in general use and that no detailed description of its structure and operation is required here. Briefly, this type of classifier comprises inner and outer concentric cones having their smaller ends directed downwardly and terminating in separate discharge openings for coarse and fine particles. Comminuted feed solids to be classified are fed downwardly into the top of the machine where they are acted on by a horizontal rotating distributor plate and by air currents generated by a horizontal fan. Control of particle size classification is effected in part by the adjustment of the horizontal position of a plurality of plates or vanes disposed in a circumferential pattern in the upper part of the machine so as to control the air currents. Typically, the vanes are mounted on threaded rods which project

radially through the vertical side wall of the machine and which are provided at their outer ends with rotatable adjusting nuts. Adjustment of the rods in their longitudinal direction is obtained by rotating the nuts, this operation usually being carried out manually with hand tools. In practice the manual adjustment of the nuts often becomes quite difficult as a result of the packing of dust in the threads and consequent freezing or binding of the assembly. A further disadvantage of the arrangement is that considerable time is required to adjust all the nuts with the result that during this period the particle size in discharge stream does not correspond to the desired size.

According to the principles of one feature of the present invention there is provided an improved drive for the control vanes which automatically adjusts a plurality of vanes simultaneously and which is not subject to freezing by packed dust. Briefly, the improved drive comprises a mechanical drive subassembly associated with each vane, a single source of reversible rotary power associated with a plurality of vanes and a transmission for delivering rotary power to all the subassemblies simultaneously. In the preferred construction the transmission includes a plurality of flexible drive shafts connecting the subassemblies with each other, each flexible shaft lying in an arc on the circumferential pattern of the subassemblies. Each subassembly in the preferred embodiment includes a longitudinally movable control rod carrying a vane at its inner end and a chain drive for converting rotational movement into longitudinal movement of the rod, the arrangement being constructed to minimize dust packing and freezing problems so that excessive stress will not be developed in the transmission. This is highly important for automation of the equipment, because true automation exists only when substantially every likelihood of breakdown has been eliminated.

Closely related to the automatic drive for the vanes in an air classifier is a second feature of the present invention which is concerned with obtaining a rapid and substantially continuous analysis of the particle size in the discharge stream of the classifier. The technique of measuring particle size which is in general use includes the periodic withdrawal of a sample from the classifier discharge and a laboratory-type analysis of the sample. Generally the sample is tested with a gas-permeability instrument which measures the resistance of a predetermined weight and predetermined volume of the sample to the flow of gas therethrough, the resistance being an indication of the particle size when the instrument has been properly calibrated. The time lapse between the taking of a sample and the determination of particle size varies with the particular instrument and the number of refinements which have been incorporated to speed up operation, but in any event, the analysis of the discharge stream by this means is at best intermittent and involves delays which when coupled with the usual manual adjustment of the vanes does not permit rapid adjustment of the classifier vanes following a change in particle size.

According to the principles of the second feature of the present invention there is provided a particle size tester which may be operated substantially continuously to give a signal substantially instantaneously with the passage of classified material out of the classifier so that immediate adjustment of the vanes may be effected as soon as a change in particle size is sensed. The tester makes use of a known instrument, a density gauge of the nuclear radiation absorption type, in a heretofore unknown manner which permits the automatic measurement of the size of dry solids. More specifically, the tester includes a special sampling device which is designed to pass a column of comminuted material past the detecting head of the density measuring instrument at a constant rate and at a constant degree of compac-

tion. Under these conditions the density of the material passing the detector is constant for a given particle size of a given material. A change in particle size results in a change in density and this in turn results in a change in the output signal of the instrument. The signal may be employed to give visual instructions to an operator or it may be fed directly into a control circuit for the vane drive so as to effect a fully automated system.

The sampling device constructed in accordance with the principles of the present invention includes a special plunger which cooperates with the bore of a vertical sample tube to assure that dry powdered solids in the tube will be metered at a carefully controlled rate. Briefly, the plunger is constructed in the form of a slightly flexible truncated hollow cone the periphery of which at its larger end closely fits the bore of the tube. In a preferred construction the plunger is formed of a truncated thin-walled spring steel cone the larger end of which is divided into a plurality of slightly arcuate segments by radial slots. The arcuate segments are slightly flexible so as to form a good seal while at the same time compensating for variations in the bore of the tube.

While the tester is described hereinafter in combination with an air classifier it will be understood that the tester is not limited to this combination and may be employed to test the particle size of any stream or mass of dry, powdered solids. It will be understood, also, that the special plunger construction has application wherever metering of dry solids is desired and may be employed, for example, to dispense a first powder at a controlled rate into a stream of a second powder. The invention will be further understood from the following detailed description taken with the drawings in which:

FIGURE 1 is an elevational view of an air classifier having a vane control and a particle size tester constructed according to the principles of the present invention;

FIGURE 2 is a fragmentary horizontal sectional view of the air classifier of FIGURE 1 taken above the level of the control vanes;

FIGURE 3 is a vertical sectional view of one of the drive subassemblies of FIGURE 1;

FIGURE 4 is an end view, with some parts removed, of the drive subassembly of FIGURE 3;

FIGURE 5 is a fragmentary elevational view, on an enlarged scale, of the particle size tester of FIGURE 1;

FIGURE 6 is a sectional view taken on the line 6—6 of FIGURE 5;

FIGURE 7 is a sectional view taken on the line 7—7 of FIGURE 5;

FIGURE 8 is a fragmentary vertical sectional view of the sample tube and plunger of FIGURE 5; and

FIGURE 9 is a fragmentary elevational view of the lower end of the sample tube.

Referring to FIGURE 1 there is shown an air classifier 10 of the kind which includes an inner cone member 12 and a concentric outer cone member 14 both disposed below a cylindrical portion 16 having associated therewith a feed conduit 18 for the introduction of dry comminuted material. The inner cone 12 terminates at its lower end in an inclined discharge pipe 20 for coarse solids. The outer cone 14 terminates at its lower end in a vertical discharge section 22 for fine solids. Associated with the fine discharge section 22 is a sampling and testing device 24 which includes an upper screw conveyor 26 for withdrawing a portion of the fine solids and a lower conveyor 28 for subsequently returning the withdrawn solids. The sampling and testing device 24 is described in more detail with reference to FIGURES 5-9.

The air classifier 10 is of a known internal construction and need not be described in detail. This type of machine typically includes in the upper cylindrical portion a horizontal rotating plate (not shown), a horizontal rotating fan (not shown) and a plurality, for example sixteen, of horizontal vanes 30 (FIGURE 2) which are disposed in spaced apart relationship in a circular pattern. Powdered solids entering the top of the machine are distrib-

uted in radial directions and are then acted on by air currents created by the fan. Separation of coarse particles from fine particles takes place by centrifugal force with the coarse particles being collected in the inner cone 12 and the fine particles being collected in the outer cone 14. The size of the fine particles which are separated is controlled within limits by the size of the circular opening defined by the pattern of the vanes 30. Accordingly, the vanes 30 are adapted to be adjustable in radial directions so that the size of the central opening may be adjusted. As already pointed out it is conventional to mount each vane 30 on a radially extending rod having a threaded outer end projecting through the side wall of the machine and to provide a rotatable adjusting nut for each rod.

According to the principles of one feature of the present invention the vanes 30 are provided with a power driven adjusting system which moves all the vanes simultaneously and which is relatively free from binding due to the packing of dust into the drive mechanism. As pointed out heretofore power driven systems previously have not been considered practical because of the frequent necessity to free the bound-up drive mechanism. In the construction illustrated in FIGURES 1-4 each vane 30 is provided with a powered adjusting assembly in the form of a special transmission 32 which converts rotary drive motion into longitudinal movement of a vane control rod 34. As seen in FIGURES 1 and 2 the transmissions 32 are supported in spaced apart relationship along the circumference of the cylindrical portion 16 of the classifier 10. Each transmission 32 includes an endless chain 40 looped over a pair of sprocket wheels 42, 44 which are spaced apart along a radius of the classifier 10. The inner sprocket wheel 42 is disposed within the classifier 10 and the outer sprocket wheel 44 is disposed within a housing 46 which is secured to the exterior of the classifier by bolts 48. The inner sprocket wheel 42 is fixed to a shaft 50 which is journaled in a bracket 52 depending from the inner end of an elongated support member 54. The outer end portion of the latter is slidably retained between a pair of side walls 56 and a top wall 58 which form part of the housing 46. The outer sprocket wheel 44 is fixed to an input drive shaft 60 which is journaled in flange bearings 62 mounted on the side walls 56 of the housing 46. The shafts 50 and 60 are parallel to each other, and the input drive shaft 60 is disposed generally tangent to a circle drawn through the outer ends of all the transmissions 32.

The elongated support member 54 also supports the control rod 34 for the respective vane 30. As shown in FIGURES 3 and 4 the member 54 is a channel-like member having its open side facing downwardly and defined by opposed flanges 64 which project toward the center line of the channel. The control rod 34 is slidably retained in the bore of the channel 54 by means of four radial ribs 65 and is connected to the upper run of the chain 40 by a downwardly projecting member 66 which rides in the slot between the flanges 64. The channel member 54 can be moved longitudinally inwardly by means of an adjusting screw 72 carried by the housing 46 for the purpose of adjusting the tension in the chain 40. Immediately below the adjusting screw 72 the outer wall of the housing 46 is provided with a hole 73 through which the position of the rod 34 may be measured manually. A fixed structure 74 forming part of the internal arrangement of the classifier 10 supports the rod at a location inwardly of the channel 54.

According to an important aspect of the present invention the transmissions 32 are drivably interconnected so as to be driven simultaneously when it is desired to adjust the classifying action of the machine 10. To this end a single source of driving power is drivably connected to a plurality of the transmissions 32, preferably by means of flexible drive shafts. As shown, the driving power source includes a reversible gear motor 76 and a speed reducer 78, the latter having a double-ended output shaft 80 disposed between two of the transmissions

32 and lying generally tangent to the aforementioned circle drawn through the outer ends of the transmissions 32. The ends of the output shaft 80 are connected to the nearest ends of the input shafts 60 of the two adjacent transmissions 32 by means of two flexible drive shafts 82. All the other transmission input shafts 60 are interconnected in series with the first-mentioned input shafts by a plurality of flexible drive shafts 84. As seen in FIGURE 2 when these connections are made, all the flexible shafts 84 will lie generally on the aforementioned circle.

The illustrated embodiment of the drive arrangement includes, as refinements, a clutch 86 and a handwheel 88 disposed between the gear motor 76 and the speed reducer 78. Conveniently, a tachometer 90 may also be provided for indicating the position of the vanes. To prevent damage to the drive or to the transmissions 32 one of the transmissions 32 may be provided with a limit switch 92 which is electrically connected to the motor 76. As shown in FIGURE 4 the switch 92 is mounted on the housing 46 and is actuated by a rod 94 connected at its inner end to the chain 40.

The flexible drive shafts 84 are of conventional construction. As is known, shafts of this type are formed from a single straight wire core around which is wound a plurality of layers of high tensile strength wire, successive layers being wound with alternating pitch directions. The result is a flexible cable-like structure which is capable of transmitting rotary motion through a curved path in either direction with little or no lag between the drive element and the driven element. Conventionally the shafts are manufactured with attached end fittings, such as coupling members 96 shown in FIGURE 4.

Reference is now made to that part of the invention which relates to the provision of a signal which is a measure of the particle size of the comminuted solids and which may be employed for various purposes including the control of the direction and period of operation of the vane control motor 76. Heretofore, in the operation of air classifiers, it has been the practice to take samples of the product periodically, measure the particle size in each sample independently and make periodic adjustments on the basis of the measurements. The present invention contemplates the automatic, substantially continuous measurement of the particle size substantially simultaneously with the discharge of material from the classifier. This feature together with the accurate and simultaneous control of all the vanes 30 achieved with the above-described drive system permits almost instantaneous adjustment of the classifier 10 upon the occurrence of a sensed change in particle size in the discharge. The sampling and testing device 24 is illustrated in FIGURES 1 and 5-9 and, as previously noted, includes a known radiation detector, available commercially, which is employed in a heretofore unknown manner to measure the particle size of dry comminuted solids.

The essential parts of the measuring instrument are a source 98 of penetrating radiation, such as a small mass of the radioisotope cesium-137 which emits gamma rays, and a radiation detector 100 such as an ionization chamber. The instrument is conventionally manufactured in the form of two assemblies 102, 104, one containing the source and the other containing the detector, which are adapted to be clamped to opposite sides of a pipe, such as a sampling tube 106, so that radiation passes through the tube 106 to the detector 100. The instrument operates by emitting an electrical signal, transmitted through an output cable 108, which is proportional to the magnitude of radiation striking the detector 100. Since the magnitude of the radiation reaching the detector 100 depends on the radiation absorption characteristics of the material in the tube, changes in these absorption characteristics produce corresponding changes in the electrical output signal of the instrument.

In conventional practice the instrument is employed broadly to measure changes in the density of a pumped

liquid or liquid-solid mixture in which the components of the liquid or mixture differ in individual specific gravities. More specifically, the instrument is first standardized and calibrated for the particular material flowing through the pipe. These procedures are prescribed by the manufacturer of the instrument and need not be considered here in detail. Briefly, calibration involves correlating the output signal of the instrument with the actual density of the pumped product as measured by some other means. Conventionally this is done by periodically taking samples of the material in the pipe, measuring the density of the samples by a standard procedure and plotting on a graph the density of the sample against the output signal. During subsequent operation with the same product the output signal may be read directly in units which are related to the density of the measured solution or slurry. For example, the signal may be calibrated in terms of actual density, specific gravity, degrees Baumé or percent solids (in the case of a slurry).

In the case of a mass of dry pulverized solids moving through a pipe there will normally be inherent variations in the compaction of the powder as it tumbles along. While the compaction will depend in part on the particle size of the powder, the normal forces of gravity and the mechanical agitation causing the movement will produce random variations in compaction and thus random variations in the density of the material. The application of a radiation-type density instrument to such a pipe will give a signal which varies with the total density changes, but the signal will not be an accurate measure of the particle size. According to the principles of the present invention, the output signal is made responsive only to particle size by assuring that the compaction produced by other means is uniform throughout the mass being tested and remains constant as the mass passes by the detector. When this is done the density variations, after proper calibration of the instrument for the particular material being tested, will be a measure of the particle size. The signal transmitted by the output cable 108 may be employed to control the vane drive motor 76 automatically or to produce a visual signal for use by an operator.

Referring now to the sampling portion of the device 24 it will be recalled that it includes the previously mentioned horizontal screw conveyors 26, 28 which are associated with the fine discharge section 22 of the classifier 10. As seen in FIGURE 1, the upper, or sampling conveyor 26, is provided with an inlet hopper 110 having an open upper end adapted to receive a portion of the solids which descend through the discharge section 22 during operation of the classifier 10. The right hand, or discharge end of the upper conveyor 26 communicates with the adjacent end of the lower conveyor 28 by means of a short vertical chute 112. The left hand, or discharge end of the lower conveyor 28 communicates with the classifier discharge section 22 through a discharge opening 114 in the bottom of the conveyor housing. In operation the conveyors 26 and 28 may be operated at the same speed so that a stream of solids which is withdrawn from the classifier 10 will be returned thereto. During a testing operation, however, a small proportion of the solids passing through the lower conveyor 28 will be withdrawn downwardly into the sampling tube 106. The conveyor 28 may also be provided with sample retrieving container 115 and associated valve 117.

The conveyors 26 and 28 are driven by an electric motor 116 which is shown mounted on a suitable support plate 118 above the upper conveyor 26. One end of the motor output shaft drives the lower conveyor shaft through a belt drive 120. The upper conveyor shaft is driven from the left end of the lower conveyor shaft through a belt connection 122 which includes a clutch 124 for disengaging the upper shaft.

As best shown in FIGURES 5, 6 and 7, the testing portion of device includes the sampling tube 106 and a dispensing arrangement for uniformly delivering a small proportion of solids from the lower conveyor to the

upper end of the tube 106. In the illustrated embodiment the dispensing arrangement includes a longitudinal section of the housing of the lower conveyor, this section being in the form of a sleeve 126, provided with a longitudinal slot 128 through which solids may pass by gravity and by the action of the screw so as to drop into the tube 106. The latter is provided with a plunger 130 which is moved slowly downwardly during a testing operation, the rate of movement of the plunger 130 and the size of the slot 128 being so related that the entering solids form a uniformly loosely compacted column within the tube 106 above the plunger 130. In the illustrated embodiment it is desired to discharge the column of solids back into the lower conveyor 28 after the testing operation. In order to accomplish this, the slotted housing sleeve 126 is mounted for 180° of rotation and is provided with a large discharge aperture 132 diametrically opposite the slot 128.

The sampling tube 106 may have a diameter of, for example, 12 inches and conveniently is constructed of transparent material such as Pyrex glass. As seen in FIGURES 5 and 6 the upper end of the sampling tube 106 is disposed within a support frame 129 and is seated and sealed therein by a gasket 131. As best seen in FIGURE 9 the lower end of the sampling tube 106 rests on a support spider which consists of a hub and three arms 133 each terminating at its outer end in an upwardly extending finger 134. The hub is supported from below by the upper end of a threaded stud 135 which is carried by a rigid frame member 136.

Referring more specifically to the dispensing sleeve 126, it will be seen that in the illustrated embodiment, the mounting includes a ring gear 138 attached concentrically to each end of the sleeve 126, each ring gear 138 being supported by upper and lower spur gears 140. The latter are keyed to axles 142 which are journaled in the supporting casing 129. The axles 142 extend beyond the casing and terminate in suitable fittings which may be gripped for rotation by hand tools or by a motor connection. As seen in FIGURES 5 and 6 there is provided within the supporting casing 129 a fixed semicylindrical shroud 146 disposed above the dispensing sleeve 126 and in engagement therewith so as to close the discharge opening 132 when the sleeve 126 is in the sampling position. Similarly, the shroud 146 will close the sampling slot 128 when the sleeve 126 has been rotated 180° from the position shown in the drawings. Conveniently the shroud 146 is supported by a pair of stationary wings 144 suspended from the upper axles 142.

FIGURE 8 illustrates the details of a preferred form of plunger 130 for supporting the column of pulverized solids in the tube 106. As shown, the plunger 130 includes a pair of thin-walled, truncated cone-like steel blades 148, 150 which are disposed coaxially in the tube 106 with their smaller ends facing downwardly and with a thick-walled rubber member 152, of similar configuration clamped between them. The clamping means includes upper and lower horizontal discs 154, 156 which are drawn toward each other by a suitable connection, such as an exteriorly threaded nipple 158, a pair of nuts 160 and a spacing disc 162. The lower end of the nipple 158 is shown capped but may be connected to a source of air pressure when it is desired to air blend the sample in the tube 106. The lower ends of the blades 148, 150 abut an upwardly and outwardly facing frusto-conical surface 164 on the lower disc 156, and the upper ends are ground to sharp edges 166 which engage the wall of the tube 106. The lower portions of the blades 148, 150 are engaged by oppositely facing frusto-conical surfaces 168, 170 on the discs and forced tightly against the rubber member 152. The portion of each blade 148, 150 which extends beyond the discs is slotted at a plurality of circumferentially spaced locations 172 so as to define a plurality of segments 174. The material of the blades 148, 150 is sufficiently thin, for example 1/64-inch, that the segments 174 are flexed inwardly without breaking when the plunger

130 is forced into the tube 106. During movement of the plunger 130 the segments 174 are biased outwardly by their own resiliency into tight contact with the wall of the tube 106. The resiliency and flexibility of the segments 174 are important also in eliminating chattering which would tend to compact powder in the tube 106 in a non-uniform manner.

Ordinarily pulverized powder will not follow the plunger 130 smoothly as it moves downwardly because the friction of the powder particles with themselves and with the wall of the tube 106 causes uneven packing and arching of the powder. To offset these effects, there is provided a pair of chains 176 connected to the plunger 130 and embedded in the powdered material. Conveniently, the chains 176 are also employed as part of the drive for the plunger 130. As shown, the chains 176 are disposed as vertical loops supported at their upper ends by a pair of sprocket wheels 178 mounted on the upper support plate 118 and at their lower ends by another pair of sprocket wheels 180 carried by the frame member 136. One run of each loop is disposed inside the tube 106 where it is connected to the upper and lower clamping discs 148 and 150 of the plunger 130. The other runs lie outside the tube 106 where they conveniently ride in vertical tubular members 182. Tension in the chains 176 is adjusted by rotating the stud 135 so as to move the frame member 136 up or down. Proper alignment of the frame member 136 during this movement is obtained by two sleeves 183 fixed to the member 136 and slidably engaging the lower end of the tubular members 182.

The driving mechanism for the chains 176 may take any suitable form. As shown, there is provided a variable low speed gear motor 184 mounted on the upper support plate 118 with its output shaft coaxial with the shaft of the conveyor drive motor 116. The output shafts of both motors are drivingly connected to both upper sprocket wheels 178 through a pair of clutches 186, 188 and a gear reducer 190. Both clutches 186, 188 are controlled by a manual lever 192 arrangement which engages one clutch while disengaging the other. When the left hand clutch 186 is engaged, the chains 176 will be driven by the low speed motor 184 in a direction to move the plunger 130 downwardly at a low speed, for example, 5-20 inches per hour. When the right hand clutch 188 is engaged, the chains 176 will be driven by the high speed motor 116 in the opposite direction at a much higher rate, for example, 30 inches per minute. Limit switches 194 and 196 may be provided near the bottom and top of the tubular member 182 to prevent overtravel of the chains 176.

Operation

The actual movement of the vane control rods 34 by the transmissions 32 requires no detailed description. It is apparent that rotational movement of the flexible drive shafts 82 and 84 impart rotational movement to each drive sprocket 44 with the result that the upper and lower runs of the chains 40 move in linear directions along radii of the classifier 10. The control rods 34, being secured to the upper runs of the chains 40, are moved inwardly or outwardly relative to the vertical axis of the classifier 10 in accordance with movement of the chains 40. The range of movement is limited by operation of the limit switches 92 which will stop the vane drive motor 76 at predetermined in and out positions of the control rods 34 in the event that the equipment should malfunction and over-run.

The construction and arrangement of the control rods 34 and their supporting members 54 are designed to minimize dust collection and to be self-cleaning of dust which does accumulate. When the rods 34 are disposed in their full out positions, their bearing surfaces are fully protected from dust by being encased within the channel shaped supporting members 54. In any of the inner posi-

tions, part of the bearing surfaces of the rods 34 are exposed to the dusty atmosphere in the classifier 10 and will collect dust. However, the provision of the longitudinal ribs 65 on the rods 34 aids in loosening accumulated dust when the latter 34 are moved outwardly.

The drive motor 76 for the vanes may be under the control of an operator or it may be controlled automatically with a servo-mechanism in accordance with a signal generated, for example, by the instrument 102, 104. In either case the vane motor 76 is driven in one direction or the other depending on whether it is desired to increase or decrease the size of the particles being discharged through the inner cone of the classifier 10. One of the important features of the arrangement is the simplicity and economy of the manner in which uniform and simultaneous power is transmitted to the drive sprockets 44 of the transmissions 32 and then to the chains 40. This is effected primarily by the use of the single motor 76 in combination with the plurality of flexible shafts 82, 84 connecting the transmissions 32. This combination eliminates the need for a separate power source for each vane 30 and at the same time does not require a complicated or expensive drive linkage between the single power source 76 and the transmissions 32. The flexible shafts 82, 84 are simply installed and, by virtue of their flexible nature, they eliminate the need for the more expensive mechanical components generally employed for transmitting rotary power along a curved path. The shafts 82, 84 require no lubrication along their lengths or at the points of connection to the transmission drive shafts and thereby require no maintenance.

Further, the flexible shafts 82, 84 provide positive uniform transmittal of power by virtue of their low internal friction and their lack of distortion under load. That is, the shafts transmit rotary power without any differential movement or time lag between the power input shaft and the driven shaft. Thus, if a vane control rod 34 tends to bind, the force necessary to free the rod 34 is automatically transmitted to that rod without any disturbance of the synchronous movement of all the rods. The arrangement therefore assures synchronous movement of the vanes 30 by means of a simple and maintenance-free drive system. It would be possible, of course, to provide each rod with a separate electric or hydraulic motor, but synchronization of such systems would require sensitive electrical or hydraulic controls.

It will be understood that the above-described advantages of simplicity, economy and accuracy may be achieved even if more than one vane drive motor 76 is employed so long as each motor 76 is drivingly connected to a plurality of transmissions 32.

The sampling and testing device 24 operates continuously during a test, the length of the test being determined by the length of the sample tube 106 and the speed at which the plunger 130 moves downwardly. Sampling periods of from 8 to 24 hours are suitable for most installations. During this time, a portion of the pulverized solids passing downwardly through the hopper 110 and be carried to the right by the upper conveyor 26. The material will drop through the chute 112 and then be returned to the discharge section 22 by the lower conveyor 28. Generally the capacity of the conveyors 26, 28 will be about 50 percent of the mass flow rate into the discharge section 22 so that the material in the conveyors will constitute a representative sample of the main product stream.

When it is desired to run a particle size test, the plunger 130 is moved downwardly at a slow constant rate while a portion of the solids in the lower conveyor 28 is allowed to drop through the slot 128 in the sleeve 126 and into the sampling tube 106. The material will have been thoroughly mixed by the screw in the upper conveyor 26 so that the relatively small sample which is deposited in the tube 106 is representative of the main product stream. Downward movement of the plunger

130 is obtained by operation of the low speed motor 184 operating through the clutch 186, the speed reducer 190 and the sprockets 178, a plunger speed of 5 to 20 inches per hour being suitable for most installations. The width of the slot 128 is so related to the "pourability" of the powdered solids and to the speed of the plunger 130 that solids pass into the tube 106 at a rate equal to the rate of descent of the plunger 130 with the result that solids in the upper part of the tube 106 are uniformly loosely packed. In addition, the size and shape of the slot 128 is designed so that screw conveyor forces will not create variations in compaction due to disturbance of the sample in the upper part of the tube 106.

The action of the chains 176 also contributes to the formation of a uniformly loosely compacted mass of powder by urging the powder downwardly at the same rate as the plunger 130. This prevents arching of the material and the consequent formation of pockets and zones of higher density. Ordinarily powder will not fill a tube evenly because the friction between the particles and the wall of the tube will prevent the material from following the plunger smoothly. The chains 176, however, overcome this friction by straddling the powder and urging it in unison with the plunger yet without disturbances which would produce variations in compaction. The radiation beam from the source 98 passes between the inner runs of the chains 176 so that the latter do not affect the operation of the measuring instrument, 102, 104.

The operation of the measuring instrument 102, 104 to produce a signal which is a measure of the particle size has been described previously. The successful use of the instrument to measure the particle size of dry powdered solids requires that the solids pass the instrument at a constant rate in a uniform state of compaction, and this is achieved by the coaction of the above-discussed dispensing arrangement 126, 128 with the plunger 130 and the chains 176. Under these conditions the density of the material passing downwardly in the tube 106 is constant for a given material having a given particle size. A change in particle size produces a change in density, and since the particle size is the only variable, the density change is a measure of a change in particle size. Preferably, the test is made just after the solids enter the top of the tube 106 so that variations in compaction near the plunger as the column increases in height will not alter the measurement. When the instrument 102, 104 has been calibrated for the particular material being processed under constant operating conditions, the output signal from the detector portion 104 may be employed in any suitable manner as by plotting on a strip chart recorder for the benefit of the mill operator. The signal may also be fed to a servo-mechanism for controlling the vane motor 76 or to the control system for other types of classifiers such as those which are controlled by varying the speed of an internal fan.

It will be understood, of course, that the measurement of particle size in the described manner is not limited to its application to the output of a classifier and may be applied to an operation in which dry comminuted solids are handled.

The sample is also subject to visual inspection inasmuch as the tube 106 is transparent. Changes in the product may be observed as changes in color in different levels of the sample. Since the sampling technique is closely controlled, it is a relatively simple matter to relate the color changes to variables in the operation of the grinding and classifying equipment.

When the plunger 130 reaches the bottom of the tube 106 it is necessary, of course, to empty the solids from the tube and to return the plunger to the top of the tube. In the illustrated embodiment, the apparatus is adapted to discharge the solids back into the lower conveyor 28 by moving the plunger 130 upwardly. This is accomplished in part by rotating the slotted sleeve 126 one-half revolution so as to dispose the large aperture

132 in a position adjacent the top of the tube 106. Rotation may be effected manually by rotating one of the axles 142 which cooperates with the sleeve 126 through the spur gears 140 and ring gears 138. The movement of the plunger 130 is then reversed at a relatively fast rate so as to force the column of solids through the aperture 132 into the lower conveyor 28 where they will be engaged by the screw and carried back to the classifier discharge section 22. If desired, the sample may be retrieved by opening the valve 117 and collecting the material in the container 115. To prevent interference with solids already being transported by the lower conveyor 28, the upper conveyor 26 is shut off by disengaging the clutch 124 at the left hand end of the conveyors.

Movement of the plunger 130 at a relatively fast rate, for example, thirty inches per minute, is conveniently obtained by driving the sprockets 178 and chains 176 with the high speed conveyor motor 116. This is effected in the illustrated embodiment by manually shifting the lever 192 in a direction to disengage the clutch 186 and engage the clutch 188, the latter effecting a driving connection between the left end of the shaft of the motor 116 and the sprockets 178. When the plunger 130 reaches a point near the top of the tube, the lever 192 is manually shifted to reverse the clutches 186 and 188 so that the low speed motor 184 will operate the plunger 130 during the next test. The slotted sleeve 126 is also rotated manually to dispose the slot 128 in a position adjacent the end of the tube 106. In this position of the sleeve 126 the discharge aperture 132 is closed by the semi-cylindrical shroud 146.

The purging action of the plunger 130 is facilitated by the chains 176 which prevent packing of the powder and the creation of radial forces which might break the tube 106. The straddling of the powder by the moving chains 176 distributes the moving forces along the length of the column of material and overcomes the frictional forces which tend to concentrate at the wall of the tube 106. In the absence of some means for reducing the wall friction, many types of powder would pack so tightly that jamming of the plunger 130 or bursting of the tube 106, or both, might occur. The ability of the plunger to flex and the sharpened edges 166 of the segments 174 assure that the wall of the tube 106 will be cleaned of all traces of powder.

It will be appreciated that the above-described purging operation renders the tube and plunger combination useful as a metering device for conveying dry powdered solids at closely controlled rates. This part of the invention may therefore be employed, for example, as a dispenser for continuously adding one powder to a process stream of another material which may be gas, liquid, slurry or another powder.

The various features of the invention are particularly applicable to a continuous grinding operation where it is necessary to obtain a closely graded product. In the manufacture of cement, for example, the economics of the process and the properties of the ground clinker which is the ultimate product, are closely related to particle size. The presence of under-sized and over-sized particles in a batch adversely affects the entire batch so that blending of various batches is often resorted to in order to obtain a satisfactory product. In addition, under-sized particles represent higher manufacturing costs because of the over-grinding which has occurred. As previously pointed out, prior methods of controlling the particle size either by adjusting the grinding machinery or the classifier, or both, have depended on the periodic taking of samples and the subsequent analysis of each sample followed by adjustment of the process equipment. These sequential procedures do not provide continuous and accurate control over the process with the result that relatively large changes occur in the particle size of the product stream.

The present invention, on the other hand, provides continuous automatic measurement of particle size almost instantaneously with the passing of the product stream from the process. The process variables may therefore be

adjusted almost as soon as a product change is sensed. In the case of a classifier of the type controlled with radially adjustable vanes, the invention provides a further advantage in effecting simultaneous accurate movement of all the vanes.

The details of the illustrated embodiment of the invention are given by way of example and are not intended to be limiting except as they appear in the appended claims.

What is claimed is:

1. In a particle size air classifier of the type having inner and outer cones for the discharge of coarse and fine particles, respectively, a generally cylindrical casing above said cones and a plurality of adjustable control members disposed within said casing in circumferentially spaced apart relationship for controlling the air currents in said classifier in a manner to adjust the classifying action of said classifier: a drive subassembly associated with each control member for moving the latter between predetermined control positions, said subassemblies being mounted on said casing in arcuately spaced apart relationship, each of said subassemblies including a rotary input shaft and a transmission driven by said input shaft for converting rotary motion to the desired movement of its respective control element; and drive means for delivering rotary motion simultaneously to a plurality of said subassemblies, said drive means including a motor having a rotary output shaft, a driving connection between said motor and at least one of said transmission input shafts and a plurality of rotary drive shafts, said drive shafts connecting said one transmission input shaft in sequence with the input shafts of a plurality of other transmissions.

2. Apparatus as in claim 1 wherein said drive shafts are flexible drive shafts constructed of a central straight wire core and a plurality of layers of wrapped wire surrounding said core.

3. Apparatus as in claim 2 wherein each of said transmission input shafts is generally tangent to a circle passing through all said transmissions and wherein said flexible shafts connect said input shafts end-to-end.

4. Apparatus as in claim 1 wherein said transmission includes inner and outer sprockets horizontally spaced apart along a radius of said generally cylindrical casing, said outer sprocket forming part of the driving connection between said transmission and said drive shaft, a chain looped over said sprockets, an elongated horizontal support member carrying at one end, one of said control members; means connecting said chain to said control member near its other end whereby rotation of said outer sprocket moves said support member longitudinally of itself; a fixed generally tubular member surrounding at least a portion of said support member and cooperating therewith to remove accumulated dust from said support member upon longitudinal movement of the latter.

5. Apparatus as in claim 4 wherein said generally tubular member is an elongated horizontal member having a longitudinal slot in its lower surface, said connecting means riding in said slot.

References Cited

UNITED STATES PATENTS

2,148,452	2/1939	Fraser.	
2,243,859	6/1941	Fraser.	
2,312,730	3/1943	Ring	222—365
2,361,663	10/1944	Stine	222—365 X
2,807,523	9/1957	Wood.	
2,973,861	3/1961	Jager	209—1
3,128,786	4/1964	Badgett.	
3,244,325	4/1966	Lindquist	222—371 X
3,328,587	6/1967	Brown et al.	

FOREIGN PATENTS

972,056 10/1964 Great Britain.

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