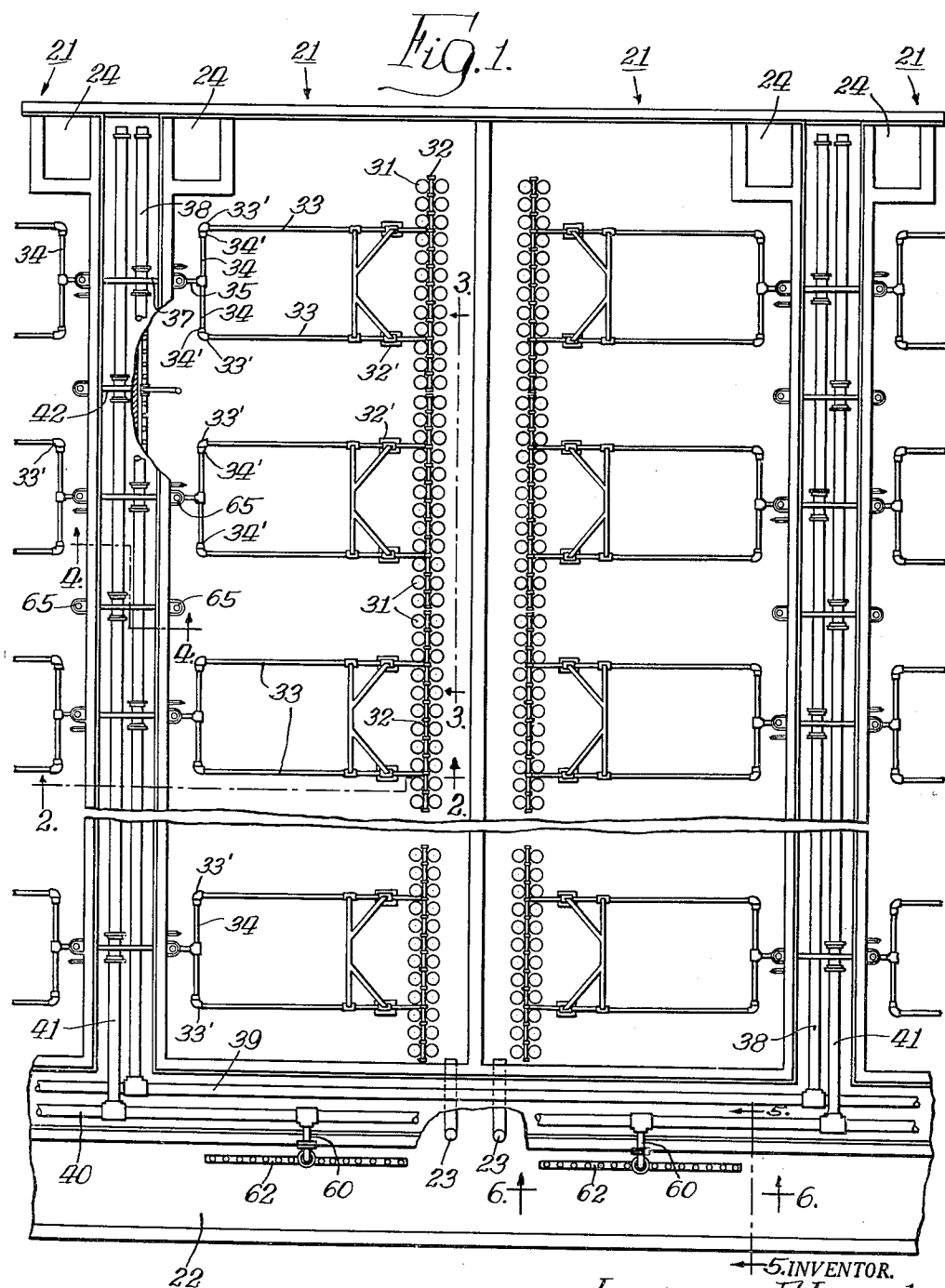


L. E. LANGDON
GAS DIFFUSING APPARATUS

Filed June 21, 1956

5 Sheets-Sheet 1



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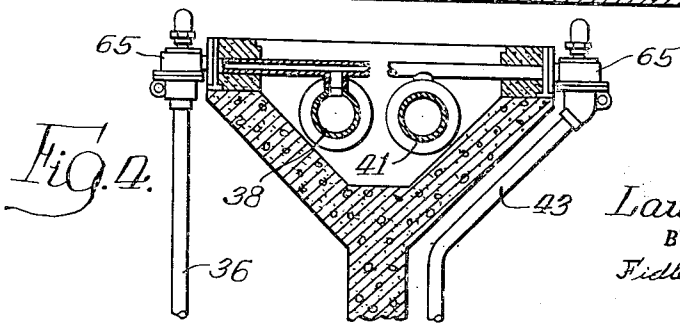
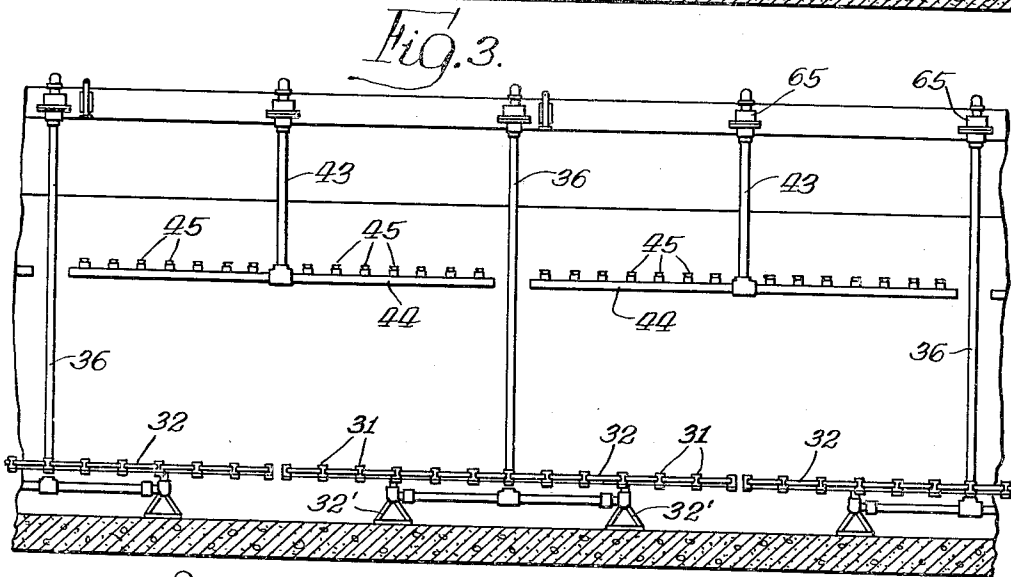
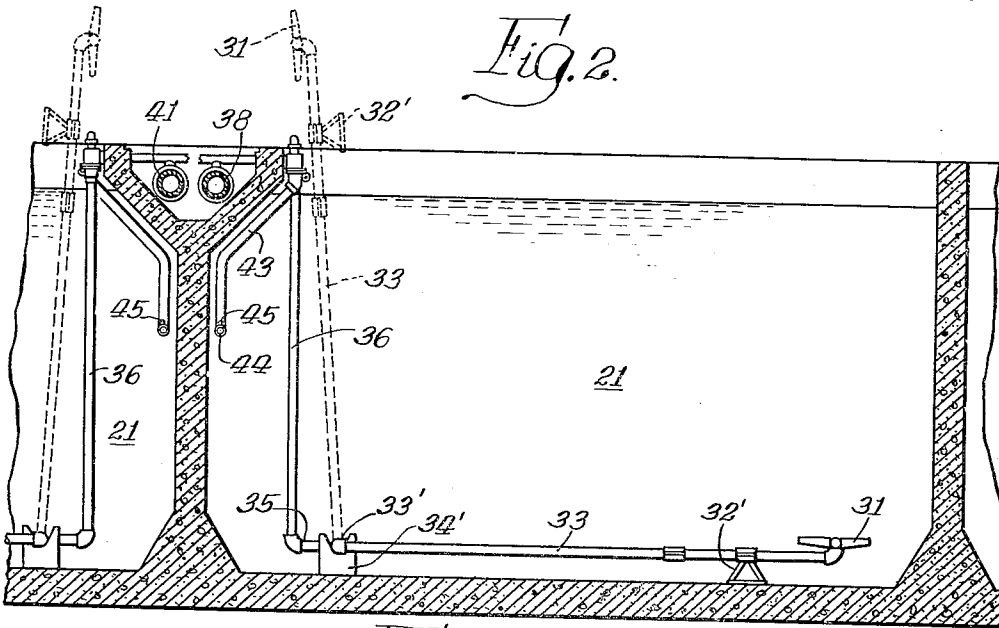
May 30, 1961

L. E. LANGDON
GAS DIFFUSING APPARATUS

2,986,382

Filed June 21, 1956

5 Sheets-Sheet 2



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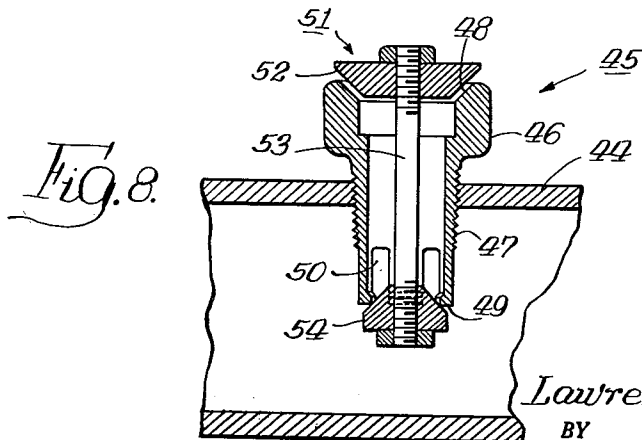
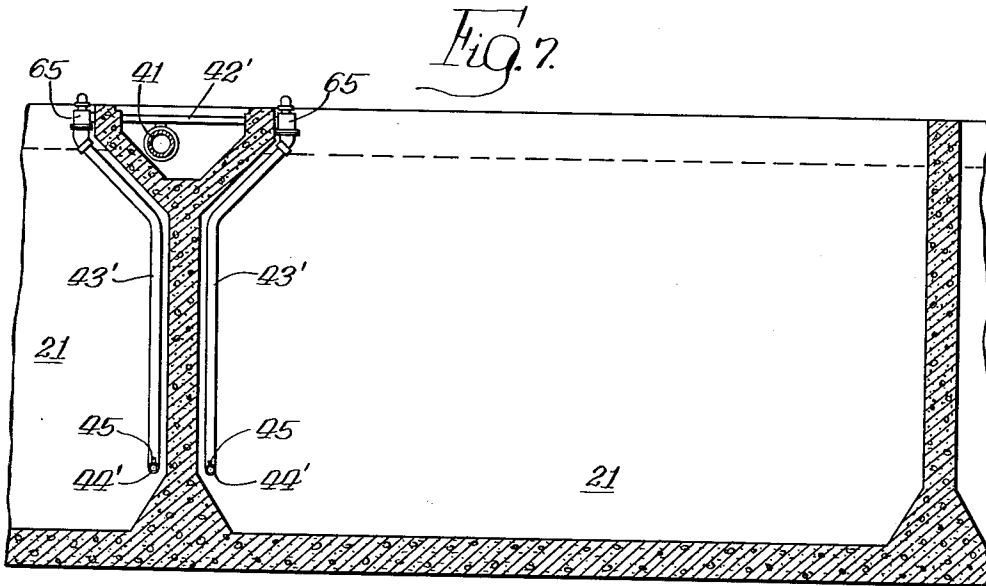
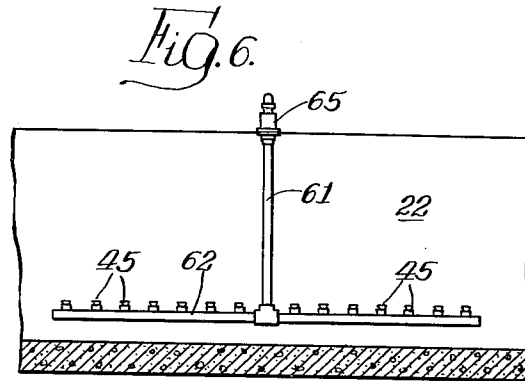
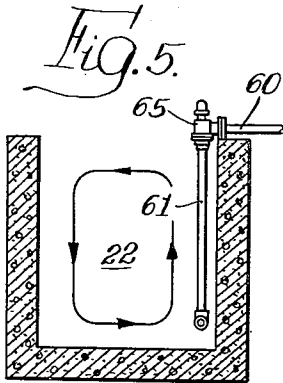
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GAS DIFFUSING APPARATUS

2,986,382

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5 Sheets-Sheet 3



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2,986,382

Filed June 21, 1956

5 Sheets-Sheet 4

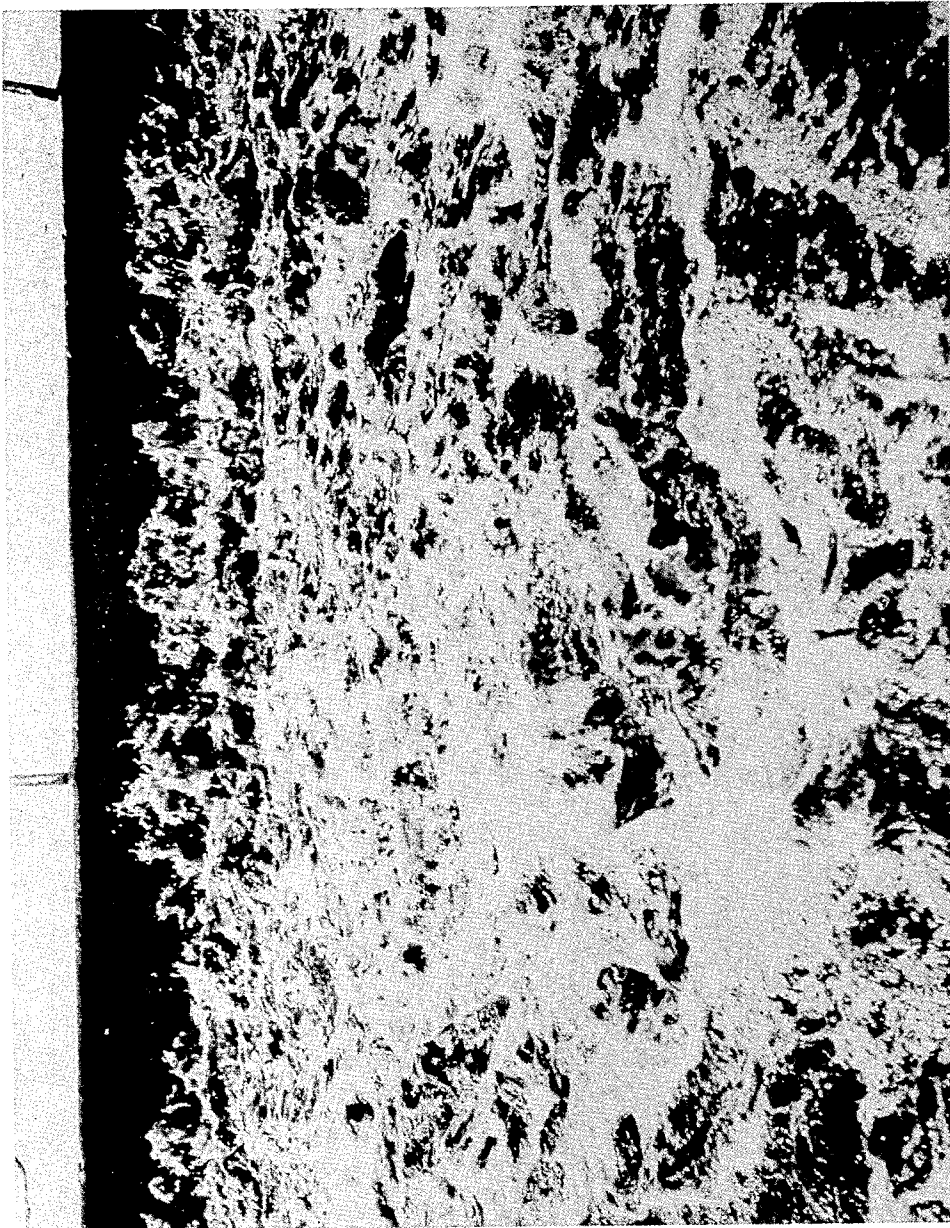


Fig. 9.

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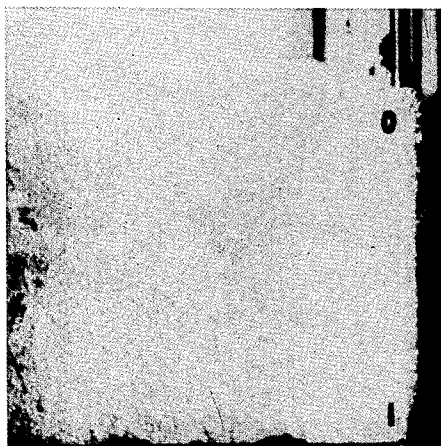
May 30, 1961

L. E. LANGDON
GAS DIFFUSING APPARATUS

2,986,382

Filed June 21, 1956

5 Sheets-Sheet 5



STATIC LEVEL
OF LIQUID

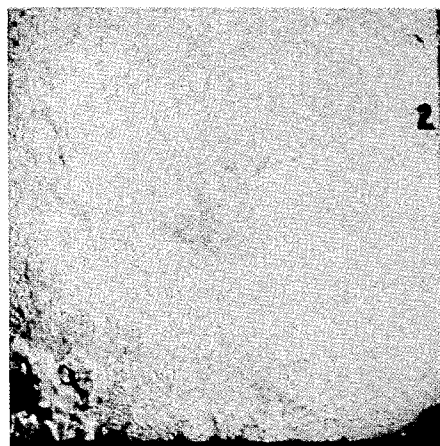


Fig. 10.

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2,986,382

GAS DIFFUSING APPARATUS

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Filed June 21, 1956, Ser. No. 592,969

11 Claims. (Cl. 261—124)

This invention relates to diffusion apparatus and has to do more particularly with apparatus for diffusing a gaseous material in a liquid. It is an object of the invention to provide improved apparatus of that character.

Diffusers for introducing a gaseous material into a liquid as heretofore known have taken various forms and two of the most common are what may be termed the "orifice" type and the porous member type.

In the orifice type of diffuser the diffuser is provided with one or more orifices, usually of relatively large diameter, through which the gaseous material is discharged into the liquid. This type of diffuser is subject to two serious disadvantages. In the first place, it discharges the gaseous material into the liquid either in successive large bubbles or successive puffs or "globs" with the result that the gas is not distributed in the liquid, particularly at levels close to the level of the orifice. Moreover, where the liquid contains suspended solids of certain size and composition the latter tend to be forced into the gas line by the liquid pressure whenever the gas supply is shut off and eventually such solids clog the orifice or orifices with the result that it is necessary to clean the discharge element either by removing it from the tank, or other container for the liquid, or by draining the tank.

One example of use where such clogging has been troublesome is in connection with aerators for aeration tanks used in sewage treatment. In such tanks the liquid to be aerated contains suspended solids of such size and composition that upon each shut-off of the air pressure the solids enter the orifices in the aerators and upon repeated shutdowns, tend to clog the orifices.

The porous member type of aerator includes a member formed for example of ceramic material and having a large number of relatively minute openings through which the gas is discharged. Such member requires that the gas be thoroughly filtered or cleaned prior to reaching the diffuser element. If such cleaning or filtering is not effected the solid particles that are almost always present in the air soon clog the very fine pores in the aerator element and necessitate cleaning of the latter which is time consuming and expensive and eventually requires replacement of the element. The porous member type also requires a substantial air pressure in order to pass a significant flow of gas because of the smallness of the pores.

In accordance with one feature of the present invention a diffuser is provided which has the characteristic of preventing back-flow of liquid into the gas supply line whereby plugging of the diffuser is prevented. At the same time this diffuser has relatively little pressure drop thereacross, is not subject to plugging by foreign matter suspended in the supply of gas, and produces fine bubbles of gas in the liquid whereby good diffusion is obtained.

Still further, the same device produces turbulence at the surface of the liquid whereby any gas, such as air, which is above the top surface of the liquid may be absorbed by the liquid in considerable quantities. It will be apparent therefore that a diffuser device constructed

2

in accordance with the invention may be used individually as an effective means of diffusing a gas in a liquid.

A second feature of the invention involves the use of a plurality of such devices in closely spaced relationship, each device abetting the diffusion of gas in the liquid by adjacent devices, whereby the total diffusion of gas in the liquid may be greater than would be the total diffusion of the individual devices operating independently.

Still another feature of the invention involves the use of one or more of such diffusers acting as combination diffusers and distributors and working in combination with other diffusers, the latter being of the porous type described above, the novel type disclosed herein, or any other suitable type. In such an arrangement gas from the novel form of diffuser not only diffuses gas and produces turbulence at the surface of the liquid, but also may cause a general flow of the liquid downwardly over the other diffusers such that fine air bubbles from the latter are maintained under water for a greater length of time than would otherwise be the case.

Accordingly, it is another object of the invention to provide an improved device for diffusing gas in a liquid which may operate on a substantially lower gas pressure than does a porous type diffuser, which prevents the reverse flow of liquid into the gas supply line, which is not subject to clogging by foreign matter in the gas supply, which produces fine gas bubbles within the liquid, and which may be employed to produce turbulence at the surface of the liquid.

It is another object of the invention to provide improved apparatus for diffusing gas in a liquid incorporating a plurality of diffusers in closely spaced relationship and having the characteristics mentioned above, and which cooperate with each other to produce greater diffusion of gas into the liquid than might be obtained by the same number of diffusers operating independently.

It is another object of the invention to provide improved apparatus for diffusing gas in a liquid in which novel gas diffusion and distributing means cause substantial diffusion of gas in the liquid and causing a downward flow of liquid over other diffusers.

This invention, together with further objects and advantages thereof, will best be understood by reference to the following description taken in connection with the accompanying drawings, and its scope will be pointed out in the appended claims.

In the drawings in which like parts are designated by like reference numerals:

Fig. 1 is a fragmentary plan view partially broken away of sewage aerating apparatus incorporating various features of the present invention;

Fig. 2 is an enlarged cross-sectional view taken along the line 2—2 of Fig. 1;

Fig. 3 is an enlarged cross-sectional view taken along the line 3—3 of Fig. 1;

Fig. 4 is an enlarged cross-sectional view taken along the line 4—4 of Fig. 1;

Fig. 5 is an enlarged cross-sectional view taken along the line 5—5 of Fig. 1;

Fig. 6 is an enlarged cross-sectional view taken along the line 6—6 of Fig. 1;

Fig. 7 is a view similar to Fig. 2 but illustrating another embodiment of the invention;

Fig. 8 is a cross-sectional view of a single diffuser employed in the apparatus of Fig. 1 and constituting one feature of the present invention;

Fig. 9 is a reproduction of a photograph showing the turbulence produced by the apparatus of Fig. 1 at the surface of the liquid; and

Fig. 10 is a reproduction of a series of photographs showing the distribution of gas in liquid as expelled from a pair of diffusers like that of Fig. 8.

This invention finds numerous applications in various fields wherein it is desired to diffuse a gas (or mixture of gases such as air) into a liquid or an essentially liquid material, such as a clear liquid or a liquid containing suspended solids. One important application of the invention is its use in diffusing air into the liquid in an aeration tank such as is commonly employed in the treatment of sewage. Aeration tanks are used for aerating raw sewage, either prior to sedimentation as in pre-aeration tanks, or in activated sludge aeration tanks wherein quantities of solids are returned in the form of activated sludge and which must be held in suspension by the agitating action of the released air. Even where considerable solids are added to the activated sludge aeration tank the material is essentially liquid. The invention is shown and described in connection with such type of tank although it will be understood it is not limited to such use, and that the various features of the invention are applicable to various other uses wherein it is desired to diffuse a gas in a liquid.

It is to be understood that the term "liquid" as used herein refers to a liquid material which may be clear liquid or a liquid containing suspended and/or dissolved solids.

In the particular embodiment of the invention shown in Figs. 1 to 6 of the drawings the installation includes a substantial number of aeration tanks 21. Sewage is delivered to the tanks 21 by a supply channel 22, the liquid flowing along the channel 22 and through valved inlets 23 to the individual aeration tanks 21. After the liquid in the individual tanks has been aerated, overflow liquid in the tanks 21 is permitted to escape through passages 24, the liquid flowing over suitable flow control weirs (not shown in the drawings).

The liquid in the aeration tanks 21 is preferably aerated to increase the oxygen content thereof using at least in part for this purpose aeration means constructed in accordance with the present invention.

In accordance with one embodiment of the present invention, two different sets of diffusers are employed for aerating the liquid. One set may comprise porous type diffusers 31, a plurality of which are arranged in two parallel rows along the entire length of the individual tanks. As may be seen best in Fig. 2, these diffusers are arranged close to the bottoms of the tanks and adjacent one longitudinal side thereof. This set of diffusers may be of any desired type including the novel form disclosed herein.

Where porous type diffusers are employed they may be of various forms, the preferred form being sintered ceramic material. Such material is readily provided with very fine pores through which air may pass in extremely fine streams. When air is supplied under substantial pressure, the result is a succession of minute air bubbles escaping through a large number of pores. This is desirable since the division of a given volume of air into a large number of small bubbles increases the total air to water surface, and it is of course at the boundary surface between the air and the water that absorption of oxygen by the water takes place. Furthermore, small bubbles tend to rise more slowly than large bubbles, with the result that small air bubbles remain under water for a greater length of time. It will be noted that the diffusers 31 are circular in plan view. Such a diffuser is disclosed in detail and claimed in application Serial No. 735,884, entitled Gas Diffusion Apparatus, filed May 16, 1958, by Lawrence E. Langdon and Marion Richard Stiles.

The porous type diffusers 31 are supported and fed with air under pressure by pipes 32 which extend along the bottoms of the tanks, each pipe supporting and feeding a large number of these diffusers. Air is fed to the pipes 32 by pipes 33, 34, 35, 36 (see Fig. 2), and 37. The latter pipe connects to a header 38 which extends along the length of the tanks 21 and feeds all of the porous type diffusers of two adjacent settling tanks. The

headers 38 in turn connect to a main header 39 extending along the ends of the tanks.

The pairs of pipes 33 feeding a given pipe 32 are preferably braced, as shown in Fig. 1, to form a rigid unitary construction, and are preferably hingedly connected to the pipes 34 through any suitable connector 33' such that an entire diffuser assembly may be pivotally raised to the position shown in dotted lines in Fig. 2. As seen in Figs. 1 and 2, the pipes 34 are rigidly supported near their ends by suitable brackets 34' to support the diffuser assembly in its raised position, and feet 32' are provided for supporting the diffuser assembly just off the bottom of the tank in operating position. This arrangement facilitates the cleaning of both the tank and the diffusers, the latter being shown just above the tank wall when in raised position. By proper positioning of the pivotal connectors 33' the diffusers may swing upwardly to positions just above the tank walls where they may readily be in-spaced and worked on, all as indicated in Fig. 2.

The air supplied through the above described headers and pipes to the porous type diffusers 31 is necessarily of relatively high pressure. This is partly because the diffusers are arranged near the bottoms of the tanks where there is a water pressure of several pounds, but primarily because the pressure drop through the diffusers with a substantial flow of air therethrough is quite significant. An objectionable amount of power is, in fact, required to force the required amount of air through porous type diffusers if these diffusers are the sole source of air.

In accordance with the present invention, novel means are provided for injecting additional air into the tanks 21 and for effecting a circulation of the air injected by the porous type diffusers. A main header 40 extending along the ends of the tanks supplies low pressure air to headers 41. These extend along the length of the tanks, one header supplying two adjacent tanks. The headers 41 supply low-pressure air to pipes 42 and, as may be seen in Figs. 2 and 3, to pipes 43 and 44, each of which feeds and supports a plurality of novel diffusion devices 45. Alternative to the arrangement seen best in Figs. 1, 2 and 3, these diffusers (not shown) may be supported at opposite sides of the pipe 44, similarly to the porous type diffusers 31, and may be arranged in staggered relationship.

The diffusers 45 can supply large amounts of air to the tanks with relatively little pressure drop. This is partly because they are at a substantially lesser depth than the porous type diffusers 31, but primarily because there is substantially no pressure drop thereacross.

One embodiment of the novel diffuser device 45 is shown in detail in Fig. 8. It includes a body portion 46 having external threads 47 whereby it may be threaded into a tapped opening in the pipe 44. The body portion includes a valve seat 48, a valve stop seat 49, and suitable openings 50 for permitting free passage of air from the supply pipe 44 to the interior of the body member. A movable valve member 51 is also provided. This includes a valve 52, a stem 53, and an adjustable stop element 54 for engaging the valve stop seat 49.

It will be seen that the opening movement of this diffuser is limited by engagement of the element 54 with the valve stop 49. Accordingly, when the device is in its open position, a limited annular opening is provided between the valve 52 and the valve seat 48. It should also be noted that when the device is in its open position, the upper end of the valve member 51 is free to move laterally of the valve seat, to the extent that the valve 52 can engage the valve seat at one side with a corresponding increase in size of the annular opening at the opposite side.

Opening and closing of the diffuser is accomplished primarily through the action of air pressure and liquid pressure on the valve member. The valve member of course is subject to the action of gravity thereon, but this effect would normally be small and is not further considered herein. It is sufficient for the purpose of this application

to point out that the effect of gravity should be considered where precise operating characteristics are desired. If the air pressure is less than the liquid pressure the force of the latter retains the device in closed position, whereby the liquid is prevented from entering the body member 46 or the pipe 44. On the other hand, if the air pressure is substantially in excess of the liquid pressure, the valve member is raised thereby to its full open position, whereupon air is expelled into the surrounding liquid as long as the air pressure is maintained above the liquid pressure.

With air flowing through the orifice defined by the valve seat 48 and the tapered sides of the valve 52, the valve member 51 is unstable laterally, with the result that it sways continuously and rapidly. Basically, a cone-shaped stream or jet of air bubbles is emitted into the surrounding liquid, but because of the fact that the upper end of the valve member 51 is tilted and tends to "wobble," a heavier stream of air is emitted where the annular opening is thus made larger and this heavier stream of air also tends to move about the axis of the valve, with the result that the stream of air bubbles, as it rises in the liquid, is in the form of an upwardly expanding spiral. This effect is well illustrated in Fig. 10.

The cone-shaped stream or jet of air expelled by this device tends to break into fine bubbles, and the wobbling of the upper end of the valve member 51 further tends to break the air stream into fine bubbles.

An illustration of the diffusion produced by the present invention is shown in Fig. 10. This figure is a reproduction of three photographs, taken at different levels, of a tank containing a liquid in which a pipe is located at the bottom of the tank and is provided with a plurality of diffusers constructed in accordance with the present invention. The numerals at the sides of the several sections of Fig. 10 indicate the depth of the liquid in the tank, it being understood that the three photographs do not comprise a continuous showing of the tank and its contents. It may readily be seen that with the diffusers 5 feet below the surface of the liquid, and the diffuser devices approximately 12 inches apart the streams of air bubbles from the two adjacent aeration devices mingle and produce uniform diffusion at a depth of about 3½ feet, or 18 inches above the devices 45. The air stream leaving the right-hand device may be seen in particular to be arranged in a vortex formation producing considerable turbulence. When the two streams of air bubbles mingle, the interference causes further turbulence. Attention is directed to the minute size of the air bubbles within the liquid.

Accordingly, it is apparent that the diffusing device 45 produces very fine gas bubbles in the surrounding liquid. This results in greater gas-to-liquid contact surface and correspondingly greater absorption of the gas by the liquid. As opposed to the porous type diffuser 31, there is very little pressure drop of the gas as it passes through the diffuser 45. As a practical matter, the principal factor in determining the air pressure it requires is the depth of the device below the level of the water. This greatly reduces the power required for injecting a given quantity of gas into a liquid in the form of fine bubbles. Still further, the air supplied to this diffusing device 45 need not be filtered since fine particles of matter suspended in the air will readily pass through the annular orifices. This further reduces the power requirements and eliminates the necessity of frequent cleaning of such a filter. A still further advantage of this device over a porous type diffuser is the fact that it does not require cleaning whereas the fine pores of a porous type diffuser invariably become clogged in spite of the fact that the air supply is filtered.

The diffusing device 45, as compared to a simple orifice or nozzle, has the advantage that it breaks the air up into fine bubbles rather than ejecting the air into the liquid in large bubbles or globs and relying upon turbulence to break these up into somewhat smaller bubbles. Furthermore, the diffusing device 45 prevents the reverse flow of liquid into the device and into the air pipes when the air

pressure fails or is cut off. The air pipes and the diffusing device are thereby maintained in clean, operating condition.

The diffusing device 45 furthermore acts as a distributor since it can eject large quantities of air and thereby produce great turbulence and a general current in the liquid. Referring to Fig. 2, it will be seen that the diffusing devices 45 and the porous type diffusers 31 are located at opposite sides of the tanks 21. The large quantities of air ejected by the devices 45 cause an upward current of the liquid thereabove. This current tends to carry across the top of the tank and downwardly over the porous type diffusers 31. This delays the rise of the fine air bubbles from the porous type diffusers and thereby allows a greater length of time for absorption of the air or oxygen by the water. Furthermore the large flow of air from the diffusing devices 45 violently agitates the water, the effect being enhanced by the sloping portion of the tank wall thereabove.

The overall effect may be seen in Fig. 9 where extreme agitation appears in the background adjacent the sloping wall portion over the diffusing devices 45. The entire surface of the liquid may be seen to be extremely choppy and covered with fine bubbles. As previously indicated, turbulence on the surface of the water results in substantial absorption of oxygen by the water from the overlying atmosphere.

In view of the above it will be seen that the diffusing device 45 has most of the advantages and none of the disadvantages of the conventional distributing orifice or nozzle, and of the conventional porous type diffuser.

One important characteristic of the diffusing device 45 is that it is operable by the gas and liquid pressures exerted thereagainst. A conical seat with a mating conical valve member is believed to be the most desirable construction, but it will be apparent that various other constructions may be employed, depending upon the results desired. The form of the valve stop is not critical with the exception that engagement of the valve member with the valve stop should be such that it does not materially counteract the tendency of the valve member to flutter or precess when air flows through the orifice. Assuming a given diameter of annular opening, the device may be constructed or adjusted to limit opening movement such that a relatively narrow annular opening is provided. This will call for a greater pressure to produce a given flow, but the increased velocity of the air through the annular orifice will produce greater turbulence and smaller air bubbles. Conversely, the annular opening may be made wider to permit a given flow of air with a smaller pressure.

In the preferred embodiment of the invention, where it is employed to aerate sewage or effluent, the diameter of the annular orifice is approximately $\frac{1}{16}$ inch at the bottom of the seat, and approximately 1 inch at the top of the seat, with a vertical valve movement of approximately $\frac{1}{4}$ inch and a normal opening width of approximately $\frac{3}{32}$ inch and a maximum opening width (when the valve is tilted) of approximately $\frac{5}{32}$ inch. The devices preferably are arranged on 12 inch centers. Under these conditions each device passes approximately 5 cubic feet of air per minute and there is substantially uniform distribution of air in the water 18 inches above the devices.

If it is desired to dewater any of the aeration tanks for servicing the air diffusion equipment or the tank or any of its appurtenances, this may be done inasmuch as there are multiple tanks and the process may continue with one tank out of service. When one tank 21 is thus drained, the remaining tanks may remain in operation. This is not true of the supply channel 22 which feeds the sewage to all of the aeration tanks 21. Accordingly, it is preferred that little or no settling take place in the supply channel 22. Air may be injected into the sewage in the supply channel by the diffusing devices 45, both to agitate the liquid to reduce settling and to provide preliminary aeration of the liquid.

The apparatus for accomplishing this may be very similar to that employed in the aerating tanks and is shown in Figs. 5 and 6. The main low pressure header 40 may feed low pressure air to pipes 60 and 61 and into pipes 62 arranged near the bottom of the supply channel and adjacent one side thereof. A plurality of diffusing devices 45 may be associated with each pipe 62.

It will be apparent that as substantial amounts of low pressure air are pumped through these devices circulation of the liquid is established in the direction indicated in Figure 5. This tends to reduce settling of solids and at the same time provides preliminary aeration of the liquid.

A pressure regulating valve 65 is arranged at the juncture of the pipes 60 and 61, similar pressure regulating valves 65 being arranged in corresponding locations in the aerating apparatus for the aerating tanks 21. The purpose of such valves is to regulate the pressure in the individual air feeding systems such that those systems which are close to the supply source will not pass an excessive amount of air at the expense of those systems which are more remote from the supply source.

In accordance with the embodiment of the invention illustrated in Figs. 1-4, porous type diffusers are used in conjunction with the novel diffusing and distributing devices 45. Alternatively these latter devices may be employed in lieu of the porous type diffusers in the arrangement shown in Figs. 1 to 3.

In another embodiment of the invention diffuser devices similar to the device 45 above described may be employed as the sole diffusing means. In such case, the devices 45 are preferably located adjacent the bottom of the aerating tank in order to provide a greater period of time during which the air bubbles are within the sewage and hence a greater period of time for absorption of oxygen by the liquid. Such an arrangement is illustrated in Fig. 7. Here the low pressure header 41 feeds air to a pipe 42' which is common to the air system of two adjacent tanks. The air passes down through pipes 43' and into horizontally arranged pipes 44,. A plurality of the novel diffuser devices 45 are supported and fed by each pipe 44'. The arrangement shown in Figure 7 is suitable for any aerating installation but is particularly recommended for relatively small installations.

One specific form of the novel diffuser device 45 and various and specific applications and combinations of such device with other apparatus have been shown in the drawings and described herein. It will be apparent that the specific embodiments of the invention disclosed herein may be substantially modified without departing from the spirit of the invention.

Accordingly, it will be apparent that the invention may be varied in its physical embodiment without departing from the spirit of the invention, and it is desired, therefore, that the invention be limited only by the scope of the appended claims.

The invention having thus been described, what is claimed and desired to be secured by Letters Patent is:

1. Apparatus for aerating sewage in an elongated open top tank comprising a plurality of porous plate diffusers arranged along one long side of said tank adjacent the bottom thereof, means for connecting said diffusers to a source of high pressure air, a plurality of fixed diffuser devices arranged along the opposite long side of said tank substantially above the bottom of said tank, and means connecting said devices to a source of relatively low pressure air, each of said devices comprising means for discharging air therefrom in a stream of bubbles in the form of a progressively upwardly expanding spiral pattern of distribution about a vertical axis, said devices being disposed at the same level sufficiently below the level of said liquid and in laterally spaced positions relatively to one another at such distances that the streams intersect one another below the level of the liquid.

2. In apparatus for treating sewage including a plurality of elongated open top aeration tanks arranged in side-by-side relationship, a feeder channel extending along one

end of said tanks, means permitting the flow of liquid from feeder channel into each of said tanks, a plurality of fixed diffuser devices arranged along one side of said feeder channel, and means connecting said devices to a source of relatively low pressure air, each of said devices comprising valve means for discharging air therefrom in a stream of bubbles in the form of a progressively upwardly expanding spiral pattern of distribution about a vertical axis, said devices being disposed at the same level sufficiently below the level of the liquid and in laterally spaced positions relatively to one another at such distances that the streams intersect one another below the level of the liquid.

3. Apparatus for treating sewage comprising a plurality of elongated open top aeration tanks in side-by-side relationship, a feeder channel extending along one end of said tanks, means permitting the flow of liquid from said feeder channel into each of said tanks, a plurality of porous plate diffusers arranged along one long side of each of said tanks adjacent the bottom thereof, means for connecting said diffusers to a source of high pressure air, a plurality of fixed diffuser devices arranged along the opposite long side of each of said tanks substantially above the bottom thereof and along one side of said feeder channel, and means connecting said devices to a source of relatively low pressure air, each of said devices comprising means for discharging air therefrom in a stream of bubbles in the form of a progressively upwardly expanding spiral pattern of distribution about a vertical axis, said devices being disposed at the same level sufficiently below the level of the liquid and in laterally spaced positions relatively to one another at such distances that the streams intersect one another below the level of the liquid.

4. The combination with a tank for containing a body of liquid of apparatus for diffusing gas into the liquid in said tank, said diffusing apparatus comprising an air supply pipe leading into said tank and a plurality of laterally spaced diffuser devices each connected to said pipe and each having a single fixed orifice opening vertically upwardly and valve means for discharging gas into the liquid as a stream of bubbles in the form of a progressively upwardly expanding spiral pattern of distribution about a vertical axis, said several diffuser devices being disposed in positions relatively to one another at such distances that the streams of bubbles discharged therefrom intersect one another in the body of liquid.

5. The combination with a tank for containing a body of liquid of apparatus for diffusing gas into the liquid in said tank, said diffusing apparatus comprising an air supply pipe leading into said tank and a plurality of laterally spaced diffuser devices each connected to said pipe and each having a single fixed orifice opening vertically upwardly and valve means for discharging gas into the liquid as a stream of bubbles in the form of a progressively upwardly expanding spiral pattern of distribution about a vertical axis, said several diffuser devices being disposed at substantially the same level and spaced apart at distances not greater than one-half the depth of said apparatus below the level of the liquid, whereby the streams of bubbles discharged therefrom intersect one another in the body of liquid.

6. The combination with a tank for containing a body of liquid of apparatus for diffusing gas into the liquid, said diffusing apparatus comprising a first diffusing means in said tank including a porous diffuser element having relatively small discharge openings, a source of relatively high pressure air connected to said first diffusing means, a second diffusing means in said tank at a level above said first diffusing means, including a plurality of diffuser devices each having a single fixed, relatively large discharge opening directed vertically upwardly, and valve means for discharging gas from different points progressively around the periphery of said opening as a stream of bubbles in the form of a progressively upwardly expanding spiral pattern of distribution about a vertical axis thereby to effect mixing of the gas with the liquid in both horizontal

and vertical directions and a source of relatively low pressure air connected to said second diffusing means.

7. Apparatus for aerating a liquid comprising a tank for containing the liquid to be aerated and a plurality of diffuser devices in each tank, each of said devices having a single, fixed, relatively large discharge opening directed vertically upwardly and valve means for discharging air into said tank from different portions of said orifice progressively around the periphery of said orifice as a stream of bubbles in the form of a progressively upwardly expanding spiral pattern of distribution, said devices being positioned at points sufficiently below the level of the liquid and spaced apart at such distances that streams from adjacent diffuser devices intersect below the level of the liquid in said tank.

8. Apparatus for aerating sewage which comprises a tank for containing sewage in essentially liquid form, diffusing means for introducing into the sewage in the tank a plurality of streams of finely diffused air under relatively high pressure, a plurality of diffuser devices disposed in said tank at the same height above the level of said diffusing means for discharging into the contents of said tank a plurality of separate streams of air bubbles at substantially lower pressure than said first streams and each in the form of a progressively upwardly expanding spiral pattern of distribution about a vertical axis, said diffuser devices being disposed at points spaced apart at distances whereby adjacent streams intersect at levels below the surface of the tank contents.

9. The method of aerating a liquid which comprises introducing into a body of liquid to be aerated a plurality of streams of bubbles of air, each stream being formed by discharging air in the form of a jet of bubbles from different portions of said orifice progressively around the periphery of a single stationary orifice opening vertically upwardly into said body of liquid to form a progressively upwardly expanding spiral pattern of distribution, the several streams being introduced into the body of liquid at the same level and at a sufficient distance below the surface of the liquid and spaced apart at distances sufficient whereby said streams intersect below the surface of the liquid.

10. The method of aerating sewage in essentially liquid form which comprises introducing into a body of sewage a plurality of streams of finely diffused air under relatively high pressure, introducing into the body of sewage at a level above the level of introduction of said finely

diffused air a plurality of streams of air bubbles at lower pressures than said first streams, each of said latter streams being formed by discharging air in the form of a jet of bubbles from a single orifice opening vertically upwardly into said body of liquid, the jet being discharged from different portions of the orifice progressively around the periphery of the orifice, and the several streams being introduced into the body of liquid at a sufficient distance below the surface of the liquid and spaced apart at distances whereby said streams intersect below the surface of the liquid.

11. Apparatus for aerating a liquid comprising a tank for containing the liquid to be aerated, a plurality of diffuser devices at the same level in said tank, and means for supplying air under pressure to said devices, each said diffuser device having a single fixed orifice opening vertically upwardly into said body of liquid, a valve element disposed above said orifice and means supporting said valve element for gyratory movement about the axis of the orifice upon the flow of gas under pressure from said orifice for discharging a jet of gas bubbles into said liquid from different portions of said orifice progressively about the periphery of said orifice to form a progressively upwardly expanding spiral pattern of distribution, said devices being located at such level below the surface of the liquid and sufficiently close to one another that said streams intersect below the surface of the liquid.

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