June 7, 1960 H. HARDINGE 2,939,579

AIR CLASSIFIER

Filed July 13, 1956 2 Sheets-Sheet 1

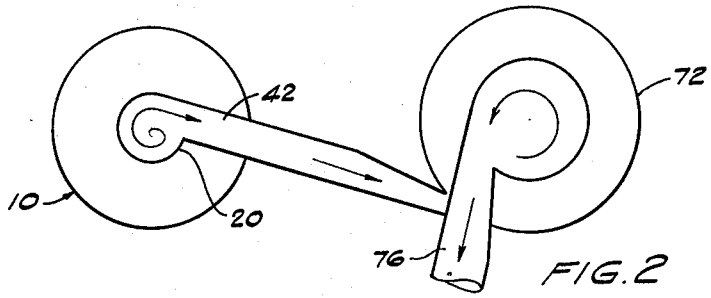


FIG. 2

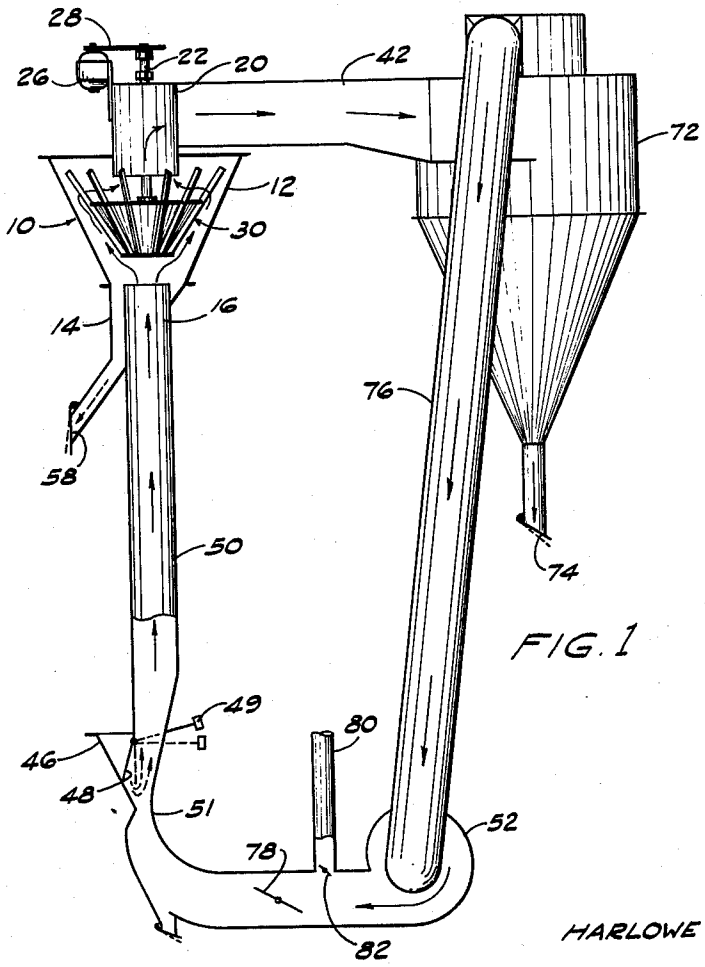


FIG. 1

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June 7, 1960 H. HARDINGE 2,939,579

AIR CLASSIFIER

Filed July 13, 1956 2 Sheets-Sheet 2

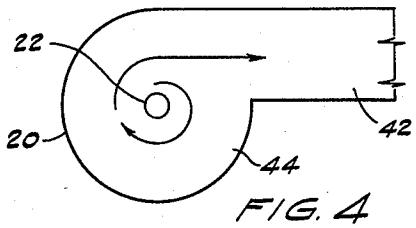


FIG. 4

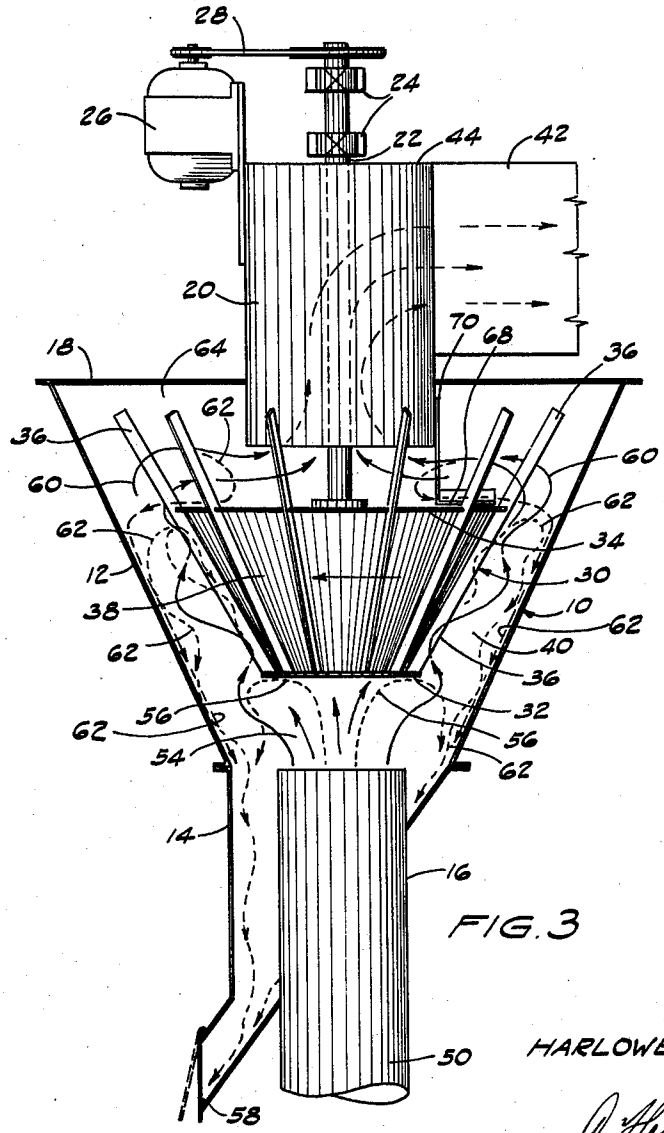


FIG. 3

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United States Patent Office 2,939,579 Patented June 7, 1960



2,939,579

# AIR CLASSIFIER

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Filed July 13, 1956, Ser. No. 597,756

3 Claims. (Cl. 209—144)

This invention relates to a process and apparatus for classifying pulverized material and particularly for separating relatively coarse particles of material of a predetermined range of sizes from a fluid stream containing a mixture of said particles with relatively finer sizes of material.

This application is a continuation-in-part of patent application Serial No. 339,271, filed February 27, 1953, and now issued as Patent No. 2,758,713, dated August 14, 1956.

The process and apparatus comprising the present invention are especially useful with grinding mills and particularly with grinding mills from which a fluid stream carrying entrained particles of solid material of various sizes moves upwardly for transmission to a classifying system such as comprises part of the present invention. However, it is to be understood that the invention is not to be restricted for use with grinding mills or machines of this type or having upwardly directed discharge means since the invention has other applications of use.

A problem frequently encountered in classifiers of the type to which the present invention pertains is that stratification and agglomeration of the material occurs during the passage thereof through the apparatus. This is particularly so in classifiers wherein a fluid stream is established and utilized for purposes of moving the material through the classifiers while entrained in said stream. Various attempts have been made to reduce this tendency but the efficiency of most of these attempts has not been as great as desired. Further, many of the classifiers which have been developed in an attempt to solve this problem have been expensive to manufacture and operate, and also have been complicated.

The principal object of the present invention is to provide a process and apparatus for classifying pulverized material and, more particularly, for separating relatively coarse material from relatively fine material entrained as a mixture in a fluid stream, the details of the process and the apparatus being such as to result in substantially no stratification and agglomeration of the particles as they pass through the apparatus, the speed and directions of movement of the stream through the system being such as to effect greater efficiency of separation and prevention or stratification than has been possible heretofore.

More specifically, the process and apparatus comprising the present invention includes a system comprising a casing which communicates preferably at the bottom with a suitable conduit. A fluid stream having various sizes of particles of solid material entrained therein enters the lower end of said casing through said conduit. An impeller is provided in the casing which has means operable to produce a circular component in the path of the stream while the stream progressively rises, and conduits connected in the system and communicating particularly with the upper portion of said casing preferably have a negative pressure maintained therein so as to



produce a desired movement of the fluid stream through said casing and conduits comprising the system.

As the stream moves through said casing, the impeller also engages particularly the coarser particles and deflects them transversely against the walls of the casing, whereupon these particles drop to a suitable collector for return to the mill or otherwise. The finer particles remain entrained in the stream as the stream continues to move upwardly through the casing and the simultaneous circular movement of the stream results in the path thereof being spirally upward, particularly as the stream exits from the upper part of the casing.

While the details of certain elements of this system and especially said impeller are described and claimed in aforementioned Patent No. 2,758,713, dated August 14, 1956, the present application, although including drawings similar to those in said patent, pertains principally to the apparatus and process by which the particle entrained fluid stream is caused to move not only through the casing which contains the impeller but also through the exit conduit means of the system in a highly efficient manner which minimizes stratification of solid particles within the stream.

Further, the invention described and claimed herein concerns a process and apparatus which combines dynamic movement with the force of a discharging, particle entrained, fluid stream to produce an effective centrifugal force with minimum power loss, as well as increasing classification efficiency and the lowering of overall power comsumption for a given efficiency as compared with existing classifiers. Correspondingly, the dynamic movement of the vaned impeller is continued in its centrifugal movement by virtue of the nature of the outlet from the confined chamber being substantially in line with the direction of movement of the fluid stream as produced by said impeller.

Further, an important aspect of the improvement offered by the present invention comprises the abrupt changing in direction of the exhausting fluid current, for example, from a substantially vertical direction to a substantially horizontal direction, without appreciable loss in pressure drop and while subjected to only minimum frictional losses, due to minimizing of eddy currents.

Still further, the inlet passage of the apparatus of the present invention is provided with a constriction so arranged as to produce a venturi effect, thereby increasing the movement of the particle entrained fluid stream through the system with all of its attending benefits.

Another advantage of the present invention is that a column is available wherein a teetering effect is produced relative to the particles in the stream of such size that tend to remain in suspension in the fluid column. These will be subjected to further cleaning action while being teetered. Eventually the coarser fraction of such particles will find their way downward, while the finer fraction thereof is carried upward by the fluid stream, thereby enhancing the separation of such finer fraction of particles in the stream from the coarser particles.

Details of the process and one exemplary embodiment of apparatus capable of performing said process to produce the benefits of the present invention are illustrated in the accompanying drawings comprising a part of the application and are described in the following specification.

In the drawings:

Fig. 1 is a vertical elevation, partly in section, of an exemplary classifying system including a classifying unit illustrated in greater detail in Figs. 3 and 4.

Fig. 2 is a diagrammatic top plan view of the system illustrated in Fig. 1.

Fig. 3 is a side elevation, partly in section, illustrat-

ing principally an exemplary embodiment of classifying unit incorporated in the classifying system illustrated in Figs. 1 and 2.

Fig. 4 is a fragmentary, diagrammatic plan view of the upper portion of the unit illustrated in Fig. 3.

The process comprising the present invention may be performed in a number of different types of apparatus, one exemplary embodiment of which is illustrated in Figs. 1 through 4.

Referring to Fig. 1, a classifying system is shown which includes one embodiment of classifying unit **10** comprising a casing **12** which preferably is generally frusto-conical in shape, the axis of the casing extending substantially vertically. The lower end portion of the casing **12** is shown connected to a collector **14** which receives coarser particles separated from a fluid stream in which said particles were entrained as will be described in detail hereinafter.

Extending upward through the collector **14** is an inlet or entrance end **16** of a conduit which extends preferably axially of the casing **12**. The top of the casing **12** is closed by cover **18** through which an exhaust conduit **20** extends substantially vertically and preferably in axial alignment with the casing **12**. A shaft **22** extends into the conduit **20** and is rotatably supported by suitable bearings **24** fixed relative to the conduit **20**. A motor **26**, which is preferably of the variable speed type, is fixedly supported relative to the conduit **20** and a belt **28** connects suitable pulleys on the motor **26** and shaft **22** as clearly shown in Fig. 3, whereby the motor positively drives the shaft **22**.

An agitator or impeller **30** is fixed to the lower end of shaft **22** and is rotated thereby dynamically to cause the stream to assume a curved path while rising, resulting in the particles in the stream being subjected to centrifugal force while the stream moves spirally upward due also to negative pressure in unit **10**, to be described hereinafter.

Referring particularly to Fig. 3, it will be seen that the impeller **30** comprises a pair of plate-like members **32** and **34** which extend transversely to and are also fixed to the shaft **22** in longitudinally spaced relationship to each other. A plurality of elongated vanes **36** extend between and are secured to the plate-like members **32** and **34**, said vanes preferably being spaced peripherally even distances around said members and the outer edges of the vanes **36** are also preferably disposed at an acute angle to the side walls of the casing **12**, as clearly shown in Figs. 1 and 3. This is made possible by the member **34** having a substantially larger diameter than member **32**.

The impeller will function to achieve desirable results, in accordance with the present invention, which are described in detail hereinafter when only the members **32** and **34** and vanes **36** are fixed thereto. However, the efficiency of the apparatus, and correspondingly of the process, usually is increased by providing shield means **38** which preferably is a cone of suitable material such as sheet metal and extends between the members **32** and **34** as well as between the vanes **36** adjacent the inner edges thereof to enhance the teetering effect referred to above when such condition is desired and advantageous. This arrangement produces a well defined annular, frusto-conical space or passage **40** between the casing **12** and the impeller **30**, said space having the diameter thereof progressively expand from bottom to top. Also, the angle of the frusto-conical shield means **38** is greater than that of casing **12** and the difference in these angles preferably is such that, as the space **40** increases in diameter, it decreases in width, or thickness, whereby a passage of substantially constant cross-sectional area and substantially uniform velocity is provided. This arrangement allows the coarser particles which may enter this zone to drop down against a rising fluid column without encountering an increase in average



velocity as would result if the area of the zone was reduced materially at the lower portion of passage **40**.

Extending tangentially from and communicating with the outlet conduit **20** is another conduit **42** and the upper end of the conduit **20** is closed by a cover or plate **44** which may be coextensive with the upper wall of the conduit **42** as shown in Fig. 1.

While a classifier unit of the type described above and illustrated in Figs. 1 and 2 is useful to perform various kinds of classifying operations, it is particularly useful in a pulverizing and classifying system, one exemplary illustration of such system being shown in Figs. 1 and 2, wherein the classifier unit **10** is illustrated in sectional view. Said system may be used in conjunction with a mill, not illustrated, if desired, the mill for example being disposed below the conduit outlet end **16**. In any event, it is contemplated that material to be classified is in the form of a fluid stream in which a relatively wide range of particles of pulverized material is entrained and said stream is introduced through entrance **46** to the system.

As illustrated in Fig. 1, said entrance has a balanced air-lock **48** operatively positioned so as to control the inlet of material to the lower portion of uptake conduit **50**. Said air-lock **48** is adjustable by means of a movable weight **49** or the like so as to control desirably the inlet of air as well as material to be classified. Somewhat of a choke feed thereby is afforded to permit a desired amount of vacuum to be maintained in the unit **10** and the take-off therefrom.

The system also includes a blower **52** which discharges in a direction to flow upwardly through the conduit **50** and thereby carry the fluid stream in which the pulverized material is entrained to the classifier **10**. It has been found in actual practice that, depending of course upon the force of the exhaust of the blower **52**, the fluid stream discharging from conduit **50** into the classifier **10** is capable of carrying particles of relatively large size to the classifier **10**. A wide range of smaller sizes of particles are also entrained in said stream moving to the classifier.

Further, it will be noted the inlet chute **46** permits the entering material to fall by gravity but as the material enters uptake conduit **50**, its path is immediately reversed and it is carried upward by the up-draft in conduit **50** which engages the entering material head-on. This results in a minimum amount of stratification of solid particles within the stream of material moving to the unit **10**. Such reversal of direction of the entering material also is greatly enhanced and the buoying capacity of the fluid stream in conduit **50** is increased greatly over normal values by providing constricting means **51** in the lower end of conduit **50** to produce a venturi effect; i.e., an increase in velocity and drop in pressure.

Referring particularly to Fig. 3, it will be seen that the fluid stream **54** of entrained particles enters the casing **12** in a substantially vertical path at considerable speed and impinges against the lower surface of the plate-like member **32** which is preferably planar and imperforate and transverse to the path of the stream. At least the coarsest of the particles within the stream will be deflected transversely and will be impinged against the side walls of the casing **12** as indicated, for example, by the broken line arrows **56**. The rotation of member **32** enhances this function. Said separated coarser particles will hit the sides of the casing **12** and fall by gravity down said sides into the collector **14**. The material collected in collector **14** is discharged through the oversize spout and airlock **58**.

The stream of material from which some of the coarser particles have thus been removed then moves upward through the space **40** which is defined by the casing **12** and the impeller **30**. Said impeller will be rotated at a speed suitable to achieve greatest efficiency during the

classifying operation. This impeller produces dynamic movement of the stream which combines with the upward movement to produce an effective centrifugal force that increases classification efficiency with a minimum overall power consumption for a given efficiency. The dynamically moved vanes 36 of the impeller also will engage other relatively coarse particles within the stream moving generally upward through the space 40 and will cause them to be thrown or impinged against the sides of the casing 12 and from there said particles will move into the collector 14 by gravity.

It will be noted that the passage 40 is relatively long and the vanes 36 also act continually to disturb and break up any tendency for unbalanced loading of one portion of the classifier as opposed to another, whereby the air velocities are more evenly distributed than is otherwise possible and the air loadings are maintained substantially constant when air is used as the fluid medium. In addition, the buoying effect of the air and the centrifugal force caused by the rotating member 30 is maintained substantially constant with the result that the coarser particles which are thrown out of the stream by the vanes of the impeller are kept substantially clean of the fines which would otherwise tend to be entrained with them in an unbalanced load. Thus, the coarse particles in settling and moving downward into the collector 14 contain a very minimum of fines. Further, such centrifugal movement of the fluid stream in a confined chamber aids the dynamic movement of the vaned impeller.

The fines, together with the finer particles of oversize, travel upward between the vanes 36 and through the space 40 as the stream rises toward the outlet conduit 20. The diverging effect of the vanes 36 causes an increase in the velocity of the stream and the centrifugal force produced by the impeller 30 produces further refinements and classification of the particles in this portion of the apparatus without the heavy loading of coarser particles which have been removed from the stream before the material reaches the upper zone thereof.

Vanes 36 also produce a winnowing action which is described in detail and claimed in said aforementioned patent. Such action causes the stream to assume a somewhat wavering but generally upward path indicated by the solid arrow lines 60, said stream containing the fines intermingled with relatively medium particles of oversize. Some of the latter are caused to be thrown from the stream by vanes 36 so as to impinge against the walls of the casing 12 as indicated by the broken line arrows 62. These particles move down the walls of the casing 12 by gravity as indicated by other broken line arrows 62. Some of the medium oversize particles are carried to the upper zone 64, where they drop to plate 34 and are discharged by centrifugal force or blade 68, to slide down wall 12 to discharge spout 58. The vanes 36, in conjunction with the deflecting action of member 32, cause the stream first to move toward the side walls of the casing 12 and said stream then is waveringly deflected inward toward the impeller 30 which causes engagement of the medium oversize particles in said stream with the vanes 36. The centrifugal force of the impeller will also cause diversion of the stream as subsequently deflected back toward the impeller preferably a plurality of times as indicated by the arrows 60 and resulting in a combined winnowing and deflecting effect upon the stream passing through the space 40.

As has been stated hereinabove, the operation of this type of classifier is relatively efficient even when the shield means 38 is omitted. However, a more efficient cleaning of the oversize particles results if the shield 38 is embodied in the impeller 30. Said shield also more precisely defines the annular space or passage 40 which tends to decrease the consumption of power and wear on parts in this zone by eliminating a space where turbulence is caused but which performs little or no useful purpose.

As referred to in the aforementioned patent, this classifier will function however without shield 38 being included in the impeller 30 and the above described wavering function will take place when said shield is omitted. However, the teetering effect will not occur when the shield 38 is omitted and in operations under certain conditions, such teetering is not necessary or advantageous as for example, where the cleaning of so-called intermediate sizes is not necessarily advantageous and such omission of the shield will eliminate the attendant cost thereof from the total cost of the apparatus.

It has also been found that, generally, if the perimeters of the members 32 and 34 extend somewhat beyond the shield 38, as shown in Fig. 3, the passage of the fluid stream between the edges or perimeters of said members and the casing 12 is restricted to a greater degree than the restriction between shield 38 and casing 12. Thus, the velocity of the stream past the perimeters of the plate-like members 32 and 34 is increased and such increase in velocity also enhances the winnowing and hindered-settling action of the particles within the stream as compared with the operation of a construction in which said members 32 and 34 do not extend beyond the shield 38.

From Fig. 3 particularly, it will be seen that the upper member 34 is spaced a substantial distance from the cover 18 of casing 12, as well as outlet conduit 20. In view particularly of the conical configuration of casing 12, an enlarged zone 64 is provided in the upper portion of casing 12. The upper ends of the vanes 36 preferably extend upwardly beyond the member 34 a substantial distance into the zone 64. Further, in the preferred embodiment of the invention, the lower end of outlet conduit 20 projects into zone 64 so that the fluid stream containing entrained fines which are to be removed through conduit 20 travels upward into zone 64 as shown by the arrows 60. The currents designated by arrows 60 tend generally also to curve toward the upper surface of the member 34 with the result that the relatively medium particles therein are thrown against the upper surface of member 34.

This deposit of coarser particles may be discharged from the member 34 by centrifugal force induced by the rotation of the impeller 30 if the speed thereof is sufficient for such purposes. However, under some circumstances, depending on the loading of the stream and the speed at which said stream is introduced to the classifier, the rotational speed of the impeller 30 may be such that insufficient centrifugal force is developed to produce the desired amount of discharge of the coarser particles from member 34. To insure substantially complete removal of said coarser particles from member 34, scraper 68 is supported adjacent said upper surface, for example, by a bracket 70 fixed to conduit 20. Said scraper is preferably positioned at a suitable angle within a plane parallel to member 34 so as to insure scrapping and discharge of the coarser particles from the upper surface of member 34 and cause the same to fall against the walls of the casing 12 and slide down the same into the collector 14.

While it is difficult to determine exactly what takes place in the enlarged zone 64 of the classifier, tests in transparent models tend generally to indicate that two forces seem to be exerted upon the stream in said zone. One of these is the force of the stream passing through the classifier from the entrance conduit 16 to the outlet conduit 20 and the other force is centrifugal and created by the rotation of the vanes 36. The result appears to be an inward and downward thrust of the stream with the finer particles entrained therein that have not previously settled. In this zone, a sharp degree of classification appears to take place due to the difference in the inertia of the particles within the stream. The coarser particles tend to go to the point where there is less agitation and

this is near the top of member 34. At or just above the rotating member 34, the agitation seems to be greatly reduced and a reversal of direction close to member 34 occurs with the result that the coarser particles remaining in the stream drop out and are either deposited or are thrown by centrifugal force from the member 34 as described above. These particles move through the vanes 36 and fall to the walls of the casing 12, down which they slide to the collector 14 as described hereinabove.

The fluid stream from which the coarser particles have been removed and in which fines are still entrained, flows upward through outlet conduit 20 and into take-off conduit 42. Impeller 30 introduces a rotational component of movement into the upwardly moving, spiralling stream and said rotation is in such a direction as naturally to enter the take-off conduit 42 which extends tangentially from the side of conduit 20 that naturally would receive the rotating stream in the same line of travel, as clearly shown in Figs. 2 and 4. This arrangement results in minimizing stray or eddy currents with reduction in any pressure drop at the outlet or exhaust end of the classifier and also minimizes frictional losses, thus resulting in decreased wear and power consumption in this portion of the system. Further, less head room is required by such tangential take-off as compared with conventional systems of this nature and a very effective and simple mounting for the impeller and drive means therefor is also made possible.

Take-off conduit 42 is illustrated in Fig. 1 as conducting the stream of fines into a separator 72 which separates the fine product from the fluid, such as air, in a manner well known in the art. The fine product is then recovered through a suitable air lock 74. The air thus freed of the fine product is returned to the blower or fan 52 through conduit 76. Thus, the blower 52, being in communication with conduit 76, separator 72, and conduit 42, places a suction upon the outlet conduit 20 and thereby facilitates movement of the fluid stream from the classifier 10 into the outlet conduit 20. Flow of air through the system illustrated in Figs. 3 and 4 is also controllable by damper 78 in a well known manner in systems of this nature. Back pressure produced by the damper 78 is sufficient to create a negative pressure on the other side of the damper 78, thus putting the system under a partial vacuum as is well known in the art. Any leakage entering the system through the various air locks or otherwise is vented through a suitable pipe 80, which venting is controlled by damper 82 at the only point in the system under pressure.

While no specific means other than a variable speed motor have been described herein for varying the speed of the impeller, it will be understood that any one of a number of other standard expedients may be utilized such for example as expansible V-pulleys or a variable gear box between the motor and drive shaft of the impeller.

By including a power driven impeller with the classifier, it is found that power consumption is less than in commonly used classifiers wherein air is passed through the classifier by suitable blower means only for example, and the force of the air itself is required to cause any centrifugal or other action to throw out the oversize particles. Thus, in the herein described classifiers as well as a system embodying the same, there is less wear on the apparatus unit, conduits and the system generally due to the fact that the stream containing entrained particles may be moved through the system at a lower rate of speed than is required in the above described classifiers which have no rotating impellers.

While the specific merits and advantages of the details of the impeller and its relation to casing 12, as well as the wavering and winnowing effects produced thereby, are advantageous to the classifying system described and claimed herein, these details are claimed in the aforementioned patent. The principal novel features of the invention described and claimed herein comprise the process and system by which a particle-laden fluid stream is moved steadily and progressively along a path and during a portion of such path, the stream dynamically is caused to move spirally to facilitate the development of centrifugal forces to separate certain coarser particles from the stream while not substantially impeding the continued movement of the stream. Then, when the stream leaves the spiral portion of its path, it is caused to change direction abruptly from upward to horizontal, for example, but due to the take-off conduit 42 being tangential to the substantially vertical outlet conduit 20, no appreciable loss by friction or drop in pressure is caused. This arrangement also results in minimum head room being required to install the classifier unit of the system.

The exemplary illustration of one embodiment of apparatus suited to perform the process referred to is well suited to being constructed, installed, and operated economically and also comprises part of the invention. Other structures, however, are capable of performing the process described and claimed herein.

While the invention has been shown and illustrated in its preferred embodiments, and has included certain details, it should be understood that the invention is not to be limited to the precise details herein illustrated and described since the same may be carried out in other ways falling within the scope of the invention as claimed.

I claim:

1. A classifier system for separating particles from one common fluid stream containing the same and comprising in combination, an upwardly and outwardly tapering casing having an entrance adjacent the lower end thereof and arranged to introduce said fluid stream substantially axially through said entrance into said casing, the upper end of said casing having an axially extending outlet for said stream, an impeller extending axially within said casing for substantially the major portion of the length thereof and rotatable about the axis of said casing and operable to cause said axially moving stream also to move spirally and outwardly as it continues to move axially through said casing, vanes on said impeller extending upwardly from the lower end thereof to induce spiralling of said stream, and a conduit extending substantially transversely to the axis of said casing and tangentially connected to and intersecting the outlet at the upper end of said casing in a direction corresponding to the spiral motion of said stream as it enters and exits from said outlet, whereby said spiral movement imparted to said stream serves to change the discharge direction of said stream from axial movement through said casing to movement susbtantially transverse thereto with a minimum of pressure drop and frictional losses.

2. A classifier system for separating relatively coarse particles from a single continuous fluid stream containing intermixed relatively coarse and fine particles and comprising in combination, a casing extending substantially vertically and having an entrance at its lower end arranged to receive all of said fluid stream of mixed particles, a substantially cylindrical outlet conduit projecting axially from the upper end of said casing, said stream being movable substantially longitudinally upward through said casing, a drive shaft extending axially through said outlet conduit and depending into said casing, impeller means within said casing extending longitudinally thereof at upwardly and outwardly diverging angles and connected to said drive shaft for rotation thereby within said casing about the axis of said shaft in spaced relationship to said casing, vanes on said impeller extending upwardly from the lower end thereof to induce spiralling of said stream, said impeller means when rotated serving to deflect the coarser particles from said stream against the walls of said casing and causing said stream to assume a substantially spiral path as it progresses in its entirety upwardly to said outlet conduit, means ar-

ranged to receive said coarser particles deflected from said stream, closure means for the outer end of said outlet conduit, and a take-off conduit for the exiting fluid stream tangentially intersecting said outlet conduit in a direction corresponding to the spiral direction of said stream induced by said impeller means, whereby pressure drop at said outlet is minimized.

3. A classifier system for separating particles from a fluid stream containing the same and comprising in combination, a substantially conical casing flaring upwardly and having an entrance adjacent the lower end thereof and arranged to introduce a fluid stream substantially axially into said casing, the upper end of said casing having an axially extending outlet for said stream, an impeller within said casing having a conical wall flaring upwardly at a wider angle than said casing and spaced inwardly therefrom to provide a conical passage between said casing and impeller wall having a substantially constant cross-sectional area, said impeller being rotatable about the axis of said casing and operable to cause said axially moving stream also to move spirally as it continues to move axially through said conical passage of said casing, and a conduit extending substantially transversely to the axis of said casing and tangentially connected to and intersecting the outlet of said casing in a direction corresponding to the spiral motion of said stream as it enters and exits from said outlet, whereby said spiral movement imparted to said stream serves to change the discharge direction of said stream from axial movement through said casing to movement substantially transverse thereto with a minimum of pressure drop and frictional losses.

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