Aug. 27, 1940. D. E. HENNESSY 2,212,662

DISPERSING MILL

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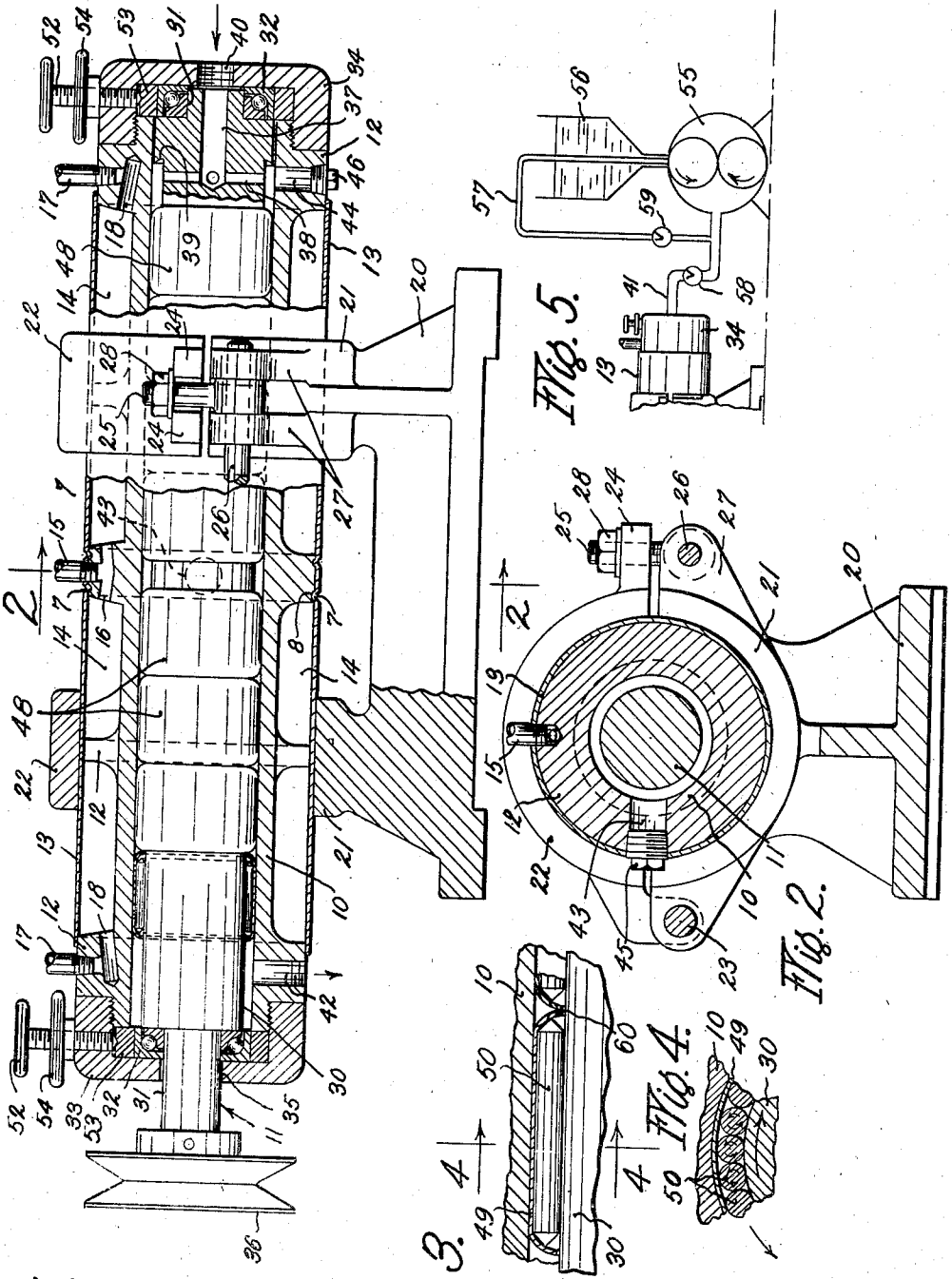


Fig. 1.

Fig. 5.

Fig. 2.

Fig. 3.

Fig. 4.

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FIG. 6.

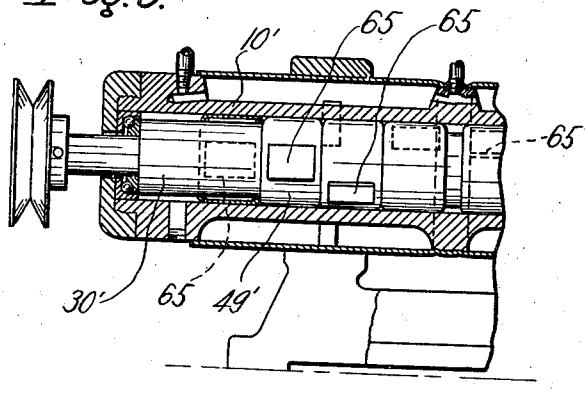


FIG. 7.

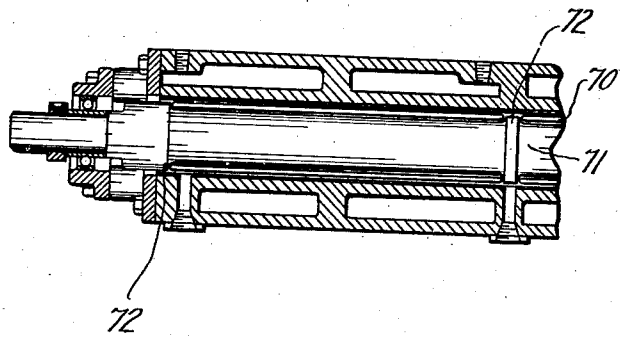


FIG. 8.

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DISPERSING MILL

Daniel E. Hennessy, Leominster, Mass.

Application January 10, 1939, Serial No. 250,199

5 Claims. (Cl. 83—93)

This invention relates to apparatus for making dispersions, more particularly colloidal dispersions.

A general object of my invention is to materially increase the output of mills of this character and to improve the quality of the product. A more specific object is to provide mechanism by which the material to be dispersed, which is generally in an agglomerated condition, may be reduced to a much smaller particle size than is possible by the apparatus heretofore employed for the purpose, and by which at the same time greater uniformity in the size of the particles secured throughout the dispersion. A further object is to increase the amount of any given material that can be dispersed in a given quantity of liquid.

The present application is a continuation in part of my prior applications Serial No. 133,246, filed March 26, 1937, and Serial No. 165,030, filed September 22, 1937.

Other and further objects residing in the details of the apparatus will be made apparent in the following specification and claims.

In the accompanying drawings, which illustrate one embodiment of my invention:

Fig. 1 is a side elevational view, partly in section, of a dispersion mill constructed in accordance with my invention;

Fig. 2 is a transverse section substantially on line 2—2 of Fig. 1;

Fig. 3 is a detail view, on a larger scale, of a part of one of the dispersing elements as it appears at the left hand portion of Fig. 1;

Fig. 4 is a sectional view on line 4—4 of Fig. 3;

Fig. 5 is a diagrammatic view on a smaller scale of one preferred manner of feeding material to the mill;

Fig. 6 is a detail, similar to a portion of Fig. 1, of a type of mill in which a different method of subjecting the dispersing rollers to a laterally unbalanced pressure is employed;

Fig. 7 is a detail similar to Fig. 6 showing a different type of dispersing unit; and

Fig. 8 is a graph showing the effect of using different ratios of shaft size to roller size.

Referring to the drawings, 10 designates a hollow cylindrical member in which rotates a shaft 11. Member 10 is provided on its outer surface with flanges 12 which support an outer shell 13 forming chambers 14 through which a cooling or heating liquid such as water may be circulated. The flanges 12 are provided with grooves 8 into which the metal of the shell is spun as at 7 to hold the shell in fluid-tight relation on the cylinder. As shown, water is supplied through a pipe 15 connecting with a passage 16 formed in the central flange 12 and is discharged through pipes 17 connecting with passages 18 formed in the end flanges. It will be understood that the flanges intermediate the central and end flanges are notched or perforated to provide suitable openings permitting a free flow of water through the water jacket formed by the chambers 14.

The water jacketed cylinder is supported on a base 20, provided with spaced semi-cylindrical seats 21 in which the cylinder is held by semi-cylindrical members 22 hinged at 23 to the seats. The free end of members 22 are provided with spaced lugs 24 to receive a clamping bolt 25 hinged on a rod 26 extending through lugs 27 on the seats 21. Nuts 28 threaded on the bolts 25 are adapted to tightly clamp the cylinder between seats 21 and members 22.

The portion 30 of the shaft 11 within cylinder 10 is preferably hardened and has a diameter sufficiently less than the interior diameter of the cylinder to permit a plurality of novel dispersing units to be interposed between the shaft and cylinder as later described. The ends of the shaft are reduced as at 31 to receive thrust bearings 32 which are held in position by cap members 33 and 34 threaded on the ends of the cylinder. Cap member 33 is apertured at 35 to permit the reduced portion of the shaft to extend through the cap, and the extending portion of the shaft is provided with means such as a pulley 36 for driving the shaft.

The end of shaft 11 adjacent cap 34 is provided with an axal bore 37 which intersects radial bores 38 communicating with the space between the shaft and cylinder wall. Cap 34 is provided with a tapped opening 40 to which a supply pipe 41 (see Fig. 5) may be connected.

A discharge opening 42, tapped to receive a suitable discharge pipe not shown, is formed in the cylinder 10 adjacent the end remote from the opening 40. Preferably an alternative supply opening 43 is provided intermediate the ends of cylinder 10 to permit use of only half of the mill if desired, in which case a second delivery opening 44 is also provided in the opposite end of the cylinder, so that the material entering at 43 divides and after passing through half of the mill is discharged through openings 42 and 44. Openings 43 and 44 are plugged as indicated at 45 and 46 when not used. When supply opening 43 is used opening 40 will of course be plugged.

A plurality of dispersing units 48 are positioned between the enlarged portion 30 of the shaft and the cylinder. As shown, eight units are employed and arranged in two groups of four each positioned at each side of the alternative supply opening 43. Sufficient space is left at the ends of the shaft adjacent the entrance and discharge openings to accommodate the entrance of the materials and discharge of the dispersion.

As best shown in Figs. 3 and 4, each dispersing unit comprises a race 49 and a plurality of

roller or needle bearings 50 which roll in engagement with each other and with the surfaces of the shaft and race as the shaft rotates. The surfaces of the shaft and the inner wall of the cylinder are ground so that the races fit tightly in the cylinder, and the only path for the material from one end of the cylinder to the other is then between and around the rollers. While spacing devices may be used if desired to keep the bearings in position, I have found that the friction of the races 49 on the inner wall of the cylinder is sufficient for this purpose. Preferably these roller bearings, which act as dispersing units, are constructed on the same principle as the needle bearings now standard in many types of machines, but function in a different manner. One advantage of using standard needle bearings is that the dispersing units can be replaced quickly and cheaply in case they wear out, the shaft 10 being preferably harder than the rollers to confine the wear to the latter. An even more important reason for their use is the novel manner of their action in breaking up the agglomerations of particles and wetting each particle separately so as to cause its flotation in the liquid vehicle. While at present the knowledge of the improved action of this dispersion mill is empirical and the theory of its action has not fully been investigated, I will give below my present understanding of the manner in which the mill operates without in any way limiting myself to the correctness of this theory.

With ordinary roller mills the action is that of crushing under rolling pressure combined with a constant mixing of the solid and liquid phases due to the turbulence introduced into the liquid vehicle by the action of the mill. In a ball mill the crushing is supplemented to some extent by attrition occurring between the balls, this occurring, however, without any assurance that the particles will all be thus acted upon in a uniform manner. Other types of colloid mill have been based upon what is known as a hydraulic shearing action, the mixture being passed between two surfaces mounted very close together and rotating at high speed relative to each other.

In the operation of the present invention the rollers 50 are mounted so close together as to be practically in contact. No separators are used as in the ordinary roller bearings. The rollers are long in relation to their diameter, and their diameter is small in relation to that of the shaft on which they are mounted. Due to their small diameter the rollers cannot be positively driven, and it is a well known characteristic of this form of bearing that the rolls may not always rotate. See for example the description in the Patent to Gotz No. 1,717,204, June 11, 1929. As is there stated, the tendency is for the rollers to act as a single rigid shell which may slip against either the inner or the outer confining surface or both, but in which no rotation of the rolls on their individual axes occurs. It is apparent that if this condition were allowed to prevail the bearings would have no rolling action on the agglomerated particles.

The theory of action outlined above appears to be borne out in the use of my improved mill, for if the driving shaft is driven at a moderate speed and the biasing pressure hereinafter described is not used, no progression of the roller units can be detected and good grinds at a satisfactory rate of material flow cannot be obtained. I have determined that the quality of the grind is improved if the rollers are forced to rotate and progress circumferentially in the housing by creating the overloaded condition referred to in the Gotz patent. This has been done experimentally by driving the shaft at a high rate of speed, this presumably causing enough tendency towards gyration on the part of the shaft to load the bearing units to such a degree that the rollers rotate on their axes and progress circumferentially in the housing. This high speed operation, however, requires excessive power consumption and develops excessive heat in the grinding operation. When a biasing pressure or transverse pre-loading force is applied to the shaft to impart a sufficient load to the bearing so that the rollers rotate individually and progress circumferentially, the power consumption decreases, the output increases, and a better dispersing action results. As one example, a mill constructed in accordance with the present invention but without biasing pressure on the shaft was operated at low speed (200 to 1200 R. P. M.). Only a rough grinding action was obtained. The speed was then increased to 3600 R. P. M. with a power consumption of 6 H. P. and a temperature in the grind, even with water cooling, of 148° F. The quality of the grind was greatly improved but the rate of material flow still had to be kept low. A biasing pressure sufficient to cause rotation and progression of the rollers was then applied to the shaft and the shaft driven at 1160 R. P. M. Power consumption dropped to approximately ½ H. P., the temperature dropped to 87° F., and the output increased.

To assure such rolling progression of the needle bearings I provide hand screws 52 threaded through the cap members 33 and 34 and engaging rings 53 fitting around the thrust bearings 32 and somewhat loosely in the casing. By turning screws 52 inwardly the pressure of the shaft on the lower portions of the needle bearings may be increased sufficiently over that at the upper portion to assure the desired continual advance of the needle bearings around the shaft. Lock nuts 54 are provided to hold the screws 52 in adjusted position. To facilitate disassembly the end of the shaft adjacent opening 37 is provided with a shoulder 39. The face of the shoulder is shaped to conform to the curved edge of the bearing race and when the shaft is forced endwise from the cylinder, the shoulder 39 engages the adjacent bearing so that the bearings are drawn from the cylinder with the shaft.

The enforced rotation and progression of the rollers can also be secured in the manner shown in Fig. 6, in which the dispersing units are subjected individually rather than as a whole to a laterally unbalanced pressure. This has some substantial advantages. When the lateral pressure is exerted upon the shaft, as in Fig. 1, a greater pressure is applied to those bearing units adjacent the ends of the shaft than to those at its center on account of the inevitable flexing of the shaft. This in practice will decrease the efficiency of those dispersing units near the center of the shaft. In Fig. 6 the biasing screws 52 have been omitted, and their function assumed by shims 65 placed between the races 49' and the casing 10'. These shims may be of paper pasted on, of some metal like copper soldered or brazed in place; or they may be replaced by bosses or ridges formed from the material of the races or of the housing. It is preferable to distribute the shims around the circumference in such a manner as to prevent a concentration of the lateral pressures at any region of the shaft's

length. This can be done by a random arrangement or by having the shims follow a regular plan of the same nature as the firing order of the cylinders of a multi-cylinder internal combustion motor. If these precautions are followed it will be found that each dispersing unit will be subjected to substantially the same biasing pressure.

The material is supplied to the mill either under gravity or under pressure depending on the viscosity of the mixture. One preferred form of gear pump is diagrammatically indicated at **55** in Fig. 5. The material is fed to the pump from a reservoir **56** and is discharged from the pump through pipe **41** connected with the supply openings **40** of the mill. In its passage through the pump the material receives a preliminary mixing. This is taken advantage of to somewhat increase the efficiency of the whole operation by driving the pump to deliver an excess of material and providing a relatively small by-pass pipe **57** which returns the excess to the pump, the pipe **57** being extended, as shown, downwardly through the reservoir **56** to a point adjacent the feed opening of the pump. Preferably the flow through pipes **41** and **57** is controlled by suitable valves **58** and **59** respectively.

I am aware that it has in the past been proposed to employ various arrangements of rolls in mills of this kind, but as far as I am aware, none have employed the principles of construction and operation of the present invention. Mills of this type are, in their usual operation, called upon to do two kinds of work, namely, the reduction of the particle size of the material that is to form the dispersed phase, this material generally being supplied in a condition in which the particles are more or less agglomerated, and the wetting of the particles separated from these agglomerated masses, and their dispersion through the vehicle which is to form the continuous phase. In general, the finer and more uniform the particle size and the more uniform its distribution throughout the vehicle, the better the product. Also the more completely the same means can be made to reduce the agglomerates and wet and disperse the particles simultaneously, the greater the efficiency and economy. With these criteria in mind the novel operation of my mill will now be discussed.

It should first be noted that there need be no division of the work within the mill, in other words, there need be no specialized mechanisms for successively mixing and then grinding or grinding and then mixing, or a succession of differently acting means having their own specialized law of operation in preparation for the work of the succeeding means. In my preferred construction the operation is substantially uniform in kind and degree throughout the length of the mill and is exemplified by the action of any one of the bearing units **48**. As best shown in Figs. 3 and 4, the individual needle rolls **50** are closely confined in contact with each other between the individual races **49** and the surface of the shaft **30**. The races **49** fit tightly in cylinder **10** so that no material can pass between the outer face of the races and the walls of the cylinder. The edges of the races are curved over the ends of the needles into close proximity to the surface of the shaft, forming very small annular passageways **60** through which the material must pass from one bearing unit to another. The rotation of the shaft under its biased or pre-loaded pressure causes the needles to rotate individually and to progress bodily around the shaft all as indicated by arrows in Fig. 4. This mode of operation is important. It will be noted that the material is subjected to a rolling grinding action between the needles and the stationary races **49** and between the needles and the rotating shaft **30** while it is subjected to a shearing action in passing radially between the needles themselves. By reason of the small size of the rollers a very large number of contact surfaces results, increasing the efficiency of the mill greatly.

The result of this repeated grinding and shearing action to which the material is subjected throughout its passage through the mill is the reduction of the agglomerated solids to a particle size much smaller than can in commercial practice be obtained with prior mills, and the particle size is much more uniform. For example, in tests with a dispersion for paper coating comprising grinds of sixty per cent titanium dioxide and fifty per cent castor oil in a lacquer base, a single passage through a mill constructed according to my invention produced a product far superior to that obtained by passing the same grind twice through a conventional five roll mill and subsequently through three conventional stone mills in accordance with one present standard commercial practice. In this instance the difference in particle size was easily observable, the paper coated with the product of my mill showing a high gloss with an absence of visible particles under an ordinary hand magnifying glass while the coating produced by the prior art milling appeared dull in comparison and under the same glass appeared sandy and dotted with numerous large particles.

From the empirical tests which have been made upon dispersing mills constructed in accordance with the invention it is believed that the agglomerated particle masses which occur in the material to be dispersed are subjected alternately to the rolling pressure occurring between the rollers and the shaft or race and to a shearing action occurring between the oppositely moving surfaces of adjacent rolls. I do not mean to imply that a particle is subjected to only one rolling action before it is subjected to shear, as it may conceivably pass under or over several rolls before it is passed between two adjacent rolls. The fineness of the particle size obtained would seem to indicate, however, that the agglomerated masses are rolled out, broken up by shearing, and rolled and sheared again many times before they emerge from the machine.

Another feature of my mill which should be noted is that there is substantially no free passage through the mill for untreated material. All material must pass through the needle bearings, and due to the constant motion of the latter and their large number, no portion of the material escapes their action. As hitherto pointed out, the rollers used in the dispersing units are constructed on the same principle as standard needle bearings. Standard needle bearings have three essential characteristics: First, the rollers have a small diameter d with relation to the diameter S of the shaft. Standard commercial needle bearing have a value of

$$\frac{d}{S}$$

lying between $\frac{1}{6}$ and $\frac{1}{18}$ and averaging about $\frac{1}{11}$ to $\frac{1}{12}$, whereas ordinary roller bearings are constructed commercially with a value of

$$\frac{d}{S}$$

between $\frac{1}{2}$ and $\frac{1}{6}$, and averaging between $\frac{1}{3}$

and ¼. The value of this ratio occurring in needle bearings has an importance in the present use which will be discussed later. Second, the rollers have a length L_s long in relation to their diameters d, so that they may be described as long and slender. Standard commercial bearings have a value of

$$\frac{L_s}{d}$$

of more than 6. One effect of the slenderness of the rollers is to reduce their tendency to skew, which is of particular importance in the present case on account of the wearing of the rollers by the abrasive action of the pigment. Another effect of the length to diameter ratio is to increase the effectiveness of a device of given length. Third, a substantially full complement of rollers is used, without spacers, so that the adjoining rolls may always make contact with one another. This is of importance in producing the combined rolling and shearing effect discussed above.

That the reduction in the ratio of the diameter of the rolls to the diameter of the shaft to that of needle bearings produces a very radical effect in the efficiency of the device can be shown in various ways; the best of which is, of course, the performance of the device itself. Besides this empirical method the distinction between the effect of large and of small rolls can be brought out from a consideration of various properties of the two types of bearing. In Fig. 8 is given a pair of graphs which illustrate the effect of the ratio of roll to shaft diameters from two points of view. Any complete mathematical treatment would be so complex as to be meaningless, but it is possible to consider isolated properties and derive approximate expressions which are simple enough to indicate the effect of increasing or decreasing the size of the rollers with respect to the shaft. By combining several points of view, a fairly clear picture of why the device acts as it does can be reached.

Curve A of Fig. 8 is based upon the proposition that a dispersing mill should be more efficient the larger the ratio of the length of all the contact lines made by the rollers to the free space between the rollers and races. The larger the free space for the same total length of contact line the less efficient the device will be, for the greater will be the proportion of liquid which can pass through untreated. In other words,

$$E=\frac{KNL_s}{F} \qquad (1)$$

where

E is an index of the efficiency of the device,
F is the area between the races unoccupied by rollers,
K is a constant,
N is the number of contact lines, and
L_s is their individual length.

This can readily be shown to be equivalent to

$$E=\frac{K}{\beta^2} \qquad (2)$$

where K is a constant (not necessarily the same as that in Equation 1, and β is the ratio of roller to shaft diameters. Curve A of Fig. 8 is a plot of Equation 2, a change in K obviously not changing the shape of the curve but only the numbers to be put on the scale beside it. The curve means simply that if the diameter of the rolls is kept down to needle bearing proportions in relation to the shaft the resulting increase in the number of contact lines coacts with the decrease in the areas of the passages between the rolls to give the mill a much greater efficiency. It is harder for the liquid to travel straight through without treatment, and at the same time the number of contact surfaces is increased.

A different approach can be made by considering the laws of flow of a viscous liquid, a matter neglected in deriving Equation 2. By Poiseuille's law the flow through a tube is proportional to the fourth power of its radius. It can be shown that

$$Q_2=Kd^4 \qquad (3)$$

and that

$$Q_1=KN \qquad (4)$$

where the K's are constants,

Q_2 is the flow through the spaces between the rollers and races,

Q_1 is the quantity of liquid worked over by the rollers, and

d is the diameter of the rolls.

Here the efficiency or activity index is clearly the ratio of the amount worked over to the amount passed through, which can be shown to be

$$I=\frac{Q_1}{Q_2}=\frac{K_1}{\beta^4} \qquad (5)$$

Curve B is a plot of Equation 4 (K being a constant, not necessarily the same as in other equations).

Individually these curves, and the equations they represent, show approximately the results which could be obtained by varying the roll sizes while watching certain effects. Collectively, particularly when taken with the successful operation of rollers of needle bearing proportions in this field, they show that from whichever point of view the problem is regarded, high efficiency only comes when the ratio of roller to shaft size is reduced to those proportions. Above the commercially limiting figure of ⅛ or .17 for this ratio the efficiency becomes poor. At the average needle bearing ratio of $\frac{1}{12}$ or .08 the efficiency is very high. Other considerations, such as the difficulty of making very small rollers rotate, would have to be considered were the ratio of roll diameter to shaft diameter to be reduced substantially below that of commercial needle bearings.

Similar considerations can be applied to the length of the rolls in proportion to their diameter. The overall length of the device should be sufficient to insure complete treatment. In practice it has been found that the length of shaft covered by rollers should preferably be between 20 and 100 times the diameter of the rollers, or from three to twelve times the diameter of the shaft depending upon the quality of the desired dispersion and the nature of the material treated. If the shaft is sufficiently rigid an even longer total length may be used. This is much higher than the proportions used in prior devices. Another very important feature is the length of individual rollers with respect to their diameter. It can be shown that for a given length L of shaft covered by rollers the device will be much less efficient if this given total length of roller is cut up into short lengths than it will be if the rolls are longer. Each roll acts as if it were shorter than its physical length on account of the tendency of the liquid near its ends to take the path of least resistance and slip out past the roll ends rather than pass under the rolls. This effect occurs at each end of each roll, and its total effect is increased as the rolls are made

shorter and their number is accordingly increased. It can be shown that the effective length L_1 of a device of physical length L is

$$L_1 = L\left(\frac{\mu - k}{\mu}\right) \quad (6)$$

where k is a constant dependant upon the length of each end of each roll which is ineffective because of slippage, and μ is the ratio of length to diameter of individual rolls. If plotted this proves to be a hyperbola similar in general form to those in Fig. 8 but inverted. The effective length of the device approaches its physical length only if the ratio of the length of the roll to its diameter is on the order of the ratios used in needle bearings.

The long, slender character of bearings of the needle type is of importance in the present case from other aspects. An improved product will be obtained if the rollers are left free for contact one with another, which means that they will be unsupported at their ends. Under these conditions short rollers will tend to skew; thereby wearing unevenly at their ends, losing their complete contact one with another, and even tending to break. This skewing tendency is accentuated in the present case by the wear of the rollers caused by the pigment particles.

A plurality of needle bearing units may be used in alignment to produce the necessary total length, or still longer rollers may be used. I have found that if the latter course be followed, the rollers being made 30–50 times their diameter, the lateral biasing pressure described above need not be used, the longer rollers apparently having sufficient span along the shaft to insure their rotation. Such a device is shown in Fig. 7, in which the long rollers 70 have been substituted for the shorter bearing units of Fig. 1. To prevent endwise movement of these rollers the shaft 71 is provided with filleted enlargements 72. Here as previously, the shaft is made very hard. The casing 73 may also be hardened, but it is generally more convenient to place a hardened sleeve 74 between the rollers and the casing.

It has been stated that the ratio of the diameters of the shaft to that of the rolls should be greater than six, and that the ratio of the length of the individual rolls to their diameters should also be greater than six. It is preferable that both of these ratios should be somewhat greater for more efficient operation, but it should also be recognized that in one sense the ratios are mutually dependent and that one might be reduced somewhat below the limit provided the other is sufficiently increased. To express this the ratios may be multiplied together and this taken as a definition of what the proportions of the individual rollers should be to correspond with my invention.

Thus, since

$$\frac{S}{d} > 6 \text{ and } \frac{L_s}{d} > 6$$

$$\frac{SL_s}{d^2} > 36 \quad (7)$$

So complete is the action of my mill in breaking up the material for the dispersed phase, that the average particle size can be reduced sufficiently to exhibit Brownian movement if the liquid phase is light bodied enough to permit of this. As far as I am aware, this degree of reduction has never before been achieved in a commercial mill, nor by any method adapted for commercial use.

In addition to improved operation, my construction secures very substantial economies in operation. For most purposes, standard needle bearings give wholly satisfactory results. These are cheap and can be replaced without skilled labor. The other parts of the mill are simple in structure and easily manufactured with the required precision. Particularly in color work, the cleaning of the mill is important and with conventional mills presents a problem, adequate cleaning in some cases requiring at least a partial dismantling of the mill and a large amount of waste both of the dispersion and of the cleaning fluid. In one commercial form of my mill, less than a half pint of dispersion remains when the grinding operation is terminated. In most cases adequate cleaning of my mill is obtained by passing through it a quart of solvent followed by a quart of the vehicle to be used in the following grind. There is also a very substantial saving in time and labor from the use of my mill over present mills because of its vastly higher efficiency, a single passage through my mill being more than equivalent to several millings with conventional mills.

I claim:

1. A machine for dispersing materials comprising a cylindrical housing, a cylindrical shaft within the housing extending from one end thereof to permit its rotation, bearings supporting the shaft in the housing, a series of needle bearing units, each comprising a hood-like outer race and a circumferential series of free cylindrical rollers therein mounted within the housing with their outer races in frictional contact with the housing and their rollers in contact with the shaft, means for biasing the shaft-supporting bearings towards one side of the housing, and ports whereby the material to be treated may be conducted through the spaces between the casing and the shaft to be acted upon by the rollers.

2. A machine for dispersing materials comprising a cylindrical housing, a cylindrical shaft rotatable within the housing, a series of needle-bearing units, each comprising a hood-like outer race and a circumferential series of free cylindrical rollers mounted therein, said units having their outer races in frictional contact with the housing and their rollers in contact with the shaft, and ports whereby the material to be treated may be conducted through the spaces between the casing and the shaft to be acted upon by the rollers.

3. A machine for dispersing materials comprising a cylindrical housing, a cylindrical shaft rotatable within the housing, a series of needle bearing units, each comprising a hood-like outer race and a circumferential series of free cylindrical rollers mounted therein, said units having their outer races in frictional contact with the housing and their rollers in contact with the shaft, the shaft and races being laterally biased with respect to each other, and ports whereby the material to be treated may be conducted through the spaces between the casing and the shaft to be acted upon by the rollers.

4. A dispersing mill comprising a cylindrical shaft and an encircling housing having a cylindrical inner surface relatively rotatable one with respect to the other, one or more substantially circumferentially complete sets of long, slender cylindrical rolls interposed between the shaft and the housing with adjacent rolls free for contact one with another, the ratio of the diameter of the shaft to that of the rollers being greater than

six and the ratio of the individual lengths of the rolls to their diameters being greater than six, and passages for feeding material to be dispersed into the space between the shaft and the housing at one end of the assemblage of rollers and for withdrawing it from said space at the other end of said assemblage.

5. A machine for dispersing materials which comprises a casing having an inner cylindrical surface and a cylindrical shaft enclosed thereby mounted for relative rotation, a plurality of axially spaced sets of long, slender cylindrical rollers positioned between the casing and the shaft with the rollers of each set mounted to permit contact one with another, the ratio of the diameter of the shaft to that of the rollers being greater than six and the ratio of the individual lengths of the rolls to their diameters being greater than six, means for biasing the several roller sets individually in distinct directions transverse to the shaft to insure rotation of the rollers on their own axes without causing substantial flexing of the shaft, and passages for feeding material to be dispersed into the space between the shaft and the casing at one end of the assemblage of rollers and for withdrawing it from said space at the other end of said assemblage.

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