

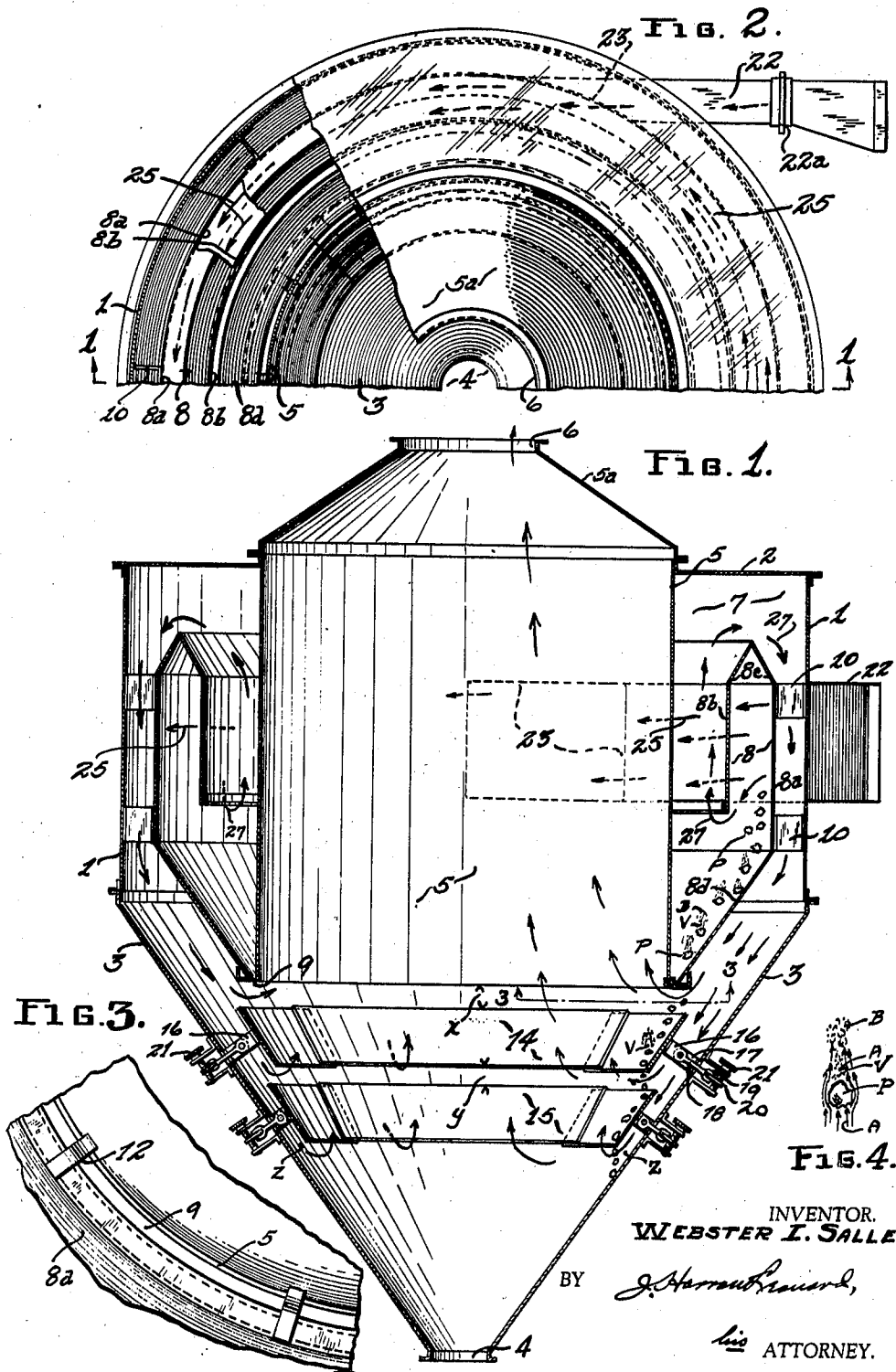
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METHOD AND APPARATUS FOR SEPARATING MATERIALS

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METHOD AND APPARATUS FOR SEPARATING MATERIALS

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This invention relates to a method and apparatus for separating pulverized particles of material of different fineness and particles of different materials of different specific gravities and particularly to an air flotation separator of the cyclone type for these purposes.

The principal object of the present invention is to separate the materials or particles more efficiently and between closer and more accurate limits of fineness.

A correlative object is to convey the particles to be separated in an air stream and cause the coarser or heavier particles to pass out of the stream along one portion of its path of travel and then to reduce the speed of and mechanically vibrate the separated coarse particles while subjecting the coarser separated particles to a scavenging air current for removing any fine particles that have been carried along thereby.

Another object is to provide a separator having greater volumetric efficiency than heretofore obtained with commensurate accuracy of separation.

Another object is to provide a simplified separator structure which may readily be adjusted and, for a given adjustment, will maintain automatically thereafter the proper accuracy in separation and high volumetric efficiency.

Another object is to effect these results with parts which, though adjustable, are stationary while in operation.

Other objects and advantages will become apparent from the following specification wherein reference is made to the drawing in which

Fig. 1 is a vertical sectional view of a separator embodying the principles of the present invention and is taken on a plane indicated by the line 1—1 in Fig. 2;

Fig. 2 is a fragmentary plan view partly in section of the separator illustrated in Fig. 1;

Fig. 3 is a fragmentary bottom plan view of a portion of the separator illustrated in Fig. 1 and is taken on a plane indicated by the line 3—3 of Fig. 1; and

Fig. 4 is a diagrammatic representation of a separated coarse particle illustrating the manner in which fine particles are carried along thereby.

Referring to the drawing, the separator comprises an upright sealed sheet casing having an upper portion 1 which is preferably cylindrical, and sealed at the top by a top wall 2. The lower end of the upper portion 1 is open and connected with a coaxial dependent portion 3, which is frustro-conical in form and is inverted so that its larger diameter is coextensive with and connected

to the lower end of the portion 1. The smaller base of the frustro-conical portion 3 has a discharge passage 4 for the discharge of coarser materials therefrom, as will later be described.

Mounted within and coaxial with the casing and extending from the top thereof downwardly part way into the portion 3 is a sleeve 5, the sleeve preferably being cylindrical and coaxial with the casing. In the embodiment of the invention illustrated, the sleeve 5 is between one half and two thirds the diameter of the casing 1. The sleeve 5 is open at the bottom and terminates at its lower end in spaced relation to the wall of the casing portion 3. At the top, the sleeve is partially closed by an upwardly tapering frustro-conical wall portion 5a, having a central opening 6 for discharge of the convection current of air containing the fine materials separated within the separator. Thus the casing and shell 5 define a relatively wide annular air channel 7.

Disposed within the channel 7 and surrounding the shell 5 and spaced both from the inner wall of the casing and the outer wall of the shell 5, is an annular baffle 8 which is generally in the form of a relatively narrow and deep inverted trough having an outer annular wall 8a and an inner annular wall 8b coaxial and parallel with the casing and sleeve 5. Joining the walls 8a and 8b is a peaked top wall 8c, the peak being disposed upwardly. The walls 8a, 8b and 8c are imperforate and spaced respectively from the wall of the casing 1, sleeve 5 and top wall 2. The baffle 8 is disposed longitudinally of the casing about midway of the upper cylindrical portion 1. The outer wall 8a of the baffle 8 is slightly longer than the inner wall 8b and, at its lower end, carries an integral baffle wall portion 8d which slopes from the lower edge of the wall 8a downwardly and inwardly toward and to the lower end of the sleeve 5. The lower end of the wall 8d terminates in spaced relation to the lower end of the sleeve 5, as better illustrated in Fig. 3, and defines therewith an annular passage, as indicated at 9, between the sleeve 5 and wall portion 8d.

The baffle 8 may be supported fixedly in the position described by means of suitable spider arms 10 secured thereto and to the casing portion 1. At its lower end, the wall 8d is secured in fixed spaced relation to the lower end of the sleeve 5 by suitable circumferentially spaced spider arms or bracket 12, so that the passage 9 is accurately fixed and remains so during all operations of the apparatus.

Positioned below the lower end of the sleeve 5 and coaxial therewith and with the casing por-

tion 3 are annular baffle control vanes 14 and 15 respectively. The vanes 14 and 15 are frustoconical, their larger ends being disposed upwardly. The upper end of the vane 14 is slightly larger in diameter than the annular passage 9 so that material passing through the passage 9 will drop on the vane 14. The vane 15, in turn, is spaced below the vane 14, its upper end being of sufficient diameter to extend radially slightly beyond the radial limits of the lower end of the vane 14 so that material dropping from the vane 14 will drop onto the vane 15.

The walls of both the vanes 14 and 15 are normally parallel to the casing portion 3. However, in separating different materials or particles it is oftentimes desirable that the vanes be adjusted for controlling the air currents, and for this purpose each of the vanes 14 and 15 is made in circumferential segments, as illustrated. Referring particularly to the vane 14, each segment is supported on bracket 16 which is pivotally mounted on a suitable bracket 17 carried by the wall of the casing portion 3. Fixedly connected to each bracket 16 is an operating lever 18 which extends outwardly beyond the pivot and is so arranged that upon swinging of the lever about the pivot, the vane segment may be adjusted to the desired position. For accuracy in adjustment, the lever 18 is provided at its outer end with a yoke arm 19 which receives a suitable annular dog 20 carried on an adjusting screw 21 so arranged that upon operation of the screw the position of the vane segment can be controlled. The segments of vane 15 are correspondingly mounted.

The material to be separated is conveyed into the separator in a stream of air from a suitable grinding mill or other source through an inlet conduit 22 which extends through the upper portion 1 partially across the space 7 and opens into the inside of the baffle 8 between the walls 8a and 8b, as indicated at 23. The conduit 22 is so arranged as to discharge into the baffle 8 tangentially thereof so that a swirling or cyclonic current of air is produced within the separator, a suitable damper 22a being provided in the duct 22 for controlling the rate of admission of air. Thus air admitted through the conduit 22 travels as a swirling stream at high velocity, as indicated by the arrows 25. Due first to centrifugal action within the baffle 8, the coarser particles, as indicated at P, are thrown out toward the wall 8a, whereupon they fall and roll down the wall 8d and drop through the opening 9.

Since air laden with the material to be separated is continuously fed through the conduit 22, this air escapes around the bottom of the wall 8b and passes upwardly while still swirling, as indicated by the arrow 27, between the wall 8b and the sleeve 5.

In order to obtain the highest efficiency in operation, the baffle 8 is so arranged and proportioned relative to the passage 7 that the air swirled circumferentially through the baffle 8 may have a velocity somewhat greater than the velocity of the air passing between the wall 8b and the sleeve 5, this decrease in velocity permitting additional coarse material to settle out. This difference in velocity is provided by the difference in cross sectional area of the spaces between the walls 8a and 8b and the space between the wall 8b and sleeve 5. Upon the reduction in velocity between the sleeve 5 and baffle 8, coarse material which may have been

initially carried in the air is discharged as described and drops down onto the wall portion 8d along with the material particles 26 which were separated by centrifugal force. Likewise, due to the abrupt change in direction around the lower edge of the wall 8b, additional coarse materials are thrown out. The passage between the top of the baffle 8 and the top wall 2 of the casing is still larger so that additional coarse material may drop out on either side of the baffle 8.

The air stream next flows between the wall 8a and the wall of the casing portion 1 which is preferably larger than either the channel in the baffle 8 or the channel between the wall 8b and sleeve 5, so that the air stream is of less velocity between the wall 8a and wall of the casing portion 1 and additional coarse material may drop out of the air stream at this location.

This channel thus afforded, however, opens into a much wider channel defined by the sloping wall 8d and the adjacent sloping wall of the casing portion 3 so that the air rushing thereinto loses its velocity quickly and preferably is only sufficient to carry particles of the desired fineness. Consequently, this portion of the air stream does not pick up additional coarse material but permits any coarse material, which has dropped out of the air stream between the upper end of the baffle 8 and the wall 1, to again pass out of the stream and drop onto the wall 3.

After passing the upper end of the baffle 8 and downwardly around the outside of the baffle 8, between the wall 8a and casing portion 1 and between the wall 8d and casing portion 3, the air passes around the lower end of the sleeve 5 and wall 8d into the interior of the sleeve 5, thus repassing through the stream of coarse material dropping out of the passage 9 to provide a scavenging air current.

Obviously, when the air from between the wall 8d and adjacent wall portion of the casing 3 enters the sleeve 5, due to the relatively large capacity of the sleeve 5, its volume decreases very quickly so that if any coarse particles of material have heretofore been held in the air stream due to its velocity they drop out of the stream and only the finest particles or particles of a predetermined fineness or predetermined density are carried upwardly with the air passing through the sleeve 5. Due to the tapered top wall 5a and the resulting contraction in cross sectional area of the sleeve near the top, as the air stream through the sleeve 5 reaches the upper limit of the sleeve, its velocity is again increased so that it passes rapidly out of the passage 6 to a suitable storage bin. Necessarily, this increase in velocity at the upper end of the sleeve 5 does not affect the coarser material as all of it has been separated out before this particular part of the path of travel of the air stream is reached.

All of the air passing from between the wall 8d and wall 3 would normally tend to flow upwardly immediately into the sleeve 5 as the passage 4 is usually substantially obstructed by coarse materials already separated out. It is desirable, however, to prevent the immediate rise of this air and to utilize this air as a scavenging current for sweeping additional fines from the material and for this purpose the vanes 14 and 15 are provided.

Referring to the drawing, it will be noted that the passage, indicated at X, between the upper edge of the vane 14 and the lower end of the sleeve 5, is substantially one third of the size of the passage between the wall 8d and the wall 3.

The passage between the lower edge of the vane 14 and the upper edge of the vane 15, indicated at Y, is equal to the passage X. The same is true of the passage between the lower edge of the vane 15 and the wall 3, as indicated at Z. Thus the air issuing from between the wall 3d and wall 3 is divided into three separate streams but without any change in the velocity of the portions thereof adjacent the point of discharge, whereas, were the baffles not provided, this air stream would immediately lose a large percentage of its velocity.

A highly beneficial result is obtained by this arrangement. As explained above, all of the coarser material dropping through the passage 9 drops into the vane 14. As it passes from the passage 9 to the vane 14, it traverses and is swept by an air stream of proper separating velocity entering through the passage X. Thus additional fines which may have been carried along heretofore by the larger particles are scavenged. As this material drops onto the vane 14, however, it bounces therealong, often changing both the direction of rotation and fall of the individual particles and setting up a drumming or vibration which mechanically vibrates the particles to free the fines therefrom. These fines necessarily drop off of the vane 14 and are caught in the portion of the now scavenging air stream issuing through the passage Y. The same action is repeated and the material is again vibrated and fines scavenged as it passes from the vane 14 to the baffle 15, and it again is swept finally with air at the proper velocity for the degree of fineness required as the coarser particles drop off of the vane 15. Thus the coarse particles have been substantially freed from any fine material adhering thereto.

Another decided advantage of the baffle arrangement can best be understood by reference to Fig. 4 wherein a single particle of falling material P is illustrated. The particle P is assumed to be dropping through the air so that there is a relatively onrushing air stream, as indicated by the arrows A. The relatively onrushing air impinging on the particle P is deflected therearound and forms immediately in the rear of the particle P a low atmospheric pressure pocket or partial vacuum V of considerable extent, followed by a slight swirling and back surging of the air, just to the rear of the low pressure pocket, as indicated at B. This low pressure pocket V is such that extremely fine particles actually carried on the coarser particles P are not subjected to the air currents. More important, however, is that already freed particles in the air through which the particles P fall will be entrapped or sucked into the pocket and will be drawn along with the particle P by the influence of the pocket V. Likewise, the small localized back surge B and air currents will be created by and trail the falling particle P, and, while swirling downwardly therewith, will carry fine particles. However, as the particles P drop from the passage 9, they must drop through a considerable space before discharge from the opening 4. By breaking this fall and temporarily arresting the fall of the particles P as they move toward the opening 4, both by the wall 3d and the vanes 14 and 15, the vacuum pockets V are destroyed or reduced so that the scavenging air currents can free the fines from the influence thereof and convey them away. Upon striking the vane 14, the particles P tend to rebound or be deflected at an abrupt angle to their normal direction of fall with the result

that the vacuum pocket V is destroyed and the fines carried therein are freed.

The velocity of the particles as they drop and bounce from vane to vane is so reduced that the air streams passing through the passages, X, Y, and Z, may overcome this tendency and prevent the particles from drawing the fines along therewith. This falling of the particles P also causes drumming or vibration thereof and tends to mechanically free finer particles clinging thereto. Thus the particles P finally dropping onto the wall of the casing portion 3 below the lower end of the baffle 15 have been vibrated and successively checked in velocity in a manner such that substantially all fines clinging thereto by adhesion or drawn along thereby, due to the vacuum pockets and localized currents are freed and diffused into the air stream which passes out through the sleeve 5 so that much higher efficiency of separation is effected.

If, due to the density and fineness relation of a given material, it is desirable to finally sweep the falling coarse particles with a higher velocity air stream, this may be done by tilting the vanes 14 and 15 slightly upwardly so as to reduce the size of the passages X, Y and Z and thus increase the speed of the air at the instant of passing there-through for scavenging and sweeping the dropping coarse particles. If, on the other hand, a much finer separation is required, the vanes 14 can be tilted so as to increase the size of the passages X and Y, thus causing a reduction in the speed of the air passing therebetween and consequently a separation only of extremely fine material from the coarse.

The structure illustrated is one which is proportioned for separating very fine and light material such as finely pulverized graphite.

In general, the passage in the baffle 8 and the passages between it and the sleeve 5 and the casing 1 are maintained in the general proportion illustrated with respect to each other for most materials though variations may be made therein.

In order to indicate generally how to determine what the changes should be for a particular material the following general rules are pointed out:

Saturation of the air current with fine particles depends upon the specific gravity or weight of the particular material.

Velocity of the air current generally controls fineness and differences in weight, the heavier material requiring a higher velocity of air than lighter materials if the size of the particles to be separated is the same in the case of both materials.

Volume of air is also a controlling feature. For separating fines from heavy material the instantaneous volume of air may be decreased and the velocity increased, the air passages and the sleeve 5 in such instance being smaller for an X quantity of material. For a lighter material the instantaneous volume of air may be increased and the velocity decreased so that the air passages and sleeve 5 are larger for the X quantity of lighter material. This is on the assumption that the quantity X is a quantity by weight. Thus in the latter instance, ample volume is provided without such an increase in velocity as would remove coarse particles from the lighter material.

As stated, the proper volumetric relation between the air and particular material is controlled in the present structure by additional outside air admitted through the conduit 22 from any suit-

able damper controlled source so that all of the air does not have to pass through the grinding mill. Because of this feature the required amount of air for efficient operation in a particular instance may be maintained without passing an excess of air through the mill, whereas, if all of the air were necessarily passed through the mill, the amount required for efficient operation might be such as to carry from the mill too large a percentage of coarse particles.

To insure proper passage and positive flow of air through the separator and in through the damper 22a a suction fan, not shown, is operatively associated with the outlet passage 6. In grinding graphite, for example, in which a relatively small and slow moving stream of air passes through the mill, additional air would be required. Assuming the body 1, shown in the drawing, to be eight feet in diameter and other parts in proportion, a suction fan having 9000 cubic feet per minute capacity may be connected with the passage 6 and operated to capacity while only 2600 cubic feet per minute is passed through the grinding mill, the difference in volume of air being supplied by air bled into the conduit 22 between the mill and separator.

By this structure and method, a large portion of the fine materials are initially withdrawn promptly and thereafter the coarser particles are subjected to scavenging air currents of proper velocity for removing substantially all the fines, clinging thereto or drawn along thereby. Experience has proven that the above structure, when operating in the same capacities as prior structures heretofore employed, will provide a much higher percentage of separation especially when separation of extremely finely ground material is performed. The structure and method are equally effective for separating different materials of the same fineness but of different specific weights.

Having thus described my invention,
I claim:

1. The method of separating fine from coarse particles of pulverized material which comprises transporting the particles in a stream of air, controlling the stream of air at one portion of its path to cause coarse particles to pass out of the stream and fall downwardly therefrom, re-directing the stream to receive again the coarse material separated, and temporarily arresting the fall of said coarse particles as the coarse particles pass through the re-directed air stream, and then additionally reducing the velocity of the air stream and directing the air stream away upwardly from the coarse material passed there-through.

2. The method of separating fine from coarse particles of pulverized material which comprises transporting the particles in a stream of air, decreasing the velocity of said stream of air along a portion of its path of travel for causing coarse particles to settle out from the stream, re-directing the air stream to direct it across the field of falling particles at a point remote from their point of separation, temporarily arresting and reducing the speed of fall of the coarse particles to dissipate localized air conditions resulting from the falling of the particles during passage of the separated coarse particles through the re-directed air stream.

3. The method of separating fine from coarse particles of pulverized material which comprises transporting the particles in a stream of air, decreasing the velocity of the air stream and

concurrently changing the direction of flow thereof, whereby coarse particles pass out of the stream and fall therebelow, re-directing the stream of air through the falling coarse particles at a location below the place of separation, successively temporarily intercepting the fall of the coarse particles as they pass through the re-directed portion of the air stream.

4. In a cyclone separator, an upright, sealed casing having top, side and bottom walls, and having a discharge passage at the lower end, an upright sleeve in the casing in spaced relation to the bottom and side walls thereof and extending through the top of the casing, said sleeve being open at its ends, an annular inverted trough baffle surrounding the sleeve and having depending inner and outer side walls spaced from each other and spaced respectively from the sleeve and casing, said baffle being spaced from the top wall of the casing, the inner wall terminating in spaced relation above the lower end of the sleeve, the outer wall, beginning below the lower limit of the inner wall, sloping downwardly and toward the sleeve and defining therewith a narrow passage, a conduit arranged for discharging tangentially of and into said trough baffle for supplying therinto a stream of air laden with material to be separated.

5. In a cyclone separator, an upright, sealed casing having top, side and bottom walls and having a discharge passage at the lower end, an upright sleeve in the casing in spaced relation to the bottom and side walls thereof and extending through the top of the casing, said sleeve being open at its ends, an annular inverted trough baffle surrounding the sleeve having depending inner and outer side walls spaced from each other and spaced respectively from the sleeve and casing, said baffle being spaced from the top wall of the casing, the inner wall terminating in spaced relation above the lower end of the sleeve, the outer wall, beginning below the lower limit of the inner wall, sloping downwardly and toward the sleeve and defining therewith a narrow passage, a portion of the casing wall adjacent the lower end of the outer side wall and therebelow sloping parallel therewith, said portion being in underlying spaced relation to the sleeve, an inwardly, downwardly sloping annular baffle vane in spaced relation to and below the sleeve and having its upper end positioned to receive material from said narrow passage and to define with the lower end of the sleeve an annular air passage, and to define with the sloping portion of the casing another air passage discharging below and within the projected limits of the sleeve, a conduit arranged for discharging tangentially of and into said trough baffle for supplying therinto a stream of air laden with material to be separated.

6. In a cyclone separator, an upright, sealed casing having top, side and bottom walls and having a discharge passage at the lower end, an upright sleeve in the casing in spaced relation to the bottom and side walls thereof and extending through the top of the casing, said sleeve being open at its ends, an annular inverted trough baffle surrounding the sleeve having depending inner and outer side walls spaced from each other and spaced respectively from the sleeve and casing, said baffle being spaced from the top wall of the casing, the inner wall terminating in spaced relation above the lower end of the sleeve, the outer wall, beginning below the lower limit of the inner wall, sloping down-

wardly and toward the sleeve and defining therewith a narrow passage, a portion of the casing wall adjacent the lower end of the outer side wall and therebelow sloping parallel therewith, said portion being in underlying spaced relation to the sleeve, an inwardly, downwardly sloping annular baffle vane in spaced relation to and below the sleeve and having its upper end positioned to receive material from said narrow passage and to define with the lower end of the sleeve an annular air passage, and to define with the sloping portion of the casing another air passage discharging below and within the projected limits of the sleeve, means to adjust said baffle vane for varying the relative sizes of said passages, and a conduit arranged for discharging tangentially of and into said trough baffle for supplying therinto a stream of air laden with material to be separated.

7. In a cyclone separator, an upright, sealed casing having top, side and bottom walls and having a discharge passage at the lower end, an upright sleeve in the casing in spaced relation to the bottom and side walls thereof and extending through the top of the casing, said sleeve being open at its ends, an annular inverted trough baffle surrounding the sleeve having depending inner and outer side walls spaced from each other and spaced respectively from the sleeve and casing, said baffle being spaced from the top wall of the casing, the inner wall terminating in spaced relation above the lower end of the sleeve, the outer wall, beginning below the lower limit of the inner wall, sloping downwardly and toward the sleeve and defining therewith a narrow passage, a portion of the casing wall adjacent the lower end of the outer side wall and therebelow sloping parallel therewith, said portion being in underlying spaced relation to the sleeve, an inwardly, downwardly sloping annular baffle vane in spaced relation to and below the sleeve and having its upper end positioned to receive material from said narrow passage and to define with the lower end of the sleeve an annular air passage, and to define with the sloping portion of the casing another air passage discharging below and within the projected limits of the sleeve, and another inwardly, downwardly sloping annular baffle vane in spaced relation below the first baffle vane and having its upper end positioned to receive material falling from the first baffle vane and to define with the lower end thereof an additional air passage, and to define with the sloping portion of the casing, another air discharge passage, whereby the particles of material falling from the narrow passage are temporarily arrested successively and vibrated by the baffle vanes as they pass through a scavenging air stream, and a conduit arranged for discharging tangentially of and into said trough baffle for supplying therinto a stream of air laden with material to be separated.

8. In a cyclone separator, an upright casing, means to discharge a stream of material laden air therinto tangentially thereof, whereby a swirling annular stream is provided, means to direct said annular stream axially downwardly, then in a reverse direction for initially separating coarse particles therefrom, thence upwardly and outwardly and downwardly in surrounding relation to the entering portion thereof, means defining a downwardly discharging passage providing greater area for the continued downward passage of said annular stream, and a sleeve

forming a central upright passage of greater cross sectional area than the last mentioned passage and extending upwardly from the last mentioned passage, whereby the annular stream is caused to be reversed abruptly in its last mentioned downward direction of flow, and means for directing the coarse materials initially separated from the incoming stream across said annular stream as it enters said sleeve, the said sleeve having a discharge passage for discharging said stream of air therefrom.

9. In a cyclone separator, a casing, means to discharge a stream of material laden air thereinto, means for causing coarse particles to fall from said stream, means for directing the air away from said particles and as a re-entrant stream through the stream of falling particles at a point remote from their point of separation, an adjustable baffle disposed in the path of the falling stream of coarse particles and the re-entrant air stream for temporarily arresting the fall of the particles while they are being swept by said re-entrant air stream, and means having a passage for the discharge of the air from the casing after passage thereof through said stream of following particles.

10. The method of separating fine and coarse particles of pulverized material which comprises transporting the particles in a stream of air, causing concurrent swirling of a portion of the air stream around an upright axis and swirling movement thereof for at least one complete revolution about a horizontal axis for separating coarse particles therefrom whereby particles may fall downwardly from their point of separation, causing re-entrance of said air across the stream of separated falling coarse particles, and discharging the air in a direction away from the direction of fall of said coarse particles.

11. The method of separating fine particles from coarse particles of pulverized material which comprises transporting the particles in a stream of air, controlling the stream of air at one portion of its path to cause coarse particles to pass out of the stream and fall downwardly therefrom, re-directing said air stream to cause it to sweep the falling coarse particles at a location below their original zone of separation from the air stream, temporarily and intermittently arresting and retarding the rate of fall of said falling coarse particles relative to the rate of flow of the said redirected portion of said air stream while they are being swept by the redirected air stream, and then directing the air stream away from the coarse particles passed therethrough.

12. The method of separating fine particles from coarse particles of pulverized material which comprises transporting the material in a stream of air, controlling the stream of air at a given location along its path of travel to cause coarse particles to pass out of the air stream, causing re-entry of the coarse particles into and passage thereof across the air stream at another portion of the air stream, and during said passage across the air stream temporarily and intermittently retarding the rate of fall of the coarse particles relative to the rate of travel of said other portion of the air stream and redirecting the falling particles and effecting vibration of the separated coarse particles, and then directing the said other portion of the air stream away from the coarse particles passed therethrough.