United States Patent

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[54] **HYDROCYCLONE**
     3 Claims, 2 Drawing Figs.

[52] **U.S. Cl.**.. 210/512,
                                            209/211
[51] **Int. Cl.**... **B04c 5/103**
[50] **Field of Search**... 210/84,
                       512; 55/459; 209/144, 211

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ABSTRACT: A means and method for controlling the separation of particles or contaminates from liquid mixtures, within a hydrocyclone by mechanically effecting a shifting of the transition zone or point between the free and forced vortex paths in a manner so as to increase or decrease the centrifugal force without significantly changing the through put.
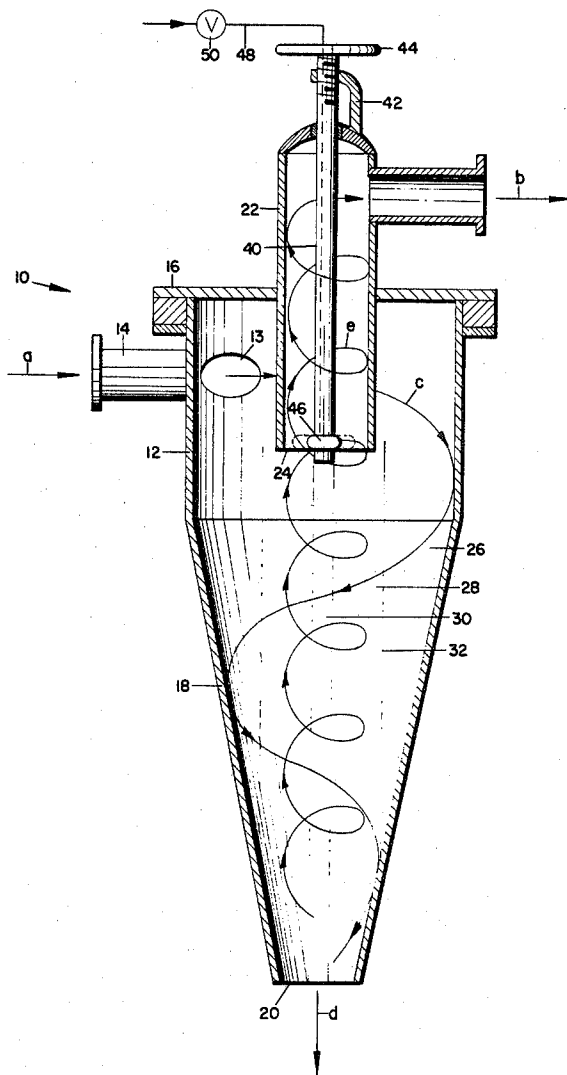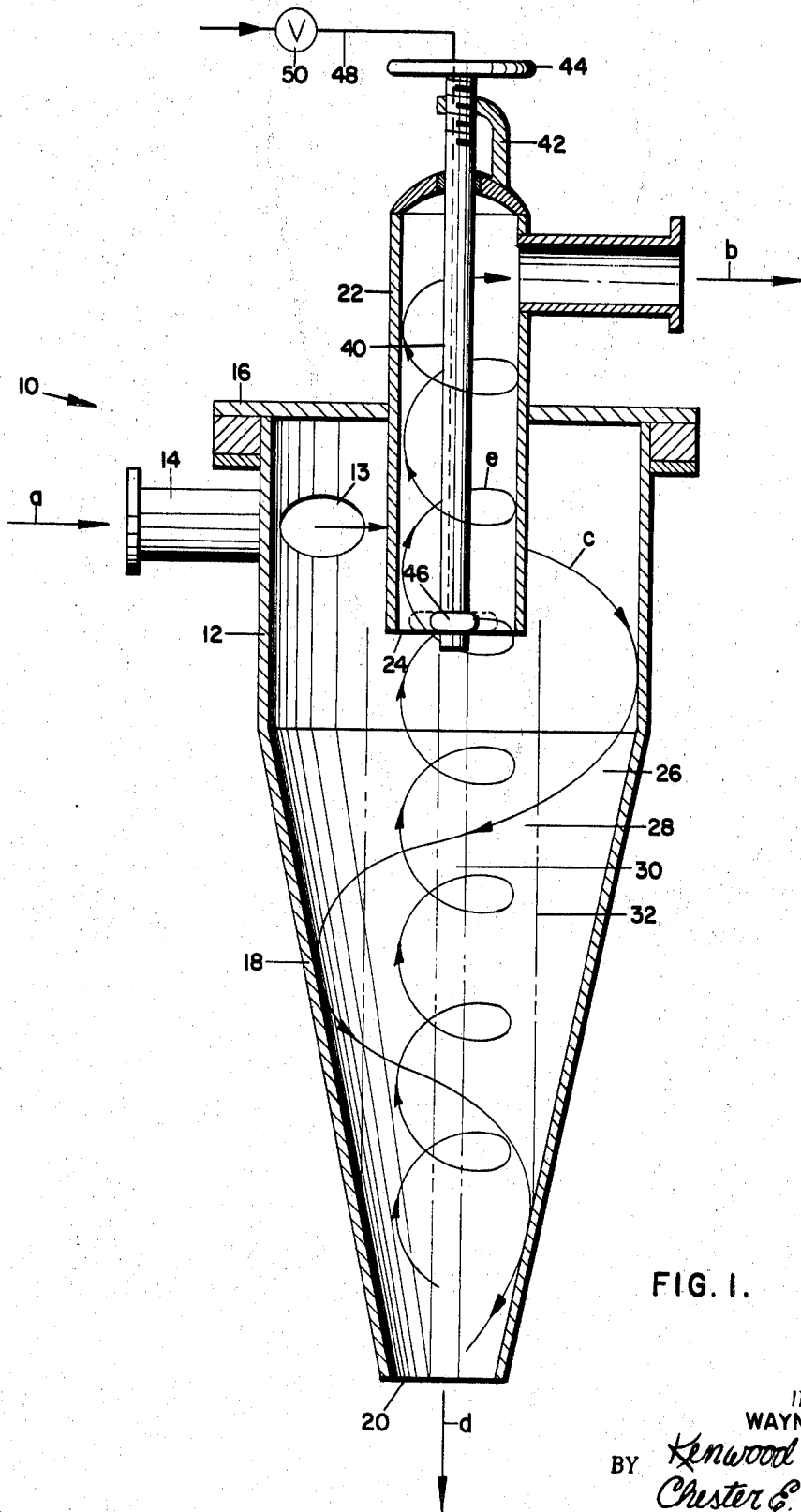
FIG. 1.

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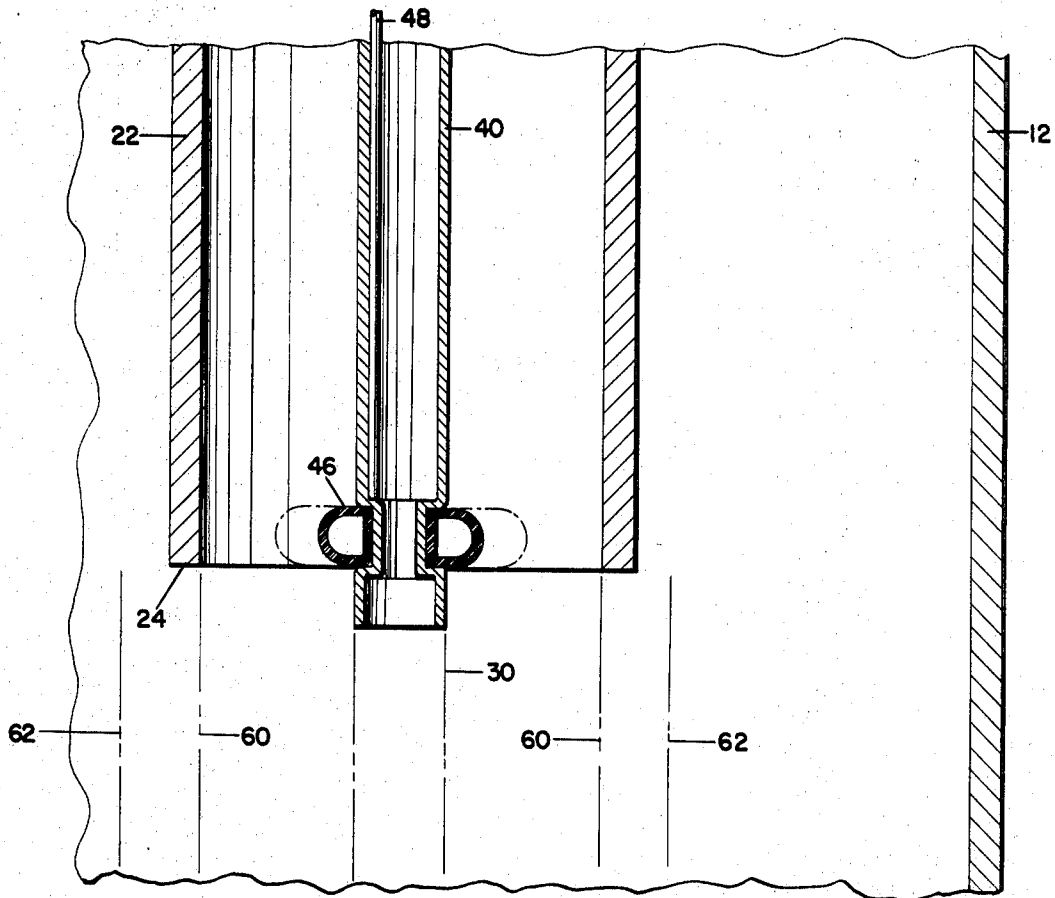WAYNE F. CARR

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FIG. 2.

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HYDROCYCLONE

BACKGROUND OF THE INVENTION

1. Field of the Invention

Centrifugal separators or cyclones are known for separating heavier components, such as solids, entrained in liquids and gases, thereby purifying such liquids or gases.

When used to separate heavier components from liquids, they are frequently termed hydrocyclones or hydroclones.

The invention relates particularly to hydroclones, but its principles are equally adaptable to the separation of heavier components from gases, the term "fluid" as contemplated herein including both liquids and gases, and the term "heavier components" including any components, solid or liquid or gas, dispersed in a base medium having a lower specific gravity than the heavier component.

The invention will find application in many fields but for convenience of disclosure, reference will be made to the use of a centrifugal separator for purifying paper stock wherein wood pulp fibers are suspended in the water solution. The invention however has application with a full range of pulps, from short-fibered hardwood soda and semichemical pulp, through groundwood, sulfite and kraft. 2. Description of the Prior Art

The hydroclone envisions the tangential introduction of a liquid mixture containing suspended solid matter under high input pressure into a cylindrical head and thence into an inverted cone or cyclone chamber so that the liquid mixture is caused to flow circumferentially within the cone. The liquid mixture assumes a rotary path of travel and, so swirling, is moved downwardly toward the cone apex so that a vortex of conical shape is formed, the cone diameter decreases, and the angular velocity and centrifugal force increase. The centrifugal force serves as the separating means.

The carrier fluid and the particles contained therein may be classified into categories as follows:

a. The main fluid (gas or liquid).

b. The acceptable fraction (e.g. woodpulp fiber).

c. The reject fraction, which may include particles of a specific weight close to the acceptable fraction and similar in material but of different geometric configuration and, therefore, of apparent greater density (e.g. bark, shives, nodules and the like); particles of other origin than the acceptable fraction but approaching it in specific weight and size; and particles of other origin than the acceptable fraction and of substantially different specific weight or apparent density.

The stream entering the inlet is immediately subjected to a centrifugal component, among other forces, which component is a function of the tangential velocity and the radius of the particular point.

Its action immediately separates that portion of the reject fraction comprising particles of different specific weight or apparent density. Such portion of the reject fraction orbits, during its presence within the cone, in a helical path close to the wall, being ultimately discharged outwardly through the cone apex.

Another force acting on the flow is the entrainment of the liquid created by the presence of a central discharge orifice. As the liquid tries to exit through this opening, it is immediately subjected to an increasingly larger centrifugal field. The intensity of this field varies according to the size of the orifice.

Particles to be rejected as part of the reject fraction are normally directed toward the cone periphery. In their paths of movement, they encounter other particles, collide, and lose part of the energy initially imparted thereto. This energy loss is coupled with a concentrating effect of the entrained particles present in the suspension between the core of the vortex and the periphery.

In cyclone cleaners heretofore used, the concentration at the wall increases rapidly until it reaches a maximum at the apex.

The centrifugal force is such that solid matters are propelled exteriorly of the stream flow whereas the accept fraction is taken from the interior.

Water, fiber and dirt particles react differently to the prevailing complex pattern of forces including:

1. a pressure differential from the periphery of the cylindrical head towards the central, liquid-free axis and towards the bottom of the cone,

2. the centrifugal force caused by the rotating liquid, and

3. the angular velocity gradient from the cone periphery to the liquid-free axis, the swirling liquid mixture adjacent the center of the vortex traveling at a greater angular velocity than the liquid mixture adjacent the outer area of the vortex.

Fiber and dirt particles, in passing through the created fields of successively-increasing centrifugal force, tend to slow down in relation to their radial travel. A dirt particle, reaching a centrifugal field which counterbalances the radial flow, is carried downwardly in this field by the downward component of liquid flow toward the cone apex. The liquid and the fibers having a high length-to-diameter ratio tend to move into zones of faster tangential velocity, that is, to be carried toward the center of the whirlpool and finally upwardly, and because of the shear, without serious entrainment of dirt.

Thus, the lighter liquid mixture and desirable particles suspended therein are drawn off as the accepted fraction through the accept outlet while the remainder, or heavier portion or dirt, of the liquid mixture, together with some fiber concentrating to a minor extent at the cone wall, recirculates in the vortex and carries downwardly toward the cone apex and is finally separated out as the rejected fraction through the reject outlet.

The desirable pulp fibers are accepted because the hydraulic drag creates radial flows which move the fibers against centrifugal force. When the hydraulic drag is greater than the centrifugal force, the particles are accepted.

Particles which move to the wall of the cone are forced, due to the increasing physical restrictions imposed by the decreasing cone diameter, to the higher angular velocity and centrifugal force zones whereat the particles may be held in a semistationary orbiting field, there to be forced, by succeeding particles, either toward the path to the accept outlet or toward the path to the reject outlet.

If the contaminate is, say, disc-shaped, its chances of responding to the hydraulic drag are greater than if it is spherical, where the ratio of surface to mass is low. Thus, sand is readily rejected by a cleaner while some larger particles may be either rejected or accepted depending on their shape.

With large "dirt," such as knots, the downward liquid components of flow may not be sufficient to overcome the component of centrifugal force acting upwardly in the cone, wherefore an orbit is established with these particles held in equilibrium, each orbit being characteristic of the particle, the unit employed and its method of operation.

A single knot may stay in orbit until worn down by attrition. However, if several such knots enter with the stock, the orbits overlap and, depending on their location, with reference to the rejected and accepted stock outlets, the knots appear eventually, either in the accepted fraction or in the rejected fraction.

Known hydrocyclones used in cleaning cellulose suspensions and similar liquid-solid slurries have been relatively ineffective in removing foreign particles from mixtures above 1 percent fiber consistency (i.e. 1 part fiber per 100 parts liquid by weight).

Small separators (i.e. below 15 inches in diameter as measured at the larger section of the hollow truncated cone) offer special difficulties when it comes to removing large particles having high length-to-width ratios, such as, shives, knots, and like objectionable contaminates, for the reason that, as a result of the shear force, such particles are pulled into the higher angular velocity zones of the vortex and eventually pass into the normal accept zone and out through the accept outlet.

Separators of larger diameter present corresponding problems in removing foreign contaminates, but for a different reason. If a high angular velocity is maintained therein, in order to achieve a resultant high centrifugal force, the particles are forced to the cone wall, and the shear force, which

would normally tend to pull these particles through the high centrifugal force field, is overcome by the mass of the particles themselves and the centrifugal force acting thereupon, so that these particles are frequently held in a stationary orbiting field, with a low probability of going either to the vortex finder area, as part of the accept fraction, or to the cone apex area, as part of the reject fraction.

Various techniques have been attempted to overcome the inherent problems.

Lower angular velocities have been used to prevent the particles from being held at the cone wall, but these lower angular velocities, and the resulting lower centrifugal forces, are objectionable in that they serve to decrease effective removal of the particles as rejects at the cone apex.

Cone diameters have been increased to as much as 35 inches. However, increasing diameter means lowering angular velocity and hence the centrifugal force acting upon the particles. It has served to minimize the difficulties inherent in stationary orbiting. Nonetheless, due to the ineffective elimination of the finer foreign particles, because of this lower centrifugal force, such a cyclone offers an objectionably narrowed particle size separation range. Too, even with the lower centrifugal force, particles having lengths in excess of 2 inches will remain in a stationary orbiting field or will be pulled by shear force into the vortex finder field to the exclusion of being rejected with the reject fraction.

The type of particle shape removal is generally dependent on the dimensions of the inlet, outlet and body diameter, and the included cone angle. Other variables, such as inlet consistency, flow rate, and reject rate usually determine the degree of specific particle sizes rejected due to the physical hydrocyclone dimensions being permanently set during construction, but particles of larger shape tend to be trapped into the accept flow due to the shear force pulling them into the accept flow.

The changing of the operating variables in order to increase a specific shape removal, when it may be increased in the feed solution, usually results in operational inefficiency.

Increasing the reject rate normally is undertaken to improve reject separation from the accept flow. This may increase the specific particle removal but the increase in rejecting from the lower section increases the percentage of desirable fiber. This dictates increased reliance upon secondary hydrocyclones for the recovery of desired fiber back into the accept flow.

The transition point within hydrocyclones remains relatively fixed once the dimensions have been determined in the physical unit. This location remains unaltered with changes in the through put in the hydrocyclone.

SUMMARY OF THE INVENTION

The invention relates to hydrocyclone or centrifugal vortex separators for the separating out of the undesirable solid impurities from the liquid mixture by way of a significant departure from and refinement over the prior art.

The invention exploits the free vortex principle in such manner as to control the highest centrifugal force zone whereby to achieve the desired particle separation.

The heart of the invention lies in the provision of means for increasing or decreasing the diameter of a flow restrictor in the area of the forced vortex path so as accordingly to cause a shift in the transition point between the free and forced vortex paths.

No known cyclone teaches the changing of the transition point once the physical characteristics of a unit have been established.

The continuous removal of particles of objectionable shape or specific gravity utilizes the free vortex principle, admittedly, but this invention exploits the movement of some of those particles by effecting changes of the transition point between the forced and free vortex.

It is accordingly the primary object of the invention to provide an improved cyclone separator which operates in a more

effective manner accomplishing better separation and which is particularly well suited for use for cleaning wood pulp stock.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a longitudinal sectional view of the centrifugal separator in accordance with the invention; and

FIG. 2 is an enlarged fragmentary detailed sectional view of a portion of the centrifugal separator shown in FIG. 1.

DESCRIPTION OF THE PREFERRED EMBODIMENT

A hydrocyclone or centrifugal separator, generally indicated by numeral 10, includes a vertically disposed elongate body or housing 12 of hollow cylindrical configuration which is tangentially intersected at 13 by a stock inlet 14. The inlet may be of either circular or rectangular or square cross section and supplies the water suspension and solid impurities to the hydrocyclone in the direction of arrow a from a line (not shown) used for transporting the mixture from one operation to another in a processing program.

The top of body 12 is enclosed by a cap or cover 16.

Depending from and communicating with body 12 is an elongate truncated cone or vortex chamber 18 extending downwardly at a continuously reduced internal diameter to a point of truncation or apex opening 20, the point of minimum internal diameter of the cone.

Body 12 defines the base of cone 18, the interior configuration of the cone converging axially in one direction toward apex opening 20 and diverging axially in the opposite direction toward body 12.

The outlet diameter of body 12 (the base of the cone) is the same as the inlet diameter of cone 18 to present no restriction to downward flow into the vortex chamber.

Extending outwardly and axially and centrally of body 12 is an outlet or vortex finder or accept line 22 for removing the accepted fraction from the separator in the direction of arrow b and delivering same to a line (not shown) for transporting the separated liquid mixture to the next subsequent processing operation.

Vortex finder 22 has a lower extremity 24 extending interiorly of the body and communicating with the separator interior.

The stock suspension, a liquid mixture, containing desirable or accept fibers and nondesirable or reject particles, is charged under pressure through tangential inlet 14 and into cylindrical body 12 and input flow may be controlled, if desired, by a valve (not shown) in inlet 14.

The suspension immediately develops a circuitous motion or vortical whirl and spirals downwardly, following a rotary path of travel, indicated by c. The rotating liquid mixture is forced downwardly, by the subsequently incoming flow, into cone or vortex chamber 18, and is forced inwardly toward the axis thereof. This causes the angular velocity of the liquid mixture to increase, with an increasing centrifugal force being imparted to the fluid and its heavier components.

This downward flow is in what is termed a free vortex path in the area delineated by numeral 26.

During downward flow in this free vortex path, the heaviest particles are forced outwardly toward the cone wall by the centrifugal force, while the lighter particles are urged inwardly toward the vortex axis. The heavier particles are entrained and move downwardly in the outer portion of the path and the lighter particles are entrained and move downwardly in the inner portion thereof.

Dirt and like reject particles which can more easily pass through the high centrifugal force field continue downwardly to and through apex opening 20 in the direction of arrow d.

The fluid with accepted particles, on the other hand, follows its downward swirling movement through the free vortex path, eventually to be turned back upon itself and to move upwardly, in a rotary path of travel, as indicated by e, in what is termed the forced vortex path in the area delineated by numeral 28, which path circumscribes a central air column in the area delineated by numeral 30.

The transition zone or point between the free an forced vortex paths which defines the area of highest centrifugal force and shear force has heretofore varied in its location within a specific hydroclone in accordance with various combinations of factors, such as the diameters of the inlet and outlets, the cone diameter, and the like.

Within vortex finder 22, a vertically adjustable, centrally located air tube 40 is provided by means of which air within an air column 30 may be released to atmosphere from the hydroclone.

If desired, a vacuum means (not shown) could be connected to air tube 40 to aid in the removal of air from within the cyclone.

Air tube 40 is threadedly engaged with an upstanding bracket 42 fixed to vortex finder 22 wherefor the air tube may be adjusted vertically relative to the vortex finder as by means of a handwheel 44. While a manual means is shown, the handwheel could be replaced by a pneumatic means, if desired.

The location of air tube 40 with respect to the location of vortex finder 22 is adjustable so as to achieve the most desirable combination of relative positions.

A doughnutlike expandable diaphragm 46 is secured to the lower end of air tube 40 in a circumscribing manner and communicates with a valved air line 48 extendable into air tube 40 and provided with a valve 50 therealong.

As desired, diaphragm 46 may be expanded or contracted via air line 48 so as to extend transversely into the flow line of the accept fraction within vortex finder 24 in more or less degree respectively.

As shown in solid line in FIG. 2, when the diaphragm is least expanded, the flow path of the accept fraction through vortex finder 22 is maximized or least interrupted and the transition zone in such instance is represented by the dash lines 60.

As shown in dash lines, when the diaphragm is most expanded, the flow path of the accept fraction is minimized or most interrupted and the transition zone in such instance is represented by the dash lines 62.

The increasing of the diameter of the diaphragm in the area of flow directly surrounding the air core in the center of the accept flow will change the transition point between the force and free vortex within the hydrocyclone. By varying the diameter of the diaphragm, the centrifugal force can be increased or decreased without a significant change in the through-put. The change in location further changes the type of particle concentration which would be rejected at the cone apex.

For purposes of illustration, a typical cyclone may be considered as incorporating the following dimensions:

Inlet diameter—7 inches
Outlet diameter—inches
Maximum diameter—16 inches
Cone included angle—16°
Transition diameter—6 inches
Application of the standard centrifugal force formula:
$V_1R_1 = V_2R_2$
wherein V_1 = Inlet velocity at a given flow rate R = Radius at inlet zone
V_2 = Velocity at transition location
and R_2 = Radius at transition location
discloses upon interpolation:
$V_1R1 = V2R_2$
$V_1 = 15$ ft./sec.
$R_1 = 0.666$ ft.
$R_2 = 0.25$ ft.
15 ft./sec. ± 0.666 ft. $= 0.25$ ft. $\pm V_2$
$V_2 = 40$ ft./sec.
Centrifugal force, not considering friction loss, is according to the formula:

$$F = \frac{V^2}{gR}$$

wherein
F = Number of gravities

V = Velocity in ft./sec.
g = 32.2 ft./sec.
R = Radius in feet
wherefor

$$F = \frac{(40)^2}{32.2 \ x \ .25} = 198$$

By applying air pressure to expand the diaphragm surrounding the air column by 2 inches in diameter, the transition location would be moved from 6 inches to approximately 8 inches with the resulting centrifugal force:

15 ft./sec. $\pm .666$ ft. $= .333$ ft. $\pm V_2$

$V_2 = 30$ ft./sec.

$$V = \frac{V^2}{gR}$$

$$F = \frac{(30)^2}{32.2 \ x \ .333 \ ft} = 85$$

Due to this slight change in diaphragm setting, the centrifugal force could be changed from 198 to 85.

The shape and size of the reject particle is not completely affected upon centrifugal force for its separation from the accept fiber flow but upon the general location of the transition point.

The location or the vertical tube may be adjusted to the location of vortex finder location within the hydrocyclone to get the best desired effect. Further, air could be removed by having the adjustment tube hollow for removing this air by vacuum means.

This control could be utilized in many cyclones of varying sizes for fine adjustment of reject particles.

I claim:

1. An elongated cyclone separator for separating from a fluid containing acceptable fibers the foreign particles suspended therein and comprising:
   an inlet chamber adapted to receive the fluid charged tangentially thereinto,
   an elongate inverted conical vortex chamber communicating with the inlet chamber for receiving the fluid therefrom,
   a discharge means communicating with the lower end of the vortex chamber for discharging the impurities separated from the fluid,
   a vortex finder within the inlet chamber for removing the accepted fraction from the vortex chamber,
   diaphragm expanded and contracted force varying means disposed within the vortex finder transversely of the flow thereinto for varying the diameter of the flow path therethrough and shifting the transition zone between the free and forced vortex paths.

2. In a cyclone separator, the combination of, an inverted truncated cone separating chamber,
   a tangential inlet adjacent the top of the separating chamber for introducing a suspension thereto,
   a tubular vortex finder extending axially into the separating chamber from the top thereof,
   a reject fraction outlet at the opposite end of the separating chamber, and
   an expandible and contractable diaphragm means disposed transversely of the vortex finder for varying the flow path therethrough.

3. A cyclone separator for separating the impurities from a suspension of acceptable fibers comprising in combination a vessel having an elongated vertical axis and being of substantially circular cross section and having an upper inlet chamber for receiving the suspension charged under pressure tangentially thereinto and a lower inverted conical vortex chamber communicating with the inlet chamber for receiving the suspension therefrom and inducing a downward spiral flow in a free vortex path outwardly of a transition zone extending

generally parallel to the vertical axis of the vessel toward the lower end of the conical vortex chamber. A discharge opening for the discharge therethrough of the reject fraction of the suspension from the lower end of the conical vortex chamber, a vortex finder disposed concentrically of the inlet chamber and having an inlet end within and substantially coaxial with the vessel and having an opposite discharge end outwardly of the vessel for inducing a reversal of the downward flow of the accepted fraction of the suspension from the free vortex path

at the lower end of the conical vortex chamber to an inner forced vortex path inwardly of the transition zone and circumscribing a formed central air core, a contactable and expandible flow restrictor disposed within and transversely of the vortex finder for selectively extending into the forced vortex low path a variable degree and accordingly shifting the transition zone laterally of the vertical axis of the vessel.

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