

United States Patent

Hoffman

[15] 3,666,186

[45] May 30, 1972

[54] THIN FILM MILL

[72] Inventor: **Carroll B. Hoffman**, P.O. Box 987, Newburgh, N.Y. 12550

[22] Filed: **July 20, 1970**

[21] Appl. No.: **56,430**

[52] U.S. Cl. **241/45, 241/65, 241/163**

[51] Int. Cl. **B02c 7/06**

[58] Field of Search **241/43, 45, 65, 152, 155, 157, 241/161, 162, 163**

[56] References Cited

UNITED STATES PATENTS

24,082	5/1859	Sailer	241/163
812,122	2/1906	Fassett	241/163 X

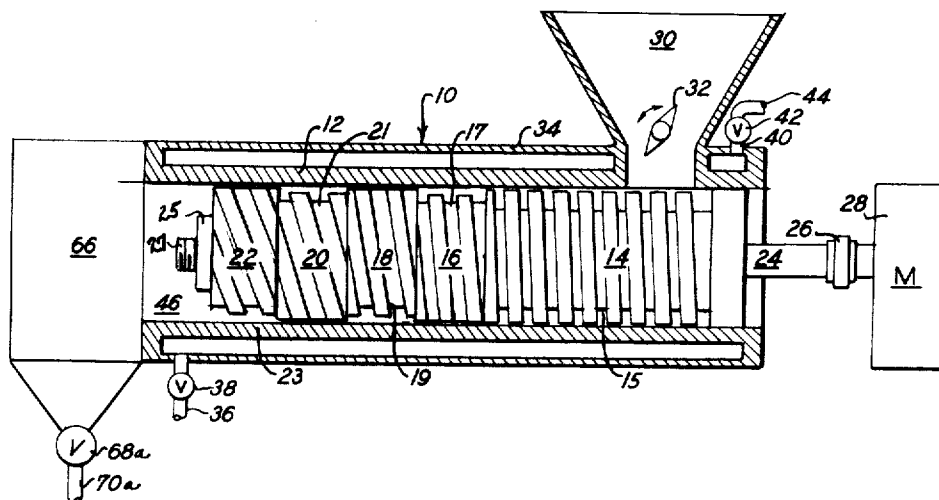
3,008,505 11/1961 Pavia 241/162 X

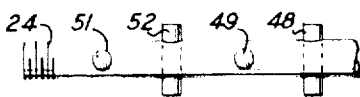
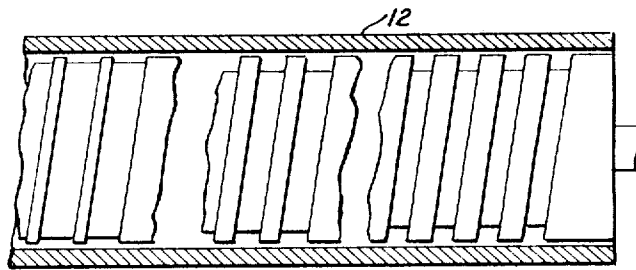
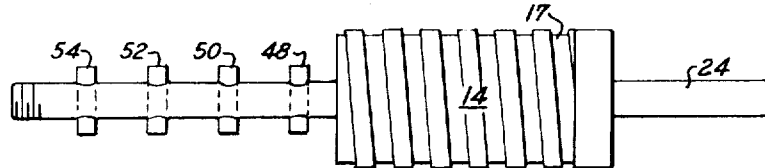
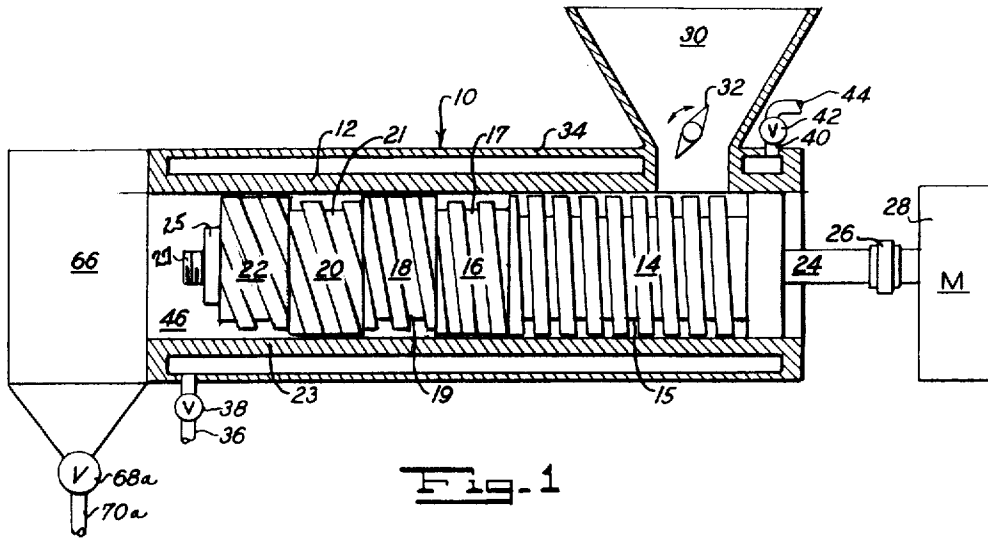
Primary Examiner—Granville Y. Custer, Jr.
Attorney—Sol B. Wiczer

[57] ABSTRACT

A thin film mill for simultaneous reduction in size as by separation of agglomerates of particle clusters and dispersion of the fine particles in a liquid carrier, constructed of a plurality of rotatable cylindrical sections arranged in a row, each section having a helical groove cut in its cylindrical surface, the grooves being variable in depth becoming shallower and wider with progressively increasing pitch from inlet to outlet, the sections being mounted for application eccentrically of radial pressure upon a thin film of the dispersion between each section and the walls of the confining casing.

21 Claims, 15 Drawing Figures





INVENTOR
CARROLL B. HOFFMAN
BY

Sol B. Wicker
ATTORNEY

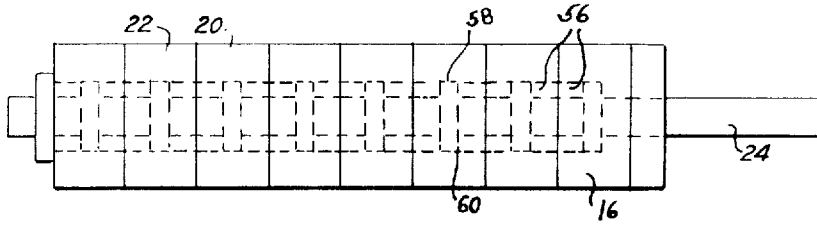


Fig. 9

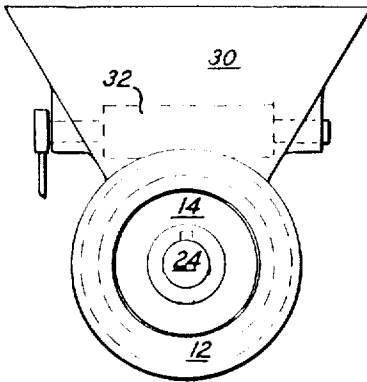


Fig. 6

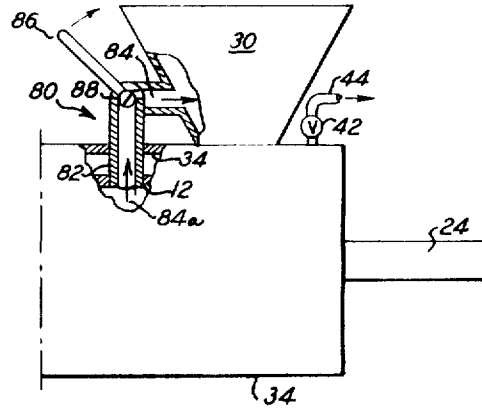


Fig. 5

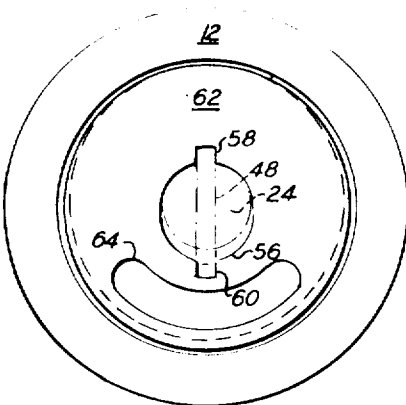


Fig. 8

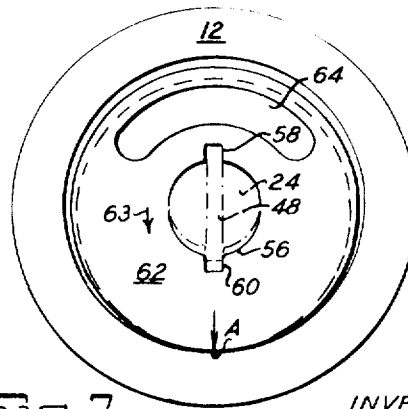
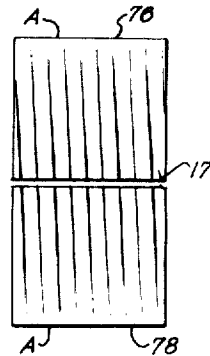
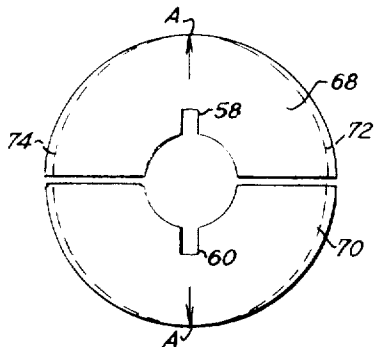
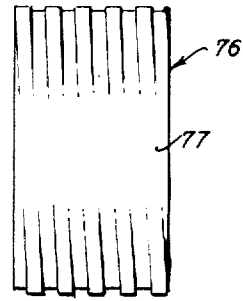
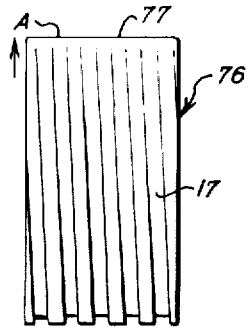


Fig. 7

INVENTOR
CARROLL B. HOFFMAN
BY

Sol B. Wiese
ATTORNEY



INVENTOR
CARROLL B. HOFFMAN
BY

Sol B. Wieg
ATTORNEY

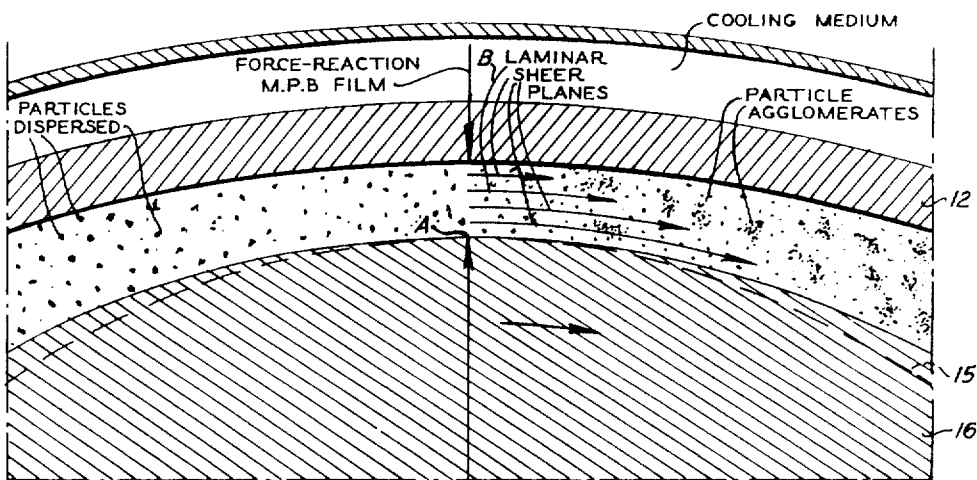


Fig. 14

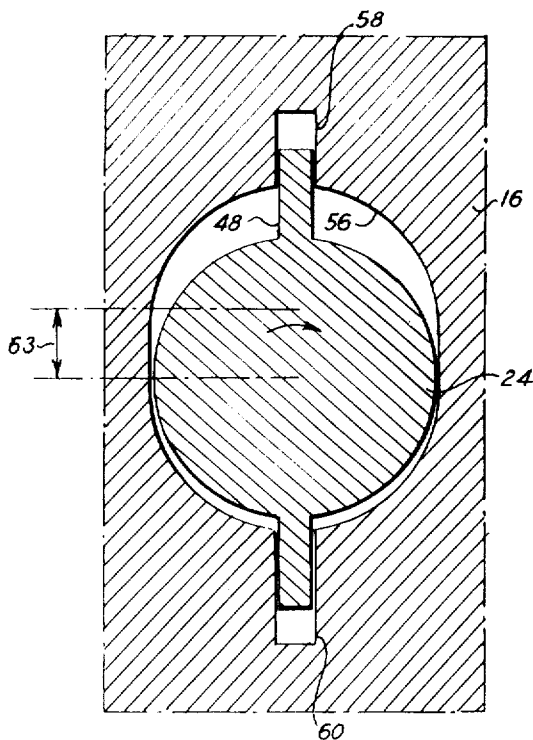


Fig. 15

INVENTOR
CARROLL B. HOFFMAN
BY

Sol B. Wicks
ATTORNEY

THIN FILM MILL

This invention relates to a thin film mill adapted for forming fine industrial dispersions of solids in liquids. More particularly, the mill of this invention is designed to treat a mixture of coarse agglomerated solids in a carrier fluid applying high pressure rubbing, smearing, and pressing forces thereto while progressively applying such forces to the fluid to form a thin film of the suspension of progressively thin dimensions in which the particles are dispersed. Moreover, the mill applies a rubbing, smearing force upon the suspension to produce a dispersion of the particles in the fluid as a film of progressively reduced thickness in which the dispersed fines are also progressively small. As the feed mixture passes through the mill from inlet to outlet, it is subjected to centrifugally developed radial pressures and transverse laminar shearing forces as it is propelled through spiral grooves dimensioned progressively in several rotatory sections to be increasingly shallow, the grooves being separated by lands of progressively increasing pitch, a structure by which an eccentric pressing and laminar shearing effect is applied upon the progressively thinned film of dispersed particles in progressive stages as the suspension passes through the mill.

The device is useful for forming industrial dispersions of solids in liquids including molten solids or liquified gases, variable in viscosity and at variable pressures and temperatures. Such dispersions may be of any selected character. They are usually high grade industrial products. Typically formable in the present mill are chemical coatings such as printing inks and paints; that is, pigment dispersions in a liquid carrier. Various solid additives including pigments may be finely comminuted and dispersed in the carrier fluid down to extremely fine as well as colloidal dimensions. Moreover, adhesive, resinous and/or polymeric solids often in the form of balled agglomerates of fine particles can be broken up, finely dispersed or dissolved in a liquid carrier or solvent.

Many commercial solid fines, even after crushing and/or grinding to desired particle size, tend to "ball-up" or agglomerate into large particles held together by electrical, magnetic or electro-mechanical forces. The device hereof is intended to break up such particles and disperse them in the liquid carrier in which they are being suspended in passing through the mill, by applying to their coarse suspension a shearing, rubbing and impacting force as explained in further detail below. It is to be understood that the sizes of the ultimately dispersed particles are a function of their original sizes as they occur in the agglomerated solids of the feed, and the mill hereof applies forces of the character needed to separate such agglomerates or clusters of fines into their ultimate particles. Such ultimate particles are not substantially further size reduced by application herein of a grinding effect, although some of that may be inherent in the mechanical forces applied in the present processing. Of course, where the particles are soluble in the liquid carrier, such size reduction is inherent in the dissolution of the particles in the liquid carrier. Consequently, the ultimate product hereof will vary as a homogeneous dispersion of fines in the liquid carrier in the ultimate particle size in which they are initially fed and then separated from the clusters in the feed.

While the dispersion is of solids in liquids, other soluble liquid or solid additives are sometimes added to the liquid carrier or coarse mixture of solids in the carrier liquid as fed to the mill for a specific function to modify the liquid and its physical effect during the processing in the present mill. For this purpose the liquid may have added such additives which will improve or reduce the viscosity, the viscosity index, thixotropy, adhesiveness, cohesiveness, wettability and dispersiveness by imparting a surface activity to the liquid carrier or to the solids being dispersed.

The carrier fluid can vary widely in viscosity but such may be controlled by controlling the temperature of the liquid as it passes to the mill or by controlling the temperature of the mill itself. Since substantial frictional heat may be developed in variation of speeds and shearing forces applied, the mill also

may be jacketed for the temperature control as needed, depending usually upon the particular dispersion being prepared.

Fundamentally there are several forces applied in effecting the present dispersion, all of these forces combining to produce an ultimately thin film of the dispersion whereby the particles suspended within the liquid film, by rubbing and impacting action, have been size reduced to ultimate fineness in the liquid carrier.

In preferred construction, some rotor sections may have the grooves eccentrically cut into the surface of the rotor, whereby material picked up in a groove is moved both axially as well as radially from a deep cut portion of the groove to a portion progressively shallow; that is, a point where the groove is substantially contiguous with the land, thus to form a point of maximum pressure where the suspension is pressed to a thin film between the rotor and the confining casing. Such rotor may be balanced about its center as mounted upon the driving shaft, but it is usually loosely keyed to allow some radial play to accommodate thin films variable in thickness with the pressure developed as the rotor rotates.

In a modified form, the rotor may be split into halves, each portion of which is keyed to the rotor shaft, but is free to move radially away from the other portion. The combined rotor portions preferably have formed on their axially aligned surfaces a continuous groove so that the split halves of each section may move radially toward and away from each other in response to radial pressures developed in the dispersion as it is moved both radially and axially as the rotor sections are rotated. The grooves cut into the rotor surfaces of such modification may be eccentrically disposed as described above with respect to its surface, the groove being deep at one point and progressively shallow at an opposite point; or a pair of oppositely disposed deep and shallow points may be cut into the rotor surface.

As a further feature of the mill, for ultimate size reduction and to provide radial impacting, as well as the shearing forces afforded by the lands of progressively increased pitch separated by broader and shallower grooves, each section is mounted eccentrically weighted to a central rotary shaft to which all sections are keyed for rotation therewith, whereby each section eccentrically and centrifugally presses the film suspension against the casing as it is formed, thus by impact further size reducing the particles as the dispersion is formed.

Other important features of this invention are inherent in the drawings of which the construction herein is illustrative and exemplified by the several figures wherein:

FIG. 1 shows an assembly of the mill in sectional elevation to show internal construction;

FIG. 2 is a detail of the first section of the rotor illustrating its mounting upon the driving shaft;

FIG. 3 shows an alternate method of pinning split sections shown in FIGS. 1, 2 and 3 to the shaft;

FIG. 4 illustrates a detail of the mounting of sections upon the rotor shaft;

FIG. 5 is a detail showing a modified inlet hopper to the mill;

FIG. 6 is an end view of the hopper and mill inlet of FIG. 5;

FIG. 7 illustrates a detail of one of the sections unbalanced to impart eccentricity during rotation;

FIG. 8 shows an oppositely weighted position of the same detail of FIG. 7 in stationary position;

FIG. 9 is an alternate disc type of rotor assembly;

FIG. 10 is an enlarged detail showing the grooves of a section disposed eccentrically;

FIG. 11 is a similar detail of the section of FIG. 10 in a position rotated about 90°;

FIG. 12 is a modified split disc type of section;

FIG. 13 is a side view of the section of FIG. 12;

FIG. 14 is a diagram illustrating the flow of forces in dispersion; and

FIG. 15 illustrated the eccentric displacement of a rotor disc and shaft.

Referring first to FIG. 1, the mill 10 comprises a tube 12 in which is fitted a series of rotors 14, 16, 18, 20 and 22. The rotors are keyed to a shaft 24 coupled by coupling member 26 to a motor 28 for rotary drive. The several rotors 14-22 are secured at the end of the shaft 24 by a nut 25 fastened in adjusted position by a thread 27 on the end of shaft 24.

A hopper 30 is provided at the right hand end for feed of a coarse suspension of solids in liquid; the rate of feed being controlled by a butterfly valve 32. For control of temperature of the fluid passing through the mill, or removal of heat frictionally developed, the tube 12 may be jacketed with an outer sleeve 34 into which a heating or cooling fluid may be passed by way of a duct 36 controlled by valve 38. After supplying or abstracting heat, the temperature controlling fluid is withdrawn by way of duct 40 controlled by a valve 42 and the fluid may be wasted or recycled after having its temperature adjusted by means (not shown) to duct 36.

In one embodiment, the several sections 14, 16, 18, 20 and 22 have spiral grooves 15, 17, 19, 21 and 23 cut into the surfaces thereof as shown in FIG. 1. The grooves of section 16 are eccentrically cut into the surface of the rotor such as shown in FIGS. 11-13 so that the grooves are integral with the surface, i.e., are even with the lands, at one point of the circumference and reach the greatest depth at another, usually opposite points of the rotor circumference. These grooves are preferably cut in such a manner that the first spiral grooves 15 are deeper, but the pitch of the grooves of section 16 is low, there being more deep cut lands per unit of linear space. In contrast, the next contiguous section rotor 18 has similar grooves 17 cut into the surface in a similar spiral but the grooves 17 cut into are shallower than the grooves 15 as well as being wider, but the lands adjacent the grooves are correspondingly narrower than those of section 14. Thus the grooves 17 despite the shallower but wider dimension will contain about the same amount of total fluid, suspension of solids in liquid, as can be accommodated in passing through the grooves 15 of the first rotor section 14. Moreover, the pitch of the spiral lands and grooves of section 16 is slightly increased from that of 14 as to increase the velocity of the passing fluid so that by dimensioning of the spiral grooves and lands and adjusting the pitch the lands and grooves are proportioned so that the rotating of the rotor section 16 together with rotor 14 passes about the same amount of suspending liquid through both sections. Progressively in section 18, the grooves again are still wider and shallower, the lands are narrower and the pitch of the lands is steeper, whereby the next succeeding section 18, despite these modified dimensions, still accommodates the same suspension flow through the section as it is rotated.

The same effect dimensionally is applied to sections 20 and 22; that is, the grooves 21 and 23 are progressively shallower and the lands progressively narrower while the pitch is progressively steeper so that progressing from rotor section 14 through section 22, the dispersion of solids in liquid is handled and spirally moved axially of the tube 12 at substantially the same rate from section to section. Hence, although each section has progressively shallower grooves from inlet to outlet, nevertheless each will accommodate by increased pitch and wider but shallower grooves the same amount of fluid. In this manner the fluid flows progressively and is squeezed from the inlet hopper 30 to an outlet section 46 in a spiral groove of increasing pitch and width but decreasing depth of the groove.

As shown for instance in FIGS. 11 through 13, the groove 17 is cut eccentrically in the surface of rotor elements 16 through 22 so that each relatively flat portion 77 of a rotor has both the grooves and the lands meeting in the same continuous surface herein referred to as point A. In the modification of FIGS. 12 and 13, there are two oppositely disposed points A. During rotation of the sections the liquid suspension contained in the grooves becomes eccentrically compressed from the deep portion of the groove to a shallow portion at a point A into a thin film between the flat surface of rotor 77 and wall of confining tube 12. That point A, as the rotor rotates within

the casing 12, is displaced angularly in a 360° circle to a thin film continuously as the rotor rotates, so that the thin film portion progressively extends all around the annular surface of the casing and simultaneously becomes displaced axially, passing from section to section, by the helical thrust of the helically cut grooves whereby the fine dispersion of thin film is displaced and moved section to section from inlet to outlet.

It will also be apparent that as the grooves become shallower from section to section, the liquid suspension becomes squeezed to a greater degree against the combining walls of the tube 12 into thinner and thinner films by dimensioning of the grooves. The last outlet section 22 has an extremely steeply pitched land 29.

The sections 16, 18, 20 and 22 are bored not merely to receive the rotor shaft 24 in sliding fit, as shown in FIGS. 7, 8, 9 and 12, but the bore is eccentric in opposite diametric directions shown in the dotted line positions of the section bores around the shaft, so that there is room for substantial radial play of each section with respect to the shaft 24 as indicated in FIGS. 7, 8 and 9 at 56. Each of the sections 16, 18, 20 and 22, moreover, may be slotted with keyways 58 and 60 disposed on opposite diametric sides. The shaft 24 is also bored and fitted with pins 48, 50, 52 and 54 upon which the eccentrically bored rotors may slide radially in keyways 58 and 60. The rotors held at opposite ends in keyways 58 and 60 may slide diametrically radially within their bores about the shaft 24, responsive to the stresses between the shaft 24 of the sections 16, 18, 20 and 22. The first section 14 is normally fixed tightly on shaft 24 and is bored concentrically for rotation without any radial motion.

In modification shown in FIG. 9, the concentrically mounted first section 14 is replaced with one or more sections which are eccentrically formed and grooved like sections 16 through 22.

As pointed out, the pitch will vary progressively from section to section increasingly, and the lands become progressively narrow while the grooves are made correspondingly wider and shallower, whereby each section will have moved the same absolute quantity of suspension from beginning to end of the mill. The volume here considered is the flow volume at the rate at which the mill is operating, and not the static volume of any particular section at rest. In such terms the volume passing through each section is equal but only when measured in terms of the rate at which it passes through each section. That is, it is the flow rate, the velocity per unit of length, that increases as the film thickness is progressively reduced.

It should be noted as shown in FIGS. 10 through 13 that various types of grooved rotors incorporating eccentricity will be useful. Thus, while the pattern may be of ultimate simplicity, as shown in these figures merely to illustrate the principle, other configurations such as even a distorted herringbone configuration may be substituted and will operate under the same principles.

The grooving, most importantly, will increase in pitch toward the outlet and can be a maximum at the end rotor 22. As a matter of fact, there may be several grooves of a differing pitch super-imposed at point A. These additional superimposed grooves will be of a greater pitch which may even approach a line parallel with the shaft. With such a groove combination the axial velocity is extremely high and the so-called smooth portions of the rotor, the eccentric wide grooves at their lowest depth, become merely a series of spaced points of any selected design which will move the suspension axially at maximum velocity, and will apply maximum reduction of film thickness. Since the shear forces developed within the suspension intensify as the film is reduced, these forces will also result in maximum shear action.

Sections 16, 18, 20 and 22 may each be formed of substantially solid webbing (central) material 62 into which the outer grooves 17, 19, 21 and 23 are spirally eccentrically cut into their surfaces, but the central portion of sections 16, 18, 20 and 22 may, and preferably have, a cutaway slot 64 as shown in FIGS. 7 and 8, which tends to unbalance the total section as

it is rotated by shaft 24, so that as the shaft rotates each section, the section will press radially against the surface 12 sliding diametrically upon each pin from one side of the eccentric clearance about shaft 24 to an opposite side, there being sufficient clearance between the shaft 24 and bore 56 of a section to accommodate that diametrical movement with respect to the shaft 24.

Thus, as shown in FIGS. 7 and 8, as the shaft 24 rotates the sections, the slotted cutaway portion 64 creates a weight imbalance of the section about the axis of shaft 24 which causes the sections to press radially in the direction of the arrows 63 and within the space between the diameter of the shaft 24 and the bore 56 of the section. This causes a radial compression of the fluid suspension of particles in the grooves against the inner wall of the tube 12 as the sections move from a dotted line to a full line circumferential position within the confining tube 12.

The forces developed are shown in FIGS. 14 and 15. A rotor section designated as 14, 16, 18, 20 and 22 as shown exaggeratedly in FIG. 15, is eccentrically bored at the surface 56 and the key 48 can slide vertically in opposite keyways 58 and 60; also shown in FIGS. 7 and 8. The arrow 63 in FIG. 7 illustrates the direction of maximum centrifugal force of the section against the inner tubular casing wall 12. The feed comprises agglomerates of small particles shown as clusters to the right hand of FIG. 14 which pass through the thinnest film point A, the point of maximum pressure. Thus as the rotor moves in the direction of the arrow, it leaves behind it dispersed particles as individual particles, broken up agglomerates or clusters, as the portion where the disc has passed and the film has increased in dimension and approaches new feed comprising clusters of particles in the carrier fluid. The forces are both the pressure developed by centrifugal forces developed by the rotor free to move radially from the shaft 24 as well as to develop laminar shearing forces, marked B, which are forces developed by the internal friction in the fluid being squeezed and smeared at the point A between the rotor and the tube.

There is, of course, a force factor developed by the groove pattern, its depth and pitch, a force related to the physical properties of the fluid passing through the mill. There is also a force relative to the speed of the rotor which, in fact, is an exponential force related to the speed. It will be recognized that the laminar shearing force is directly related to the thickness of the film and will become greater as the film becomes thinner.

These forces are widely variable with the particular characteristics of the fluid to transmit the force energy within its own mass variable with the viscosity and, in turn, the temperature at which the device is controlled to operate. Each of these forces are controlled to a degree by the device that is to control the speed of rotation, to control the maximum and minimum clearance between the tube wall and the rotor and the pitch of the helical groove which, in turn, controls the rate of the axial movement of dispersion through the mill.

A considerable amount of heat is developed frictionally within tube 12 which may be desirably removed or controlled by emplacing a jacket 34 about the tube wall 12, and a cooling fluid may be circulated through the jacket, entering through tube 36 as controlled by valve 38 leaving by tube 40 as controlled by valve 42 with possible circulation from tube 44 after modifying the temperature by intermediate heating or cooling devices (not shown). Alternately that jacket can be used to heat the suspension by suitable temperature control of the fluid passed through the jacket 34.

The suspension may be of very light or heavy liquids as desired, such as a heavy fixed fatty or petroleum oil or unguentuous solid such as petrolatum, or liquid polymer such as polybutene, or it may be a drying oil or the like. On the other hand the suspending liquid may be very volatile, in fact, it may be a liquified gas and, for that purpose, the suspension passing into section 46 at the end of the dispersing spiral may then pass into a protective housing 66 having an outlet controlled

by a valve or a starwheel 68a for discharge under pressure to containers (not shown) constructed to handle the liquified solvent under pressure conditions by way of duct 70a. Obviously, where pressurized fluids are used, ducting will be supplied to handle and store the dispersion under pressure. The particles can either be soluble or insoluble in the liquid. Thus the particles can be suspended in a liquid of any character, even such as are normally gaseous or a molten solid, but which have been liquified for purposes of providing a fluid for carrying the present dispersion, the temperature of the jacket being controlled by the heat exchange fluid in jacket 34 as needed.

As shown in FIG. 12, the section itself may be divided into portions 68 and 70, and the two half sections are used together confined by the tube 12. Moreover, the half sections may be spirally grooved in fixed eccentric portions as shown by the dotted lines 72 and 74 at diametric opposite sides as shown in FIGS. 12 and 13. Alternately, only one eccentric portion may be grooved at one end 77 as shown in FIGS. 10 and 11. These sections 76 and 78 apply both a spiral squeezing and smearing as well as pressing effect against the wall 12. In that action the pressing effect is obtained by eccentric radial movement of the section through the opposite pin slots 58 and 60 which give greater or less diametric movement tolerance. The opposite quadrants 72 and 74 have grooves cut therein in a continuous spiral, discontinuing in the regions 76 and 78, but whose overall effect by rotation of the total section is to spirally move the dispersion axially of the shaft 24 as the section is turned.

In the arrangement shown in FIGS. 10 and 11, only one quadrant portion 77 has a smooth wall. The spiral grooves are cut progressively around the section, extending the entire three-quarter quadrant portion and then the grooves disappear as they enter the smooth wall fourth-quarter portion 77. The net effect, as stated, is to evenly move the dispersion radially as well as axially of the section as it is rotated while pressing and shearing the dispersion as a thin film on the wall 12.

In operation, the coarse suspension of solids in liquid may be placed in the hopper 30 for feed to the dispersing device entering the first section 14 as shown in FIG. 1, at a rate controlled by the position of the butterfly valve 32. However, the rate of passage of the suspension through the mill is in part governed by the rate at which the particles are dispersed and to the degree of fineness to which the mill is dimensioned in its several sections.

If the dimensioning of succeeding sections with its increased pitch and shallower grooves cannot accommodate the flow of the suspension in the degree of coarseness to which it is delivered by section 14, it is useful to have a recycling means 80 as shown in FIG. 5 comprising a return tube 82 mounted vertically passing through the wall 12 so that at the speed of rotation of the groove 15 some of the suspension material passes through to section 16 and some can recycle in the direction of the arrow 84a through tube 82. That tube 82 connects with a duct 84 in turn recycling the coarse suspension back to the hopper 30. That recycle may be great or less, depending upon the positioning of hand lever 86 controlling a plug valve 88, whereby a larger or smaller quantity may be allowed to recycle from the section 14 back to the hopper.

Section 14 is the inlet initial dispersing section having the effect not only of breaking up the feed particles sized to accommodate the grooves 15, but also of correlating its size dispersion with that of the next succeeding section as various feeds to the section 14 may be accepted at different rates depending upon the coarseness, grindability of dispersability of the solids in the liquid which also is subject to some variation by the speed of rotation of the sections and the pitch of the groove of each accepting the suspension.

Initially the recycle valve 88 may be operating wide open with almost complete recycle as the dispersion operation is initiated and it may be gradually closed as the dispersion becomes satisfactorily effected in the operation of the device as the flow is established through the series of sections.

As shown in FIG. 2, the rotor 14 may have the grooves and lands equally spaced and of equal depth. The first section 14 for balance is concentrically firmly mounted for rotation upon the shaft 24. Subsequent sections held by pins 48, 50, 52 and 54, however, may have a variable pitch and the grooves may be progressively shallow. Moreover, as shown in FIGS. 11 through 13 the grooves may be eccentrically cut into the surface of one or more of the sections and such section may be unbalanced and centrally bored eccentrically to allow radial play about the shaft 24 for imparting great pressure against the inner tubular wall as the section is rotated.

In alternate construction, the rotors may be split as shown in FIGS. 12 and 13, each portion of which is mounted on a pin set at right angles as shown in FIG. 3 about the shaft 24 whereby each section can move radially 90° out of phase with the adjacent section. As further shown in FIG. 4, the first section 12 may be a single elongated rotor but the helical groove cut in its surface may vary in pitch and depth, being deep at an inlet end portion, somewhat more shallow after a few flights of the helical groove at an intermediate portion, and becoming relatively shallow toward the end portion. While the rotor adjacent the inlet end is preferably mounted firmly and concentrically upon the shaft 24, the rotor at the end need not be, but may be eccentrically disposed thereabout and optionally may even have quite steep flights which operate for rapid expulsion of the thin film near the end of that rotary section.

As thus described, a series of substantially cylindrical sections having spiral grooves cut into each periphery are each mounted about a shaft for rotation, and having a series of spiral grooves of varying pitches from section to section for increasing the speed at flow of a dispersion as particles are dispersed in a finer and finer state in a thinner and thinner film. Moreover, some of the sections are unbalanced to increase the pressure upon the progressively thin films of dispersed particles. As the material comprising solids suspended in liquids flows from section to section, it is subject to several forces having a smearing and pressing effect on the suspension while being continuously urged axially by grooves in the surfaces of each section. It is pressed radially against the dispersing surface of the combining wall 12 for progressively dispersing into finer and finer particles in the suspension by progressive decrease in the depth of the spiral grooves. Moreover, it is pressed eccentrically by diametric radial movement of some sections mounted upon the rotor shaft, tending to mechanically disperse the particles into progressively finer sizes.

The net result is the production of a very fine dispersion such as pigments, plastic particles or even polishing powders, suspending liquids such as paints, plastic liquids, polishes, clay suspensions, etc., wherein the liquids can be of any viscosity ranging from liquified gases or solvents of very low viscosity up through heavy oils, waxes and polymers including tars or molten solids. The temperature is controlled not only to melt or reduce the viscosity of the heavy suspending liquids for improving the dispersibility of the solids therein, but also to remove excessive frictional heat as may be developed in the treatment.

Consequently, various modifications may occur to those skilled in the art. Accordingly, it is intended that the description hereinabove be regarded as exemplary and not limiting, the scope of the invention being that defined in the claims appended hereto.

What is claimed is:

1. A mill for dispersing particles in a fluid carrier medium comprising a tubular casing, an inlet section for feeding a coarse mixture of particles and carrier fluid to an inlet end of said tubular casing and an outlet for withdrawing a fine dispersion of said particles in said carrier fluid from said tubular casing, several cylindrical rotary elements lying within said tubular casing and disposed from inlet to outlet, means for rotating said rotary elements, said rotary elements having helical grooves in their surfaces providing a helical passageway for conveying said particles and fluid carrier through said casing,

and progressively radially pressing and rubbing said fluid carrier and particles therein against said tubular casing to deform the same into thin films about said casing in passage therethrough by rotation of said rotary elements in said casing whereby to disperse the particles in said carrier fluid.

2. The mill as defined in claim 1 wherein said rotary elements comprise a plurality of cylindrical sections disposed in a cylindrical row between inlet to outlet ends of said tubular casing, each section having a helical groove cut into the surface thereof, the helical groove adjacent the inlet being deeper and of lower pitch than subsequent grooves, at least a second section having a helical groove shallower with respect to the groove near the inlet and having a greater pitch.

3. The mill as defined in claim 2 wherein the helical grooves of each section are progressively wider and shallower from inlet to outlet in each succeeding section.

4. The mill as defined in claim 1 wherein said rotary elements comprise a plurality of cylindrical sections disposed in a cylindrical row from inlet to outlet ends of said tubular casing, each section having a helical groove cut into the surface thereof, the helical groove of at least one section being eccentrically cut into the cylindrical surface thereof, whereby the depth of the groove at one surface point of said section varies progressively from the depth of the groove at another angularly separated point of said section.

5. The mill as defined in claim 4 wherein the eccentrically cut groove is deep at one surface point and progressively shallow in depth to an oppositely positioned point on the annular surface of said section, the shallowest groove lying substantially in the uncut surface of said section.

6. The mill as defined in claim 4 wherein the eccentrically cut groove is of equal depth at a plurality of at least two equiangularly disposed points on the surface of said section, said groove becoming progressively shallow from the said deep points of said groove to equiangularly disposed shallow points intermediate said deep groove points, the shallowest points of said groove lying substantially in the uncut surface of said section.

7. The mill as defined in claim 1 wherein each rotary element is connected to a central shaft for rotary drive of all sections, said shaft in turn being connected to said driving means for rotation of said sections, at least one of said sections being eccentrically bored to fit loosely about said shaft and being free to move eccentrically radially while being rotated by said shaft to apply radial pressure upon said particles in said fluid in eccentric radial play of said section as it rotates against said tubular means during rotation.

8. The mill as defined in claim 1 wherein at least one section, free for eccentric radial movement, has a portion of its body cut away to impart a radial weight imbalance, whereby upon rotation said imbalance accelerates radial movement and pressure against said casing during rotation of said shaft and section.

9. The mill as defined in claim 1 wherein at least one of said helical grooves in a rotary section is eccentrically disposed in the surface of its section whereby the groove at one portion of said section is substantially deeper than the groove at another portion of said section, said sections being fastened to a central shaft for rotary drive of all sections, said shaft in turn being connected to said driving means for rotation of said section, at least the said section with an eccentrically disposed groove being eccentrically bored to fit loosely about said central shaft to allow radial movement in the largest diameter of its eccentric bore between the shallowest and deepest groove portions, whereby to allow a film of said dispersion in minimum thickness to be formed by pressure between the shallowest portion of said groove and the tube wall to be formed annularly about said tube wall as said section is rotated.

10. The mill as defined in claim 9 wherein the eccentrically cut groove is deep at one point and progressively shallow to a diametrically opposite point on the uncut surface of said section.

11. The mill as defined in claim 9 wherein the eccentrically cut groove is deep at at least two equiangularly disposed points on the surface of said section and become shallow progressively to equiangularly disposed points intermediate said deep points, the shallow depth being uncut surface points in said sections.

12. The mill as defined in claim 9 wherein at least one of the sections has a helical groove cut eccentrically in its surface from end to end thereof, whereby upon two opposite sides of the cylindrical walls thereof the grooves are deep grooves varying progressively and becoming shallower in eccentric depth to another two opposite points in cylindrical walls of said section.

13. The mill as defined in claim 9 wherein at least one of said sections has a cutaway portion imparting radial imbalance, causing said unbalanced section to move eccentrically radially applying radial pressure against said casing during rotation of said shaft and section thereof.

14. A mill as defined in claim 1 wherein the first section adjacent the inlet is fixed concentric for rotation by said shaft and at least one of the next succeeding sections is eccentrically bored about said shaft and mounted free to move eccentrically radially with respect to said shaft, said section being unbalanced in weight about said shaft whereby to move radially with respect to said shaft and apply radial pressure upon said particles in said fluid by eccentric radial movement of each section against said tubular means during rotation.

15. The device as defined in claim 1 wherein the means for feeding coarse particles suspended in a carrier fluid comprises a hopper mounted above a first cylindrical section having a deep spiral groove therein extending from end to end of said section, and a valved duct connecting the surface of said cylindrical section with said hopper for return flow of a portion of the suspension to said hopper, whereby to regulate the rate of feed of said suspended particles in said fluid to said mill section.

16. The device as defined in claim 1 wherein the tubular casing has a temperature controlling jacket mounted thereabout and means for passing fluid through said jacket for temperature control of the suspension in said fluid during milling.

17. The device as defined in claim 1 wherein the outlet of said tubular casing is integrally connected to an outlet housing, a duct leading from said outlet housing having valve

means providing control of the outlet flow of the dispersion of solids in the fluid carrier accumulated in said outlet housing from said mill.

18. The device as defined in claim 1 wherein at least one of said rotor elements is split into equal halves and retained about the said drive shaft by the tubular walls of said casing whereby upon rotary drive of the split rotor element each half tends to press the fluid suspension radially in a thin film against the confining tubular wall of the casing.

19. The device as defined in claim 18 wherein a continuous helical groove is cut about the assembled split halves of the cylindrical rotor, said groove being cut eccentrically in the surface to be substantially deeper at one surface portion of the rotor and becoming progressively shallow toward another surface point of the rotor.

20. The mill as defined in claim 1 wherein the first rotor element adjacent the inlet is fixed for concentric rotation to said shaft, and having a concentric helical groove cut in the surface thereof, said groove being narrower and deeper at a portion of said section near the inlet and becoming progressively wider and shallower near the outlet end of said rotor element.

21. A mill for dispersing particles in a fluid carrier medium comprising a tubular casing, an inlet section for feeding a coarse mixture of particles and a carrier fluid to an inlet end of said tubular casing and an outlet for withdrawing a fine dispersion of said particles in said carrier fluid from said tubular casing, several cylindrical rotary elements lying within said tubular casing, a shaft mounted centrally through said rotary elements for rotary drive of each, the rotary element near the inlet being concentrically mounted for rotation by said shaft and having a concentric groove cut helically in the surface thereof for movement of suspended particles in fluid axially along the rotor surface and in radial compression against the wall of the tubular casing, a subsequently mounted rotor element having a helical groove cut eccentrically in its surface to be deeper at one surface point and becoming progressively shallow at an opposite surface point of said rotor element, at least one of the subsequently mounted helical grooved rotors being eccentrically mounted to said shaft and having means to impart a radial imbalance to said rotor element whereby to radially press the suspension of particles in fluid against said tubular wall in a thin film against the wall of said casing as said rotors are rotated.

* * * * *

45

50

55

60

65

70

75