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H. HEGE

3,250,473

ATOMIZING METHOD AND APPARATUS

Filed Dec. 18, 1963

4 Sheets-Sheet 1

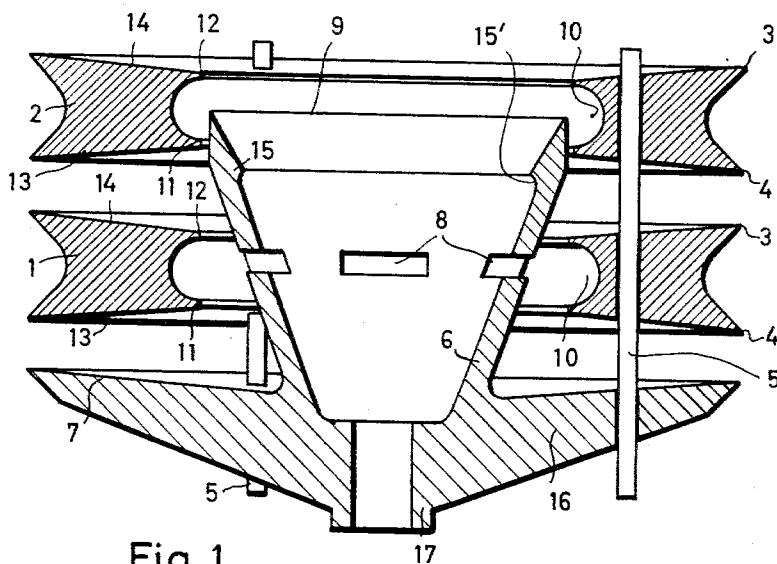


Fig. 1

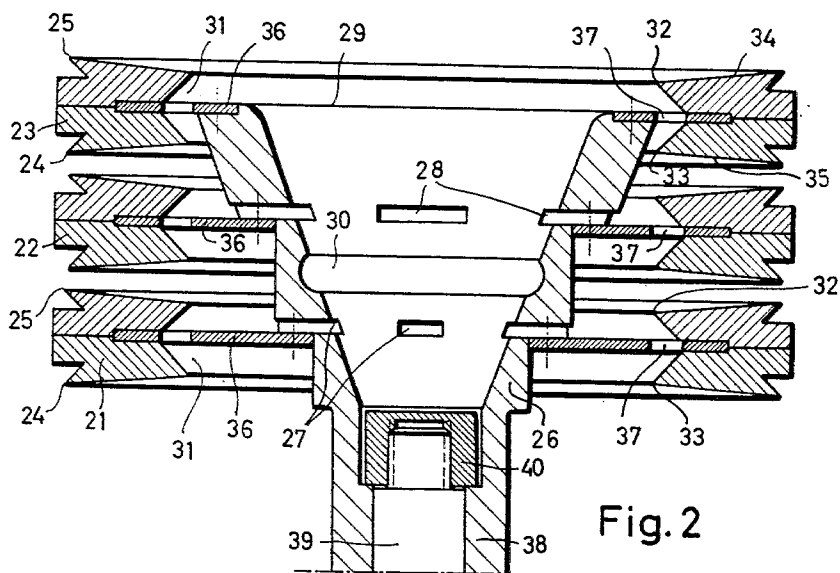


Fig. 2

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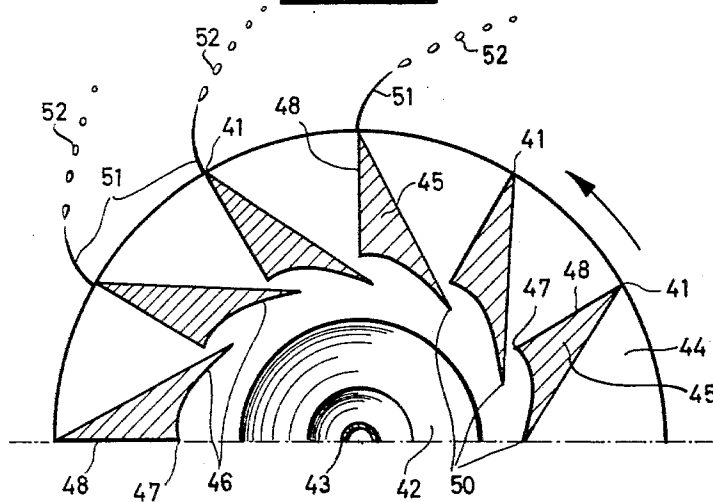
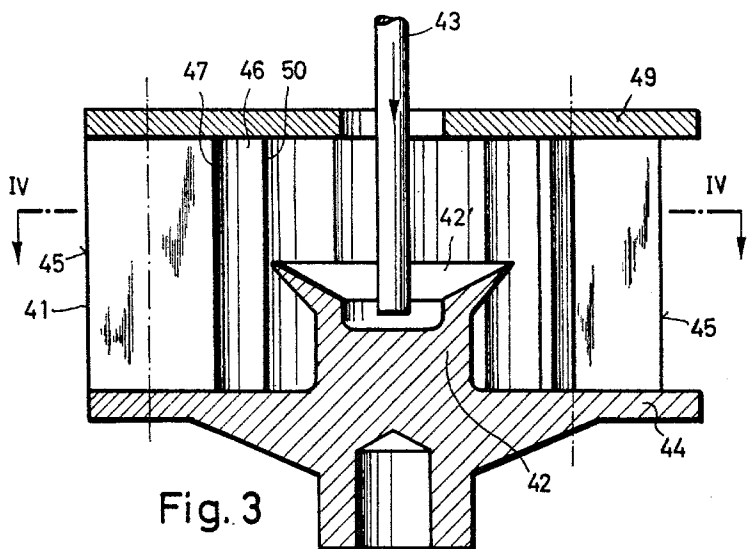
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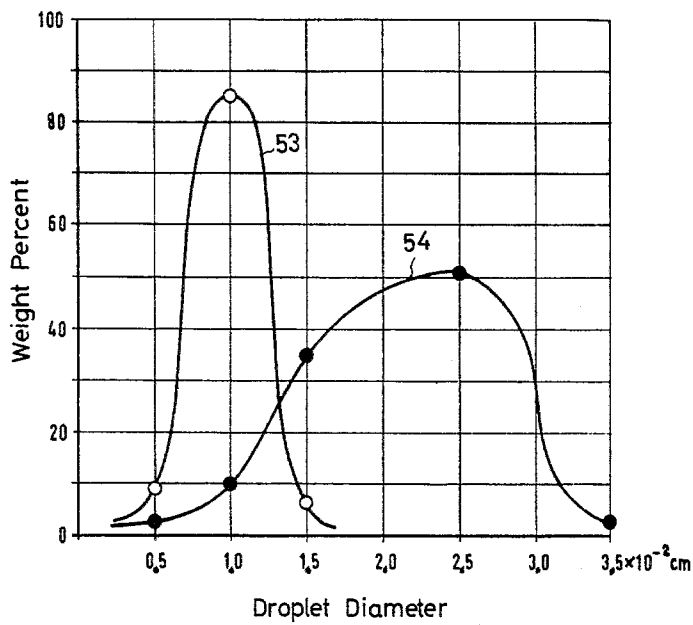


Fig. 5

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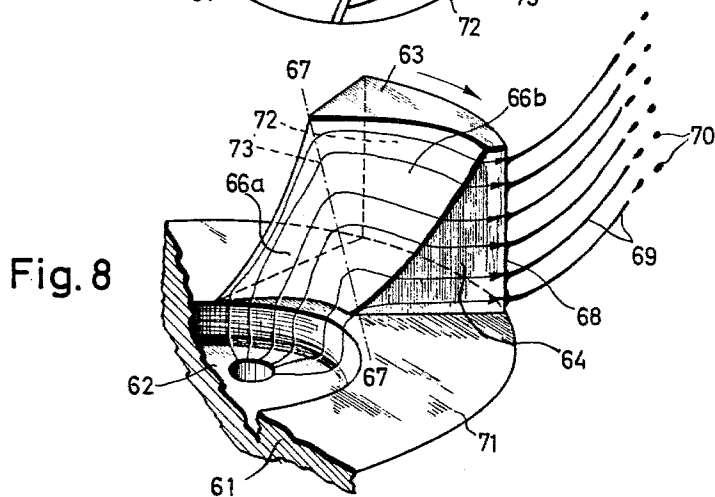
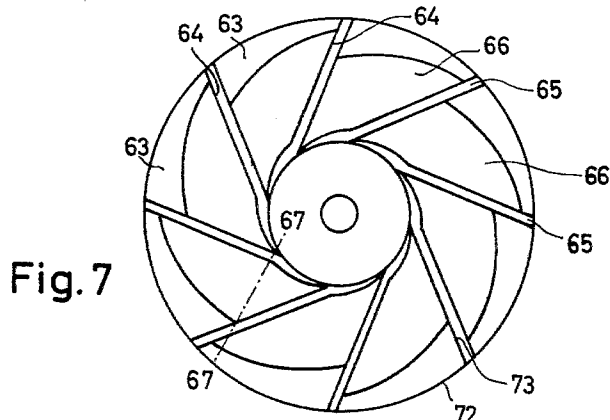
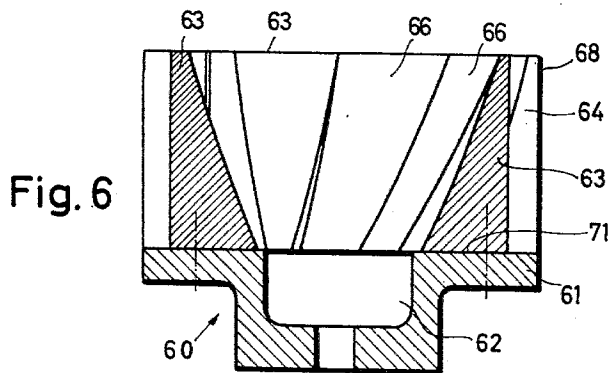
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ATOMIZING METHOD AND APPARATUS

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4 Sheets-Sheet 4



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## ATOMIZING METHOD AND APPARATUS

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Claims priority, application Germany, Dec. 18, 1962,  
H 47,726

10 Claims. (Cl. 239—7)

This invention relates to the atomization of a liquid film at a free edge of a rotating body, and more particularly to a method of atomization which yields droplets of substantially uniform size, and to an apparatus for carrying the method.

The flow properties of a particulate solid produced by spray drying of a solution thereof are materially affected by the distribution of particle sizes in the dried product. Freest flow is achieved when the particles are of uniform size. Such particles can be obtained in the drying process only if the original droplets are of practically uniform size. Atomization of a liquid to form uniform droplets is also of advantage in the fogging of crops with solutions or dispersions of pesticides. A uniform droplet size makes the settling velocity of the pesticide fog uniform, thereby avoiding treatment of localized portions of the crop with an excess of pesticide. It is particularly important to avoid droplets exceeding a certain maximum size which tend to drop to the ground near the fogging apparatus.

Known atomizing devices rely on turbulence in a body of liquid for dispersing the liquid into a large number of droplets. The dimensions of the droplets produced are randomly distributed over a wide range according to the laws of probability.

It is known to atomize liquids by means of devices which rely upon contact of the liquid with a rapidly rotating rotor body, and such devices are frequently referred to as "centrifugal atomizers." Actually, such atomizers rely on centrifugal forces mainly for feeding a liquid stream to an orifice or free edge where turbulence is induced in the stream either by a sudden change in the configuration of a contacting solid surface or by frictional engagement with the ambient gaseous atmosphere. A broad spectrum of droplet sizes is produced. The maximum dimensions of the droplets are largely a function of relative velocity of the discharged liquid and of the atmosphere. It is not possible with the known devices to produce more than a small fraction of droplets within any one narrow range of dimensions.

The primary object of the invention is the dispersing of a body of liquid in a gaseous atmosphere in a multiplicity of substantially uniform droplets.

Another object is the elimination of turbulence in the liquid body during atomization.

An additional object is the atomization of a body of liquid to droplets of predictable and reproducible dimensions.

Other objects will become apparent as the disclosure proceeds.

I have found that a liquid can be thrown from the edge of a rotating body in the form of droplets by centrifugal forces alone in the absence of turbulence and independent of the friction of an ambient gas when the kinematic viscosity of the liquid is not higher than 0.03 cm.<sup>2</sup>/sec. Such droplets will be referred to hereinafter as primary droplets.

When the kinematic viscosity of the liquid is 0.05 cm.<sup>2</sup>/sec. or higher, a bead of the liquid first forms at the edge of the rotating body, and the liquid can then be thrown from the edge by centrifugal forces alone in the shape of a string which reaches an ultimate length related to the viscosity of the liquid. The string has the approximate configuration of an evolute of a circle be-

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fore it disintegrates into droplets, hereafter referred to as secondary droplets.

I have found that the formation of primary and secondary droplets of very uniform dimensions is possible if the centrifugal acceleration applied to the liquid at the edge of a rotating body or rotor is related to the viscosity of the liquid in a critically important manner, and also depends on the rate at which liquid is fed or supplied to the edge.

Control of liquid flow to an atomizing edge cannot be controlled with the necessary precision unless the liquid is fed to the edge as a film. The flow rate of the liquid in the film must be uniform, and all turbulence must be avoided. The thickness of the film should be as uniform as possible. The rotary speed of the body from which the liquid is to be thrown off must be sufficiently high to produce the necessary centrifugal forces, but it should be low enough to eliminate atomization by the influence of surrounding air, and to avoid breaks in the film flowing toward the edge.

I have found dispersion of a liquid from a free edge of a rotor can be controlled by the rotary speed of the rotor and the feeding rate of the liquid if the equations set forth hereinbelow are satisfied. In these equations, the following symbols are being employed:

$n$  rotary speed of the rotor in revolutions per second

$x_p$  diameter of primary droplets produced, centimeters

$x_s$  diameter of secondary droplets produced, centimeters

$\sigma$  surface tension in pond per cm.

$R$  spacing of the atomizing edge from the axis of rotation, cm.

$\rho$  density of the liquid pond·sec.<sup>2</sup>/cm.<sup>4</sup>

$\nu$  kinematic viscosity of the liquid, cm.<sup>2</sup>/sec.

$c_k$  critical thread contraction (incipient formation of secondary drops), about  $\frac{1}{3}\nu^{-1/2}$ , cm.<sup>2</sup>/sec.

$V'$  feeding rate of the liquid in cubic centimeters per centimeter of atomizing edge length, per second

$g$  constant of gravitation, cm./sec.<sup>2</sup>

$\omega$  angular velocity of the rotor 1/sec.

$k_1$  a number between 0.3 and 0.7, optimally 0.425

$k_2$  a number between 0.1 and 0.25, optimally 0.16

$k_3$  a number between  $0.2\nu^{-1/2}$  and  $4\nu^{-1/2}$ , and optimally having a value of 1.

For liquids having a viscosity not materially greater than 0.03 cm.<sup>2</sup>/sec., the rotor speed  $n$  should satisfy the equation:

$$n = \frac{k_1}{x_p} \left( \frac{\sigma k_3}{R\rho} \right)^{1/2} \quad (I)$$

If the viscosity of the liquid is 0.05 cm.<sup>2</sup>/sec. or higher, the rotor speed is selected according to the equation:

$$n = \frac{k_2}{x_s} \left( \frac{\sigma k_3}{R\rho} \right)^{1/2} \left( \frac{c_k}{\nu} \right)^{1/2} \quad (II)$$

In either case, the feeding rate of the liquid is controlled to satisfy the equation:

$$V' = k_3 \frac{\sigma}{\rho} (2\pi g R^3 \omega^2)^{-1/4} \quad (III)$$

The viscosity of the liquid and the dimensions of the rotor employed are known in advance, and the rotary speed at which the rotor is to be driven, and the feeding rate of the liquid to the atomizing edge can readily be calculated from the above equations. There are obtained practically uniform drops or droplets the dimensions of which can be predicted with great accuracy from these formulas without trial.

If a feeding rate greater than that derived from Equation III is chosen, the uniformity of the droplets produced is still better than that obtained by conventional methods, but it becomes difficult to produce liquid films

of the necessary qualities, and the cost and complexity of the apparatus required for atomizing a given body of liquid increases sharply.

When a liquid whose viscosity is between the values of 0.02 and 0.05 cm.<sup>2</sup>/sec. is fed to the atomizing edge of a rotor to produce droplets by centrifugal forces alone, both primary and secondary droplets are formed. Such a liquid may be atomized by the method of the invention under conditions represented by Equations I and III. The liquid is dispersed mainly in primary droplets, but will contain a minor amount of smaller secondary droplets. If it is more important to avoid droplets smaller than the desired ones, and larger droplets are more acceptable, the conditions of Equations II and III are maintained. In either case, the primary and secondary droplets produced are each within a very narrow range of dimensions, and these dimensions are predictable from Equations I and II respectively, by solving the equations for  $x_p$  and  $x_s$ .

Operating conditions marginally meeting the requirements of my method can be maintained with certain conventional atomizers of the so-called centrifugal type. Since the known devices are not intended for operation under such conditions, the rate of feeding that is possible with the available atomizing edge length is so low that it becomes very difficult or impossible to maintain the necessary uniform and undisturbed flow of a continuous liquid film toward the atomizing edge. It is not practical to increase the available edge length by increasing the rotor diameter in the known devices. While the length of a circumferential edge is directly proportional to the radius of the rotor, the optimal flow rate of liquid toward the atomizing edge increases only proportional to the square root of the radius. The strength of the available materials of construction also limits the size to which the rotor can be enlarged.

The invention, in one of its aspects, therefore resides in an atomizing device in which a rotor arranged for rotation about its axis carries a plurality of atomizer bodies, each having a film forming face extending radially away from the axis of rotation, and a free elongated atomizing edge on the portion of the face farthest removed from the axis. The several atomizer bodies are spaced from each other transversely of the direction of elongation of their edges. Liquid is being fed to the film forming faces at a substantially equal rate.

Other features and many of the attendant advantages of this invention will be readily appreciated as the same becomes better understood by reference to the following detailed description of preferred embodiments of apparatus for carrying out my method, when considered in connection with the accompanying drawings in which:

FIG. 1 is an axially sectional elevational view of the essential working elements of an atomizing device of the invention in which the atomizing edges are circumferential about the rotor axis;

FIG. 2 shows a modified form of the apparatus of FIG. 1;

FIG. 3 illustrates an atomizing device of the invention having atomizing edges parallel to the rotor axis, the view being in elevational axial section;

FIG. 4 shows one half of the device of FIG. 3 in radial section on the line IV—IV;

FIG. 5 is a diagram of the distribution of droplet weights in a dispersion of a liquid in air produced according to the invention, and includes a corresponding distribution curve characteristic of conventional apparatus and methods under otherwise equivalent conditions;

FIG. 6 shows yet another atomizing device of the invention in axially sectional elevational view;

FIG. 7 is a plan view of the apparatus of FIG. 6; and

FIG. 8 is a fragmentary perspective view of the apparatus of FIGS. 6 and 7 which illustrates the flow of liquid to the atomizing edge.

Referring initially to FIG. 1, there is seen a hollow rotor body 6 of upwardly flaring approximately frusto-

conical shape. The rotor body 6 is integral with a coaxial flange 16 and a drive hub 17. The drive shaft normally received in the hub 6, and the motor and variable speed transmission connected to the drive shaft are not shown since they may be entirely conventional, and are in themselves not relevant to this invention. It will be appreciated that a variable speed transmission is unnecessary if the apparatus is to be operated at all times under the same conditions, and therefore at the same rotary speed.

Several eccentric pins 5 parallel to the rotor axis are fastened to the flange 16 and to flat coaxial annular atomizing disks 1 and 2. The disks are held in axially spaced fixed relationship to the flange 16, and are radially spaced from the rotor body 6. Each disk has two circular atomizing edges 3, 4 which are centered on the rotor axis and have the same diameter. The central portion of the outer circumferential face between the atomizing edges of each disk is recessed so as to form a groove. A similar groove 10 of approximately semi-circular cross section is formed in the inner circumferential face of each disk between two axially spaced overflow edges 11 and 12. For reasons which will presently become apparent, this inner face of the disk will be referred to hereinafter as a receiving face. Shallow conically dished annular film forming faces 13, 14 extend radially outward from the overflow edges 11, 12 to the atomizing edges 3, 4.

Radial passages 8 in the rotor body 6 have orifices in the inner wall of the rotor body in a radial plane which axially bisects the cavity of the rotor body. The orifices of the passages 8 in the outer wall of the rotor body are radially aligned with the receiving face of the atomizing disk 1, and more specifically with the recessed center portion 10. The orifices of the four passages 8 in the inner wall of the rotor body jointly extend over one half of the circumference of the conical inner wall. Only three orifices are visible in the drawing.

The disk 2 is so positioned that its receiving face, and more particularly the recessed portion 10 thereof, is radially aligned with the free edge 9 at the open top of the rotor body. A circumferential rib 15 closely subjacent the edge 9 in the rotor cavity has sharp angular ridge and sloping flanks. One of the flanks blends arcuately with the conical lower portion of the inner wall of the rotor body so as to form an annular liquid retaining pocket 15' under the ridge of the rib. The other flank of the rib 15 meets the outer wall of the rotor body 6 at a sharp angle at the edge 9.

The flange 16 has a top face 7 which is conically dished in a manner similar to the top faces 14 of the atomizing disks 1, 2, and whose circumferential circular edge is formed by the bottom face of the flange meeting the top face at a sharp angle.

A supply tube for feeding a liquid to be atomized to the cavity of the rotor body 6 has been omitted from the showing of FIG. 1 for the sake of clarity. It will be understood that the tube will reach axially from above into the rotor body cavity to a level well below the passages 8 in the manner shown in FIG. 3, and that the bottom of the cavity will be sealed by the non-illustrated shaft fastened in the hub 17.

The afore-described apparatus operates as follows:

Liquid is fed to the bottom of the cavity in the rotor body 6 while the rotor body 6 and the structures supported thereon are rotated by the hub 17. At the speed of rotation necessary for operation of the device, the liquid is caused to rise along the inner wall of the cavity in a layer whose thickness is uniform in each radial plane. When the zone of the passages 8 is reached, one half of the flowing liquid is diverted outward through the passages 8 whereas the remainder continues rising.

The liquid permitted to flow radially outward through the passages 8 in four separate streams is received in the groove 10 and spread out over the entire circumference of

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the groove. Centrifugal force holds the liquid in the groove 10. As more liquid accumulates than the groove 10 can hold, liquid overflows over the edges 11, 12. The rate of flow over the two edges is the same since they are equally spaced from the rotor axis. The forces of gravity which would favor overflow over the lower edge 11 are insignificant as compared to the centrifugal force. The rate of overflow over each unit of length of the edges 11, 12 is the same because of the symmetrical structure of the disks 1, 2.

The overflowing liquid is spread over the conically dished faces 13, 14 in a film whose thickness is the same in any circular area about the rotor axis, but diminishes in a radially outward direction. As the liquid reaches the edges 3, 4, it is thrown off in primary droplets or in strings of liquid that disintegrate into secondary droplets depending on the viscosity of the liquid, and the correspondingly chosen rotary speed and rate of liquid feeding.

The liquid which by-passes the orifices of the passages 8 in the rotor body 6 forms four rising streams which are collected in the annular pocket 15' until the pocket is uniformly filled to the ridge of the rib 15. The collected liquid then flows over the rib in a layer whose thickness is almost uniform over the circumference of the inner rotor body wall. The liquid ultimately reaches the edge 9 and is transferred therefrom to the groove 10 of the disk 2. Liquid films are formed on the dished faces 13, 14 of the disk 2 in the same manner as described with reference to the disk 1, and are atomized from the edges 3, 4 of the disk 2. Any liquid accidentally dripping from the disks 1, 2 is caught on the top face 7 of the flange 17, and atomized therefrom.

Since the combined circumferential length of the passages 8 is one half of the total circumference of the inner rotor body on the level of the passages, and since each groove 10 evenly distributes the liquid received between the two film forming faces of the atomizing disk, each unit length of the atomizing edges 3, 4 is supplied with liquid at practically the same rate. When this rate satisfies Equation III and if the rotary speed of the body 6 satisfies Equations I or II, the atomized liquid consists of practically uniform droplets.

The modified atomizing device shown in FIG. 2 is closely similar in its function and operation to that illustrated in FIG. 1. It has a rotor body 26 on which three annular atomizing disk 21, 22, 23 are mounted in axially spaced relationship. Each disk consists of two identical halves which have respective exposed film forming faces 34, 35 of conically dished shape, and atomizing edges 24, 25 at the circumference of these edges.

Respective flat radial faces of the disk halves are superimposed and fixedly fastened to each other and to the outer circumference of an interposed supporting disk 36 which is fixedly fastened to the rotor body 26. The faces of the disks 21, 22, 23 opposite the rotor body 26 slope from overflow edges 32, 33 at the inner circumference of the film forming faces 34, 35 toward the supporting disk 36 in a radially outward direction so as to form a receiving groove 31 bisected by the disk 36. Axial openings 37 through the disk 36 adjacent the receiving face of the associated atomizing disk provide a connection between the two halves of the grooves 31 for equal distribution of liquid between the atomizing edges 24, 25 of each disk.

The rotor body 26 has four radial passages 27 there-through whose outer orifices are aligned with the receiving face of the disk 21 and are located above and contiguously adjacent the associated supporting disk 36. The inner orifices of the passages 27 extend over one third of the circumferences of the rotor body 26 to drain one third of a liquid supplied to the lower end of the rotor cavity to the disk 21.

The remaining liquid rises along the inner wall of the cavity in four streams which are collected in an annular

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groove 30 in the same manner and for the same purpose as described with reference to the annular pocket 15'. The liquid is discharged upward by overflow from the groove 30 in a layer which is approximately uniformly distributed about the circumference of the inner wall. One half of this layer is drawn off to the atomizing disk 22 through passages 28 on a higher level of the rotor body. The passages 28 extend over one half of the corresponding circumference of the inner rotor wall, but are otherwise closely analogous to the passages 27.

The last third of the liquid originally supplied flows over the free top edge 29 of the rotor body 26 into the receiving groove 31 of the atomizing disk 23. The associated supporting disk 36 is embedded in that edge and flush therewith. Liquid intended for atomization from the several atomizing edges thus flows from the rotor body to the receiving face of an atomizing disk initially along the top face of the associated supporting disk 36.

An integral hub portion 38 of the rotor body 26 receives a drive shaft 39. A nut 40 threadably mounted on the shaft 39 has a polygonal outer axial face which is received in a conforming portion of the hub portion 38 for driving connection between the shaft 39 and the rotor body 26. The nut 40 also seals the bottom of the rotor body cavity.

The operation of the modified atomizing device illustrated in FIG. 2 is closely analogous to that of the apparatus shown in FIG. 1. The total amount of liquid fed to the cavity of the rotor body 6 is divided into six equal parts which are supplied to the six atomizing edges 24, 25 in the form of liquid films, and are atomized from the edges 24, 25 at a uniform rate per unit edge length.

Further modifications of the apparatus of FIG. 1 will readily suggest themselves. The number of atomizing disks may be increased beyond the three illustrated in FIG. 2, and the necessary arrangements for uniform distribution of liquid between the several disks may be patterned on those specifically disclosed.

If the axial openings 37 in the disks 36 are omitted from the apparatus shown in FIG. 2 in a manner not further illustrated, all liquid supplied to a disk will flow only to the upper film forming face 34, and will be atomized from the corresponding edge 25. The modification of the devices of FIGS. 1 and 2 in which each disk is provided with only one film forming face and a single atomizing edge is therefore within the scope of this invention. In the embodiment of the invention shown in FIG. 1, feeding of liquid to only one radial face of an atomizing disk is achieved by spacing one of the edges 10, 11 farther from the rotor axis than the other in a non-illustrated manner analogous to that shown at 47, 50 in FIG. 4, and more fully described hereinafter. It will further be evident that the two film forming faces of each disk may have such a configuration that they meet in a common atomizing edge, whereby liquid is supplied to the edge in two films which merge at the edge.

Atomizing edges at which two faces of an atomizing disk meet at a sharp angle have been shown in FIGS. 1 and 2, and are preferred. It will be understood, however, that such sharp edges are not necessarily employed, and that the edges may be rounded not shown. It is more difficult, however, to produce rounded edges having the necessary uniformity of contour. The operation of the apparatus is not affected by the edge contour, as long as it is uniform.

The atomizing edges of the devices shown in FIGS. 1 and 2 form closed circles about the rotor axis in respective radial planes. FIGS. 3, 4, 6, 7, 8 show embodiments of the invention in which the atomizing edges are elongated in an axial direction.

In the apparatus illustrated in FIGS. 3 and 4, the integral rotor body consists of a flanged hub portion 44 and a coaxial distributor portion 42. The latter has an upwardly open axial recess the upper portion of which

is bounded by a conical, outwardly flaring wall face 42' that terminates in a free sharp edge. A supply tube 43 feeds the liquid to be atomized to the apparatus from a non-illustrated container through a pump (not shown) whose output can be precisely adjusted, and is constant when adjusted. The orifice of the tube 43 is adjacent the bottom of the recess in the distributor portion 42.

Twelve atomizing vanes 45 are fixedly fastened to the flange of the rotor portion 44. They are equiangularly spaced about the distributor portion 42. Each vane has three straight edges 41, 47, and 50 which are parallel to the rotor axis. The edges 41 rise from the circumference of the flange 44 and constitute the atomizing edges of the apparatus. The overflow edge 47 and the trailing edge 50 bound a receiving face 46 of each atomizing vane 45 opposite the rotor axis and the distributor face 42. The receiving face 46 is of concavely arcuate cross section. The portion of each vane 45 adjacent the trailing edge 50 is radially interposed between the rotor axis and the portion of the receiving face on an adjacent vane which includes the overflow edge 47 of the latter. The edge 47 of each receiving face 46 is therefore radially farther from the rotor axis than the trailing edge 50. The film forming faces 48 of the vanes 45 extend in respective common planes with the rotor axis from the coordinated overflow edge 47 to the atomizing edge 41.

The top ends of the vanes 45 are fixedly connected by an annular cover disk 49 whose outer diameter is equal to that of the flange on the rotor portion 44, and whose inner diameter is sufficient to permit passage of the tube 43.

The apparatus illustrated in FIGS. 3 and 4 is operated as follows:

The liquid to be atomized is pumped through the tube 43 into the recess of the distributor portion 42 at a uniform rate determined according to Equation III. The liquid is forced upward in the recess by centrifugal forces, spreads over the rotating face 42', and is thrown from the edge of the face toward the receiving faces 46 of the vanes 45.

The liquid received by each face 46 and held there-against by centrifugal force is spread over the axial length of the face until it is present in an amount sufficient for overflow over the edge 47 into the film forming face 48. The uniform height of the face 48 from the edge 47 to the atomizing edge 41 favors equalization of any residual inequality of film thickness which may have existed at the edge 47, and a film of uniform thickness is atomized from the edge 41.

The portion of each vane 45 adjacent the trailing edge 50 constitutes a baffle which prevents liquid to be thrown from the rotating distributor face 42' directly outward between adjacent vanes 45. The baffle also prevents liquid from being received on a portion of a receiving face 46 which is closely adjacent the overflow edge 47. This arrangement ensures adequate uniformity of axial liquid distribution over the receiving face 46.

When operated with a liquid of low viscosity, the apparatus shown in FIGS. 3 and 4 produces primary drops at the atomizing edges 41. FIG. 4 illustrates the strings 51 of liquid which are released from the edges 41 when the rotor turns in the direction of the arrow. The strings 51 have the approximate shape of an evolute of a circle, and separate into individual secondary droplets 52 at a uniform distance from the rotor circumference.

While twelve axial atomizing edges 41 are provided in the apparatus illustrated in FIGS. 3 and 4, the number of vanes may be varied to suit specific operating conditions, particularly the desired output of the apparatus. Similar considerations govern the axial length of the edges. The spatial relationship between the atomizing edges and the rotor axis may also be varied without affecting the operational characteristics of the apparatus. More specifically, the atomizing edges need not be parallel to the axis, nor is it necessary that the film forming

faces of the vanes be arranged in axial planes. The free edge of the distributor face 42' is preferably located in a radial plane equally spaced from the flange 44 and the disk 49. A more complex distributor system may be needed for liquids of high viscosity or for liquids containing suspended matter. The distributor portion 42 may be replaced under such conditions, in a manner not specifically shown by a structure substantially identical with one of the rotors shown in FIGS. 1 and 2, and suitably dimensioned to fit between the vanes 45 and to provide them with a liquid discharged from several axial levels against the receiving faces 46.

FIG. 5 illustrates the distribution of droplet sizes in a liquid dispersed in an atomizing apparatus operating under the conditions established by Equations I, II, and III as compared to the droplet size distribution obtained by conventional apparatus relying on turbulence for atomization.

Droplet diameter is plotted in units of 0.01 centimeters against weight percent of the atomized liquid. The three measurement points determined in a liquid atomized according to this invention are connected by a curve 53. The measurements made on a conventionally atomized liquid are connected by a curve 54.

As is evident from curve 53, more than 80% of the droplets produced according to the invention have a diameter between  $0.75$  and  $1.25 \times 10^{-2}$  cm. Not quite 10% have a diameter of  $0.5 \pm 0.25 \times 10^{-2}$  cm. an even smaller portion of the liquid is dispersed in droplets having a diameter of  $1.5 \pm 0.25 \times 10^{-2}$  cm.

The conventionally dispersed liquid is distributed in sizes respectively centered on 0.05, 0.10, 0.15, 0.25, and  $0.35 \times 10^{-2}$  cm. in amounts of less than 5, 10, 35, 50 and less than 5 percent. Eighty percent of the material is spread over a diameter range at least three times as wide as in the otherwise comparable dispersion produced according to this invention.

Apparatus which partly relies upon overflow of liquid from concavely arcuate receiving faces is not well suited for atomizing relatively coarse dispersions or suspensions as are frequently encountered in the manufacture of detergent compositions. The dispersed solid tends to be retained by the overflow edges. A modified embodiment of the invention capable of handling suspensions of relatively coarse crystalline material in an aqueous medium is illustrated in FIGS. 6, 7 and 8.

The main operating elements of the atomizing apparatus shown in FIGS. 6 to 8 are a rotor body 60 and eight identical atomizing bodies or vanes 63. The atomizing bodies are mounted on a flange portion 61 of the body 60 and extend upwardly therefrom. They are of sufficient mechanical strength not to require a connecting member at their upper axial ends.

The central portion of the rotor body 60 has an axial recess 62 of approximately cylindrical shape. The eight atomizing bodies 63 are equiangularly spaced about the upper rim of the recess 62 on the top surface 71 of the flange 61. Each atomizing body 63 has flat radial top and bottom faces, and four axially extending faces which connect the top and bottom faces. The outer circumferential face 72 is cylindrical about the rotor axis. A leading face 64 and a trailing face 73 extend radially inward from the outer face 72 in respective planes parallel to the rotor axis, but not passing therethrough. The leading face 64 constitutes the film forming face of the atomizing body. It meets the outer circumferential face 72 along an atomizing edge 68.

The receiving face 66 of the atomizing body 63 is of arcuate cross section in axial and radial planes. It has the shape of a four-sided portion of a cylindrical surface about an axis which is inclined relative to the rotor axis. The lower corner of the receiving face adjacent the trailing face 73 is located at the rim of the recess 62, and the receiving face 66 slopes from this corner away from the rotor axis both in an axial and in a radial direction.

In the portion 66a of the receiving face 66 near the aforementioned lower corner, the slope away from the rotor axis is much steeper in an axial plane than in a radial plane. In a portion 66b of the receiving face 66 near the top corner adjacent the film forming face 64, the slope away from the rotor axis is steeper in a radial direction than in an axial direction. The two portions of the receiving face 66 meet along a diagonal line 67 drawn through the other two corners of the four-sided face 66.

The several atomizing bodies 63 are separated from each other by narrow slots 65 which extend between the film forming face 64 of each body 63 and the trailing face 73 of an adjacent body. The slots 65 are approximately tangential to a cylindrical surface defined by the axial wall of the recess 62.

The drive shaft which normally is received in an axial opening of the rotor body 60 and downwardly seals the recess 62 and a liquid feeding tube whose discharge orifice normally is located in the recess 62 have been omitted from the showing of FIGS. 6 to 8 in order not to crowd the drawing. The apparatus operates as follows:

The liquid to be atomized is fed to the bottom of the recess 62, and travels radially outward therefrom when the rotor body revolves. The liquid therefore rises in a layer of approximately uniform thickness along the cylindrical wall of the recess 62, and is thrown radially outward from the rim of the recess. Because of the tangential disposition of the slots 65, the liquid cannot directly enter the slots. It first makes contact with the lower edge of the receiving face 66 which is entirely in the portion 66a, and travels upward thereon as indicated by flow lines. Near the diagonal line 67 the slope of the receiving face changes from a predominantly axial direction to a predominantly circumferential direction, and the original upward flow of the liquid is diverted toward the adjacent film forming face 64. On that face, liquid flow is horizontally outward toward the atomizing edge 68 where the liquid film is dissolved into strings 69, which in turn distintegrate into secondary droplets 70.

The apparatus shown in FIGS. 6 to 8 does not rely on overflow edges and associated collecting pockets or receiving grooves. It has been successfully employed for atomizing two-phase systems consisting of a continuous liquid medium and a dispersed solid material, even where the dispersed material was a fairly coarse crystalline solid.

The construction of the specific embodiment of the invention shown in FIGS. 6 to 8 requires relatively simple shaping operations. All surfaces of the apparatus are either plane or cylindrical, but it will be appreciated that such surfaces, while easy to shape by machining or by other methods, are not critical to the operation of the apparatus, and may be modified without departing from the spirit of this invention.

It is evident that the configuration of the outer circumferential face 72 is relevant to the function of the device only to the extent that it contributes to the shape of the atomizing edge 68. The latter, while preferably elongated in a direction parallel to the rotor axis, may be obliquely inclined to some extent. The film forming face 64 need not necessarily be tangential relative to the rim of the recess 62. The receiving face 66 need not be cylindrical about an inclined axis, but may be conically tapered at a small angle about such an axis without material change in the flow pattern shown in FIG. 8.

It should be understood, of course, that the foregoing disclosure relates to only a preferred embodiment of the invention, and that it is intended to cover all changes and modifications of the example of the invention herein chosen for the purpose of the disclosure which do not constitute departures from the spirit and scope of the invention set forth in the appended claims.

What I claim is:

1. A method of dispersing a liquid in drops of substantially uniform predetermined diameter, the liquid having a

kinematic viscosity not substantially greater than 0.03 cm.<sup>2</sup>/sec., which comprises:

- (a) rotating a body having an elongated edge about an axis spaced from said edge, said edge facing away from said axis; and

- (b) feeding a film of liquid to said edge,

- (1) the rotary speed of said body about said axis satisfying the equation

$$n = \frac{k_1}{x} \left( \frac{\sigma k_3}{R \rho} \right)^{1/2}$$

and

- (2) the rate of feeding of said liquid to said edge satisfying the equation

$$V' = k_3 \frac{\sigma}{\rho} (2\pi g R^3 \omega^2)^{-1/4}$$

wherein

$n$  is the rotary speed of said body in revolutions per second,

$k_1$  is a number between 0.3 and 0.7,

$x$  is the predetermined diameter of the drops formed, in centimeters,

$\sigma$  is the surface tension of said liquid pond per centimeter,

$k_3$  is a number between  $0.2\nu^{-1/4}$  and  $4\nu^{-1/4}$ , and  $\nu$  is the kinematic viscosity of said liquid in square centimeters per second,

$R$  is the spacing of said edge from said axis in centimeters,

$\rho$  is the density of said liquid pond-sec.<sup>2</sup>/cm.<sup>4</sup>

$V'$  is the rate of feeding of said liquid to said cubic centimeters per centimeter of edge length per second,

$g$  is the constant of gravitation in centimeters per second square, and

$\omega$  is the angular velocity of said rotating body 1/sec.

2. The method as set forth in claim 1, wherein  $k_1$  is approximately 0.425.

3. The method as set forth in claim 1, wherein  $k_3$  is approximately 1.

4. The method as set forth in claim 3, wherein  $k_1$  is approximately 0.425.

5. A method of dispersing a liquid in drops of substantially uniform predetermined diameter, the liquid having a kinematic viscosity not substantially smaller than 0.05 cm.<sup>2</sup>/sec., which comprises:

- (a) rotating a body having an elongated edge about an axis spaced from said edge, said edge facing away from said axis; and

- (b) feeding a film of liquid to said edge,

- (1) the rotary speed of said body about said axis satisfying the equation

$$n = \frac{k_2}{x} \left( \frac{\sigma k_3}{R \rho} \right)^{1/2} \frac{(c_k)^{1/12}}{\nu}$$

- (2) the rate of feeding of said liquid to said edge satisfying the equation

$$V' = k_3 \frac{\sigma}{\rho} (2\pi g R^3 \omega^2)^{-1/4}$$

wherein

$n$  is the rotary speed of said body in revolutions per second,

$k_2$  is a number between 0.1 and 0.25,

$x$  is the predetermined diameter of the drops formed, in centimeters,

$\sigma$  is the surface tension of said liquid in pond per centimeter,

$k_3$  is a number between  $0.2\nu^{-1/4}$  and  $4\nu^{-1/4}$ , and  $\nu$  is the kinematic viscosity of said liquid in square centimeters per second,

$R$  is the spacing of said edge from said axis in centimeters,

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$\rho$  is the density of said liquid pond·sec.<sup>2</sup>/cm.<sup>4</sup>

$V'$  is the rate of feeding of said liquid to said edge in cubic centimeters per centimeter of edge length per second,

$c_k$  is approximately equal to  $\frac{1}{3}\nu^{-\frac{1}{2}}$  (cm.<sup>2</sup>/sec.),

$g$  is the constant of gravitation in centimeters per second square, and

$\omega$  is the angular velocity of said rotating body 1/sec.

6. A method as set forth in claim 5, wherein  $k_2$  is approximately 0.16.

7. A method as set forth in claim 5, wherein  $k_3$  is approximately 1.

8. A method as set forth in claim 7, wherein  $k_2$  is approximately 0.16.

9. A method of dispersing a liquid in drops of predetermined diameter, the liquid having a kinematic viscosity not substantially greater than 0.05 cm.<sup>2</sup>/sec., and not substantially smaller than 0.03 cm.<sup>2</sup>/sec., which comprises:

(a) rotating a body having an elongated edge about an axis spaced from said edge, said edge facing away from said axis; and

(b) feeding a film of liquid to said edge,

(1) the rotary speed of said body about said axis being intermediate two values respectively satisfying the equations

$$n = \frac{k_1}{x} \left( \frac{\sigma k_3}{R\rho} \right)^{1/2}, \text{ and } n = \frac{k_2}{x} \left( \frac{\sigma k_3}{R\rho} \right)^{1/2} \left( \frac{c_k}{\nu} \right)^{1/12}$$

(2) the rate of feeding of said liquid to said edge satisfying the equation

$$V' = k_3 \frac{\sigma}{\rho} (2\pi g R^3 \omega^2)^{-1/4}$$

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wherein

$n$  is the rotary speed of said body in revolutions per second,

$k_1$  is a number between 0.3 and 0.7,

$k_2$  is a number between 0.1 and 0.25,

$x$  is the diameter of the drops formed, in centimeters,

$\sigma$  is the surface tension of said liquid in pond per centimeter,

$k_3$  is a number between  $0.2\nu^{-\frac{1}{2}}$  and  $4\nu^{-\frac{1}{2}}$ , and

$\nu$  is the kinematic viscosity of said liquid in square centimeters per second,

$R$  is the spacing of said edge from said axis in centimeters,

$\rho$  is the density of said liquid pond·sec.<sup>2</sup>/cm.<sup>4</sup>,

$V'$  is the rate of feeding of said liquid to said edge in cubic centimeters per centimeter of edge length per second,

$g$  is the constant of gravitation in centimeters per second square, and

$\omega$  is the angular velocity of said rotating body 1/sec.

10. A method as set forth in claim 3, wherein  $k_1$  is approximately 0.425,  $k_2$  is approximately 0.16, and  $k_3$  is approximately 1.

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