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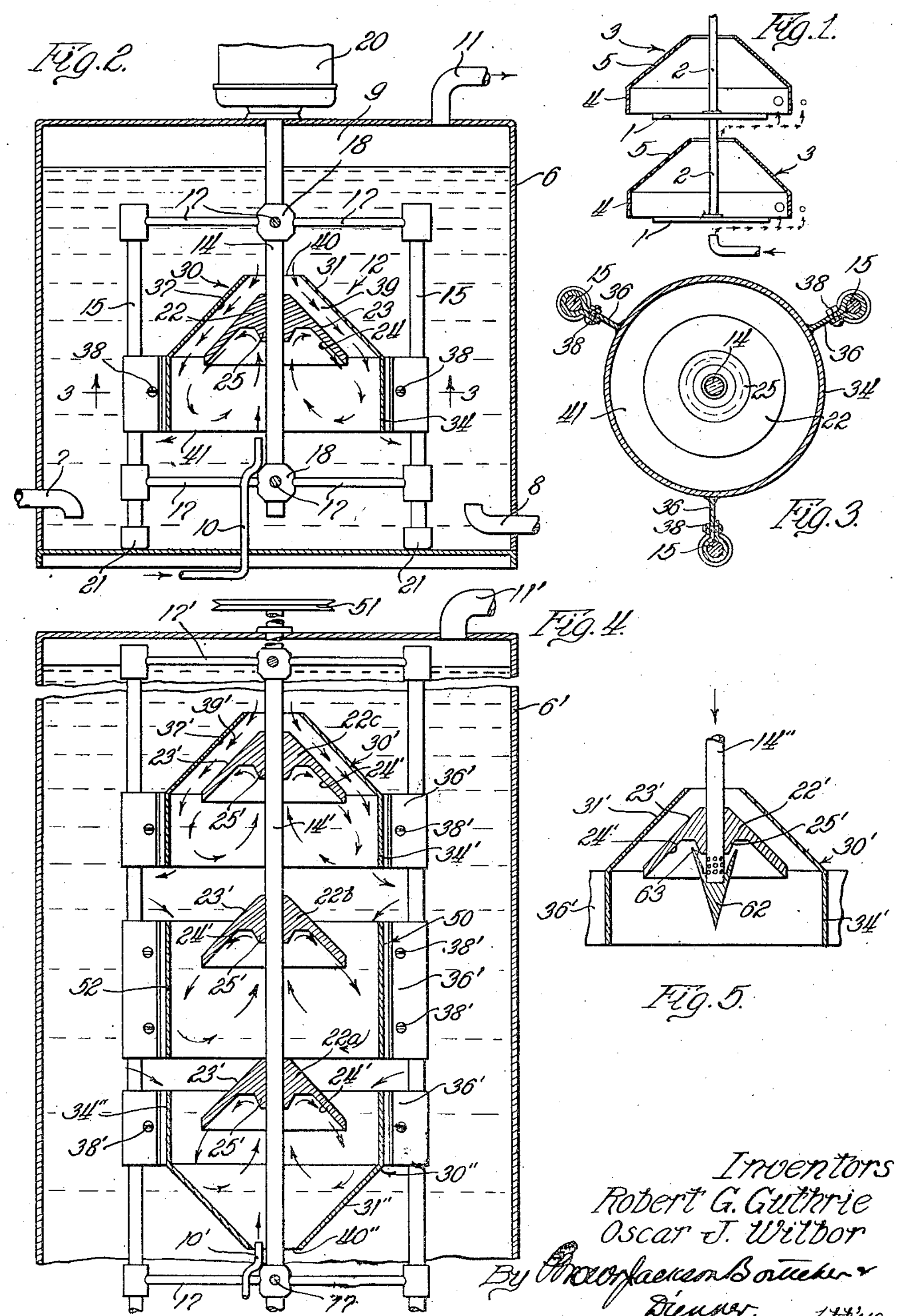

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MEANS FOR DISPERSING ONE FLUID IN ANOTHER FLUID

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The present invention relates to a means for intimately dispersing one fluid in another fluid. One practical use to which our invention is applicable is exemplified by a gas washer, although other uses will be readily apparent to those skilled in the art. The present invention may be employed in the general field of gas and liquid contact.

Gas washers are generally employed for the purpose of removing one or more solid or gaseous components, or vapors, from a gaseous fluid. The preferred type of such machines is one in which the gaseous fluid is bubbled through a liquid capable of removing and retaining one or several of the components to be removed. The thoroughness of such a washing process is dependent upon the size of the gas bubbles, the desideratum being bubbles of exceedingly small size so that a large surface area compared to volume is brought into contact with the liquid. Also, the time of contact of the gas bubbles with the fluid is dependent upon their size since, the smaller the gas bubbles the longer they will be in contact with the liquid. If the gaseous fluid is divided into exceedingly fine bubbles within the body of the liquid, they will have a small uplifting force, since they only displace a small amount of the liquid and when this force is reduced to the order of forces involved in surface tension of the liquid, the bubble finds difficulty in rising through the liquid. In present practice, rectifying columns of great height are employed, since the gaseous fluid is in the form of relatively large bubbles, and in order to attain sufficient surface contact and duration of contact of the gaseous fluid with the liquid, the bubbles are passed through a large number of stages. It follows that a gaseous fluid may be effectively washed with a comparatively small amount of liquid, if the gas bubbles can be made sufficiently fine to satisfy the requirements of surface area and time of contact of the gaseous fluid and liquid and sufficient relative movement of the gas and liquid.

The primary object of our invention is the provision of an improved means whereby gaseous fluid is caused to rise with adequate relative movement through the washing liquid in the form of gas bubbles of small size.

A further object is the provision of means which occupies a small space and utilizes a small amount of liquid in washing a gaseous fluid.

A still further object is the provision of means for the purpose noted which is of simple and inexpensive construction and which requires a comparatively small amount of power to operate.

The above objects are attained by providing means comprising an impeller adapted to be rotated in the body of the washing liquid, and a suitable stator or cage which surrounds the impeller. The gaseous fluid to be washed is introduced into the body of the liquid beneath the impeller, the rotation of which provides a source of energy to break up the gaseous fluid into bubbles of the required size. This energy is applied as centrifugal force. Since centrifugal force is proportional to mass, and when it is considered that the ratio of the mass of a liquid to the mass of a gas is generally of the order of 800 to 1, it will be seen that the bulk of the gas will be kept close to the axis of rotation of the impeller and the liquid will be thrown outwardly away from the axis of rotation. However, depending upon the amount of the gaseous fluid introduced and the turbulent state of the liquid, a certain quantity of the gaseous fluid will become entrained in the liquid in different sizes of bubbles, each of which will have a lifting force proportional to the volume of liquid displaced. The lifting force of each bubble tends to cause it to rise upwardly through the liquid and it will be observed that the larger bubbles will begin to rise more closely adjacent the periphery of the impeller than the smaller bubbles. Hence, the smaller bubbles will be carried further outwardly before they rise a predetermined distance vertically. Thus by providing a stator comprising an annular vertical wall suitably spaced from the periphery of the impeller, the large size bubbles will rise between the impeller and the wall, and the small-size bubbles will rise outwardly of the wall. By suitably spacing the annular wall from the impeller, the small-size bubbles which have a large surface area compared to volume are permitted to rise upwardly through the liquid. By providing the stator with a frusto-conical hood tapering upwardly and inwardly from the annular vertical wall and open at its top, the large-size bubbles may be directed beneath a second impeller and stator wherein the above described operation is repeated. Any suitable number of impellers and stators may be provided so that all of the gaseous fluid will be discharged into the body of the liquid in sufficiently small-size bubbles to assure a thorough washing of the gaseous fluid.

Bearing the above in mind, it will be observed that by providing a frusto-conical impeller and suitably arranging it within the frusto-conical hood of the stator, a generally downward current is created preventing the large-size gas bubbles from rising between the impeller and stator.

Preferably, in this arrangement, the annular wall of the stator extends downwardly of the base of the impeller so that a portion of the liquid and entrained gaseous fluid is reflected toward the axis of rotation to repeat the described cycle. In this arrangement, only the exceedingly fine bubbles escape beyond the annular wall of the stator whence they are free to rise upwardly through the body of the liquid. Further, we have found that by making the last referred to impeller substantially hollow to provide an inner conical surface, tapering downwardly and outwardly of the axis of rotation and providing a frusto-conical hub portion tapering upwardly and outwardly of the axis of rotation, the turbulence of the liquid and the circulation of the gaseous fluid is materially enhanced facilitating breaking up of the gaseous fluid into small-size bubbles. It will be observed, therefore, that the liquid in which the gaseous fluid is entrained in exceedingly fine bubbles is discharged outwardly of the stator by centrifugal force and the large-size bubbles, together with a portion of the liquid, is returned to the center to repeat the cycle. An impeller of a certain diameter and rotated at a given R. P. M. will only break up a certain quantity of gas. If an excess is supplied the bubble size getting out of the stator will increase. For handling more than the possible optimum per impeller, we propose to use a simple cylindrical stator, allowing the quantity of the gas bubbles which will get between the impeller and stator to rise and get into the center current of a suitably arranged second impeller, which is provided with the above described stator comprising a cylindrical portion and frusto-conical hood. If the quantity of gaseous fluid to be handled is still greater any number of appropriate impellers and stators may be employed. Preferably the impellers are all mounted for rotation about a common axis.

Now, in order to acquaint those skilled in the art with the manner of utilizing our invention, we shall describe in conjunction with the accompanying drawing preferred embodiments thereof as employed in a gas washer.

In the drawing:

Figure 1 is a fragmentary diagrammatic illustration of an apparatus embodying our invention;

Figure 2 is a vertical sectional view, largely diagrammatic, of a gas washer constructed in accordance with our invention;

Figure 3 is a horizontal sectional view taken on line 3—3 of Figure 2, looking in the direction indicated by the arrows;

Figure 4 is a vertical sectional view, largely diagrammatic of a modified form of gas washer illustrating the application of our invention as applied to a three stage gas washer; and

Figure 5 is a detail sectional view of a modified form of means for introducing the gaseous fluid into the washing liquid.

Referring now to Figure 1, we have illustrated, diagrammatically, two disc impellers **1** arranged in vertical alignment and mounted upon a shaft **2** for rotation about a vertical axis. A stator **3**, open at its top and bottom, surrounds each impeller **1**, and comprises an annular vertical skirt portion **4**, and a frusto-conical upper hood portion **5** tapering upwardly of and inwardly toward the axis of rotation of shaft **2**. It will be understood that the impellers **1** and stators **3** are submerged in a body of the washing liquid in a suitable tank or receptacle having a gaseous fluid inlet and outlet, and a liquid inlet and outlet such as shown in Figure 2. The gaseous fluid to be washed is admitted into the body of washing liquid below the lowermost impeller **1**, and rotation of the latter will throw liquid outwardly of the axis of rotation of shaft **2** by centrifugal force. The gaseous fluid being admitted beneath the lowermost impeller will become entrained in the liquid in bubbles of different sizes in the manner above described. As already noted, these bubbles will each have a lifting force proportional to the volume of the liquid displaced. It will be observed, therefore, that the large-size bubbles, as shown in the drawing, will begin to rise immediately beyond the outer periphery of the impeller, and as the bubbles decrease in size they begin to rise farther away from the axis of rotation of the impeller. Now the impeller and stator are arranged so that the skirt portion **4** defines a wall beyond which gas bubbles of sufficiently small-size to be thoroughly washed by passing upwardly through the body of the liquid are discharged. A suitable gas space is provided above the surface of the liquid for collecting the washed gas. The larger gas bubbles, i. e., those which begin to rise within the periphery of skirt portion **4** are of such size that the surface area thereof compared to volume is small, and hence would not be adequately washed if they were allowed to rise through the liquid to the surface thereof. It will be observed that the frusto-conical hood portion **5** of the lowermost stator will cause these large gas bubbles to be directed inwardly toward the shaft **2**, so that they come into contact with a second impeller **1** immediately above the lowermost stator **3** where the operation just described will again be repeated. Thus, a plurality of stators and impellers may be arranged in a vertical row to assure that all the gas will be dispersed in the body of the liquid in extremely small-size bubbles. The number and dimensions of impellers and stators required will be dependent upon the volume of gaseous fluid to be washed. It will be observed that the fineness of the bubbles permitted to escape beyond the periphery of the skirt portion **4** may be controlled by varying the distance of the skirt portion from the axis of rotation of shaft **2**.

Reference may now be had to Figure 2 wherein we have shown a closed tank **6** which is adapted to maintain a suitable washing liquid. Inlet and outlet conduits **7** and **8**, respectively, are provided in the lower portion of the tank for admitting and withdrawing the washing liquid from the tank. The washing liquid preferably should be maintained at a level somewhat below the upper portion of the tank **6** to provide a gas space **9**. A gas inlet conduit **10** extends through the bottom of the tank **6**, and a gas outlet conduit **11** extends through the upper end of the tank in communication with the gas space **9**.

The impeller and stator means of Figure 2 is indicated generally by the reference numeral **12**. A vertically extending shaft **14** is suitably supported for rotation in a supporting structure comprising a plurality of vertically extending leg members **15**, from which spider arms **17** extend horizontally inwardly toward the shaft **14**. The inner ends of the arm **17** are suitably secured in bearing blocks **18**, the latter being adapted to rotatably support the shaft **14**. The shaft **14** extends through the upper end of the tank and is adapted to be rotated by any suitable means, for example, by the electric motor **20**. The lower end of each vertically extending leg **15** has a foot portion **31** which rests on the bottom of the tank. A hollow frusto-conical impeller 22 is suitably secured to the shaft 14, as by a press fit, or if desired, the impeller may be keyed to the shaft. The impeller 22 comprises outer and inner frusto-conical surfaces 23 and 24, respectively, which taper outwardly from and downwardly of the axis of rotation of the shaft 14, and a frusto-conical hub portion 25 which tapers upwardly from and outwardly of the axis of the shaft 14. A stator 30 surrounds the impeller 22 and comprises a frusto-conical hood portion 31 and a vertically extending annular skirt portion 34. Suitable baffle members 36 are secured to the outer periphery of the depending skirt portion 34, as by welding, and serve as a means for supporting the stator in spaced relation to the impeller. The baffle members 36 preferably are formed of strips of light sheet metal or other suitable material which will not react with the gaseous fluid and liquid being used, and are adapted to be secured, one to each of the legs 15, by the nuts and bolts 38, or in any other suitable manner. The stator, by reason of this construction, is adjustably vertically relative to the impeller 22.

It will be observed that the frusto-conical surface 37 of the stator is tapered to conform with the taper of the outer or exterior frusto-conical surface 23 of the impeller, and the stator is positioned relative to the impeller so that the surfaces 37 and 38 define a passageway 39 between them.

Now, when gaseous fluid is admitted into the lower end of the tank through the conduit 10, the gaseous fluid will bubble through the liquid in the tank until the bubbles come into contact with the surface of the frusto-conical hub portion 25 of the impeller and will be deflected against the inside frusto-conical surface 24 of the impeller, whence they will be directed generally downwardly and outwardly of the axis of rotation of the impeller and against wall 34. Rotation of impeller 22 will draw a continuous stream of liquid in through the open top of the stator, and this continuous stream will be directed downwardly through and rotated in the passageway 39, as indicated by the arrows. It will be observed that the impeller will cause liquid and gaseous fluid, the latter being entrained in the fluid in varying sizes of bubbles, to be discharged outwardly of the axis of rotation of the shaft 14 by centrifugal force. The extremely small-size gas bubbles, as before, will be carried beyond the periphery of wall 34 where they are free to rise upwardly through the body of the liquid surrounding the stator and into gas space 9. The large-size bubbles within the periphery of wall 34 would normally tend to rise upwardly, but since a continuous stream of liquid is being drawn downwardly through the passage 39, they do not have sufficient force to escape upwardly through the passage 39. Further, it will be remembered that liquid containing entrained gaseous fluid in the form of bubbles and the downwardly directed stream of liquid are both being directed against the wall 34. The cylindrical wall 34 causes the large-size gas bubbles to be broken up or reflected inwardly toward the center together with a portion of the liquid. Thus some of the large-size gas bubbles will be broken up into sufficiently small sizes to be carried beyond the cylindrical wall 34 with the liquid by centrifugal force. The remaining large-size gas bubbles are thus recirculated, as indicated by the arrows, until they are of sufficiently small size to be carried outwardly of the wall 34.

Rotation of the impeller 22 tends to impart a rotary motion to the entire body of washing liquid, and we have found it desirable to provide the baffles 36, previously referred to, which prevent rotary motion of the body of liquid surrounding or outside of the stator. The inner and outer frusto-conical surfaces 23 and 24 and hub 25 are preferably smooth, highly polished surfaces, so that there is little friction of these surfaces with the washing liquid. Hence only a minimum amount of power is required to rotate the impeller in the liquid.

It is appropriate to point out at this time that the construction just described effects a high degree of turbulence of the liquid and consequently aids in the entrainment of the gaseous fluid therein.

It has been observed that as the gaseous fluid rises along the shaft 14, it comes into contact with the frusto-conical surface of the hub 25. The lifting force of the gas bubbles is a vertically and upwardly directed force, and we have found in a device constructed as above described, that if diametrically opposite elements on the surface of revolution of the hub portion 25 define an angle of substantially 60°, the gaseous fluid will be satisfactorily directed against the frusto-conical surface 24 with minimum friction losses. Also by constructing the impeller and stator so that the outer and inner frusto-conical surfaces 24 and 23 of the impeller and the inside frusto-conical surface 37 of the stator are at an angle of substantially 45° to the horizontal friction losses with the liquid will be at a minimum. When these surfaces are formed at this angle, a sufficient stream of the liquid is drawn downwardly through passage 39 and adequate deflection of the stream of gaseous fluid and liquid off of the skirt portion 34 of the stator for the purposes already described is attained.

Now if it is desired to wash large volumes of gas which the single impeller and stator, last described, cannot adequately handle, or to assure a still more intimate mixture of the gaseous fluid with the liquid, we propose to provide a plurality of impellers and stators, as shown in Figure 3. This apparatus comprises a three stage machine with one impeller and stator constituting a single stage.

A plurality of impellers 22a, 22b, and 22c are suitably fixed to the shaft 14' for rotation thereby. A stator 30' is associated with the uppermost impeller 22c, a stator 50 is associated with the intermediate impeller 22b, and a stator 30'' is associated with the lowermost impeller 22a. Each of the stators have secured to the outer peripheral portions thereof baffles 36' serving the same purpose in this assembly as the embodiment of Figure 2. The several stators are supported in spaced relation with respect to their respective impellers upon a supporting structure similar to that previously described, and the prime reference numerals indicate like or similar parts to those already described. In this embodiment of our invention, we have shown the shaft 14' extending through the upper end of the tank 6' and to which a suitable pulley wheel 51 is secured. The pulley wheel may be driven by any suitable source of power to rotate the shaft 14' and the several impellers. It will be seen that the lower stage comprises, the stator 30'' which is identical to the stator 30 already described, except that in this instance it is inverted so that the frusto-conical portion 31'' extends downwardly and inwardly of the axis of the shaft 14'. The impeller 22 associated therewith is arranged so that it rotates in the portion thereof defined by the annular skirt 34''. The stator 50 comprises an annular vertical skirt portion 52 in which the associated impeller 22a is adapted to rotate. The top or uppermost stage is arranged in an identical manner to the stator and impeller described in connection with Figure 2. It will be understood that the tank 6' is provided with a suitable base, and liquid inlets and outlets as in Figure 2.

Now, when gaseous fluid is admitted into the tank through the conduit 19' it rises upwardly through the open end 40'' of the stator 30'' around the shaft 14'. The hub portion 25' and the conical surface 24' of impeller 22a cause the gas bubbles to follow a path directed generally downwardly and outwardly against the conical wall 31''. The impeller and stator are also causing a stream of liquid to be directed downwardly, but with relatively small force since the impeller is rotating within the annular vertical wall portion 34''. The gas bubbles rise through this downwardly directed stream to the intermediate stage comprising the impeller 22b and the stator 50. If the gaseous fluid is being admitted in such large quantities that it cannot all be circulated to some extent by the lowermost stage, the excess will simply escape beyond the impeller 22a to the intermediate stage without first being circulated as noted. Obviously any number of stators and impellers may be arranged in a row as are necessary to prevent the gaseous fluid from bubbling upwardly through the receptacle without being broken up into small-size bubbles in at least one of the several stages. Referring again to the intermediate stage it will be seen that the stator 50 comprises a cylindrical wall member 52 which is supported adjacent the impeller 22b by means of the baffles 36' and is adjustable vertically relative to the impeller by means of the nuts and bolts 38'. If the stator is positioned as shown in full lines in the drawing, i. e., more closely adjacent the lowermost stator 22a than the uppermost stator 22c, substantially no gas bubbles will be discharged between the lowermost stator and the intermediate stator. This is due to the fact that the annular skirt portion 52 extends downwardly to such an extent that the gas bubbles cannot escape, but rather will rise upwardly through the stream of liquid being directed downwardly by the impeller 22b and the stator 50. With such an arrangement of the several stages substantially all of the gaseous fluid will be discharged between the uppermost and intermediate stators. The uppermost stage is identical to the preceding embodiment described, and the action at this state of the apparatus is the same as has already been described. The force of the stream of liquid being directed downwardly at the uppermost stage is greater than that of either of the other stages due to the arrangement of the hood portion 31' of the stator 30' and the associated impeller 22c so that the gas bubbles cannot pass upwardly beyond the outer periphery of the impeller 22c and through the passageway 39'.

If the intermediate stator 50 is positioned equidistant of the lowermost stator 39'' and uppermost stator 30' small-size gas bubbles will escape into the body of liquid between the several stators. Since the several stators are adjustable relative to their associated impellers, the sizes of the discharge gas bubbles and the places of discharge is subject to control, within limits, to meet any particular requirement.

We have observed in a device constructed in accordance with this embodiment of our invention, that the gaseous fluid hugs the shaft 14' in fairly large size bubbles in passing between the adjacent impellers.

In Figure 4, we have shown a modified form of shaft 14'' for rotatably supporting one or more impellers 22'. We have conceived that the shaft 14'' may be hollow and the gaseous fluid to be washed may be conducted through this shaft and introduced into the liquid below the impeller 22', through a plurality of small perforations or openings 55 formed in the end of the shaft. Secured to the end of the shaft and closing the lower open end thereof is a conical member 62. Gaseous fluid issuing from the apertures 55 in the end of the shaft will be directed upwardly by the interior frusto-conical surface 63 of member 62 against the hub portion 25', and thereafter the gaseous fluid will be entrained with the liquid and discharged in the manner already described.

While in the above description we have specifically disclosed our invention in connection with a gas washing apparatus, it will be understood that the means of our invention may be employed for other purposes. For example, the invention might be readily adaptable to the chlorination of water or other instances in which it is desired to treat a liquid with a gaseous fluid. Further, it will appear that the invention is not limited specifically to diffusing a gaseous fluid in a liquid, since in practice the means disclosed herein may be employed in any method in which intimate mixture of one fluid with a different fluid is desired, for example, in forming an emulsion.

We claim:

1. In combination, a receptacle adapted to contain a liquid, a substantially frusto-conical hollow impeller mounted for rotation about a vertical axis in said receptacle and having an inside frusto-conical surface and an outside frusto-conical surface flaring downwardly and outwardly of said axis, said impeller having a frusto-conical hub portion tapering upwardly and outwardly of said axis, means for rotating said impeller about said axis, a stator open at its top and bottom and surrounding said impeller, said stator having a frusto-conical surface and a depending substantially vertical annular skirt portion, said impeller and said stator being arranged so that a continuous rotating stream of liquid is drawn downwardly through the open top of said stator between said frusto-conical surface of said stator and said outside frusto-conical surface of said impeller, means for introducing gaseous fluid into said receptacle below said impeller, said frusto-conical hub portion, said inside frusto-conical surface of said impeller and said skirt being adapted to cause said gaseous fluid to be discharged outwardly of said axis of rotation and beyond the open bottom of said stator in the form of minute globules entrained in said stream.

2. In combination, a receptacle adapted to contain a liquid, a substantially frusto-conical hollow impeller mounted for rotation about a vertical axis in said receptacle and having an inside frusto-conical surface and an outside frusto-conical surface flaring downwardly and outwardly of said axis, said impeller having a frusto-conical hub portion tapering upwardly

and outwardly of said axis, means for rotating said impeller about said axis, a stator open at its top and bottom and surrounding said impeller, said stator having a frusto-conical surface and a depending vertical annular skirt portion, said impeller and said stator being arranged so that a continuous rotating stream of liquid is drawn downwardly through the open top of said stator between said frusto-conical surface of said stator and said outside frusto-conical surface of said impeller, means for introducing gaseous fluid into said receptacle below said impeller, said frusto-conical hub portion, said inside frusto-conical surface of said impeller and said skirt being adapted to cause said gaseous fluid to be discharged outwardly of said axis of rotation and beyond the open bottom of said stator in the form of minute globules entrained in said stream, and baffle means for preventing rotation of the body of liquid in said receptacle surrounding said stream of liquid.

3. In combination, a receptacle adapted to contain a liquid, a substantially frusto-conical hollow impeller mounted for rotation about a vertical axis in said receptacle and having an inside frusto-conical surface and an outside frusto-conical surface flaring downwardly and outwardly of said axis, a stator open at its top and bottom and surrounding said impeller, said impeller and said stator being arranged so that liquid is drawn downwardly through the open top of said stator between the latter and said outside frusto-conical surface of said impeller upon rotation of said impeller, and means for introducing fluid into said receptacle below said impeller, said inside frusto-conical surface of said impeller and said stator being adapted to cause said fluid to become entrained in said liquid and circulated therewith below said impeller upon rotation of the latter.

4. In combination, a receptacle adapted to contain a liquid, a plurality of substantially frusto-conical hollow impellers spaced vertically and mounted for rotation about a common vertical axis in said receptacle, each of said impellers comprising an outside frusto-conical surface and an inside frusto-conical surface flaring downwardly and outwardly of said axis, a plurality of stators open at their tops and bottoms one surrounding each of said impellers, said impellers and stators being arranged so that upon rotation of said impellers liquid is drawn downwardly through the open tops of said stators and between the latter and the outside frusto-conical surfaces of said impellers, and means for introducing fluid into said receptacle below the lowermost impeller, said inside frusto-conical surfaces of said impellers and said stators being adapted to cause said fluid to become entrained in said liquid and circulated therewith below said impellers upon rotation of the latter.

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