Feb. 3, 1942. F. E. HARTMAN 2,271,895

APPARATUS FOR TREATING LIQUIDS WITH ELECTRICAL DISCHARGES

Filed July 22, 1936 3 Sheets-Sheet 1

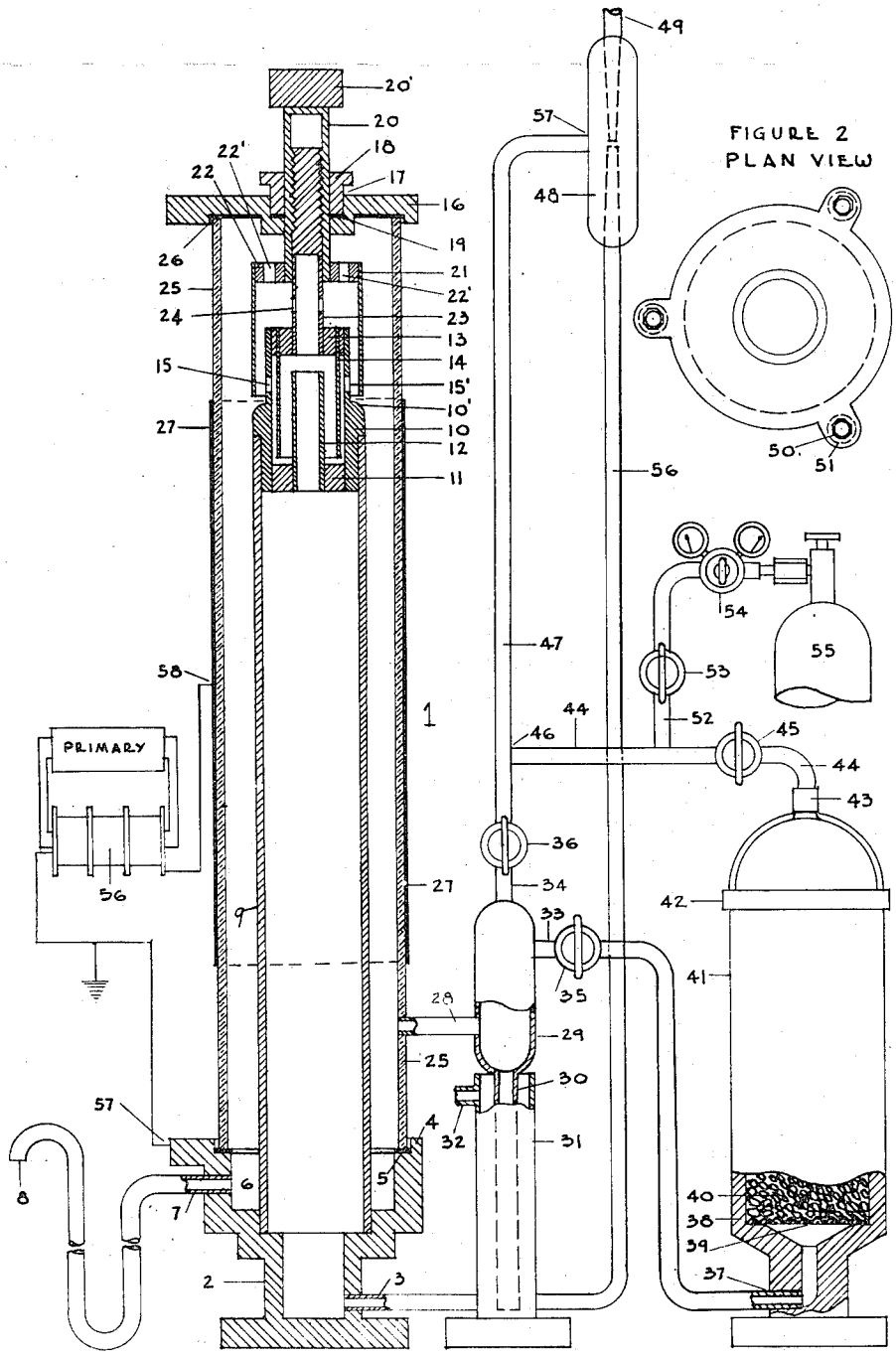


FIGURE 1

FIGURE 2
PLAN VIEW

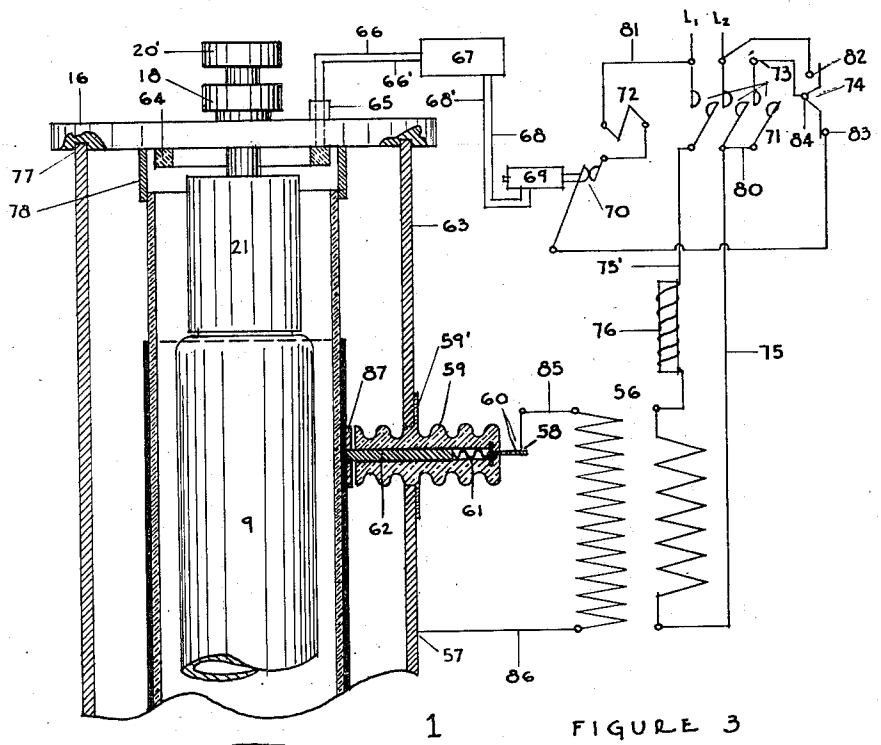
INVENTOR

Frank E. Hartman

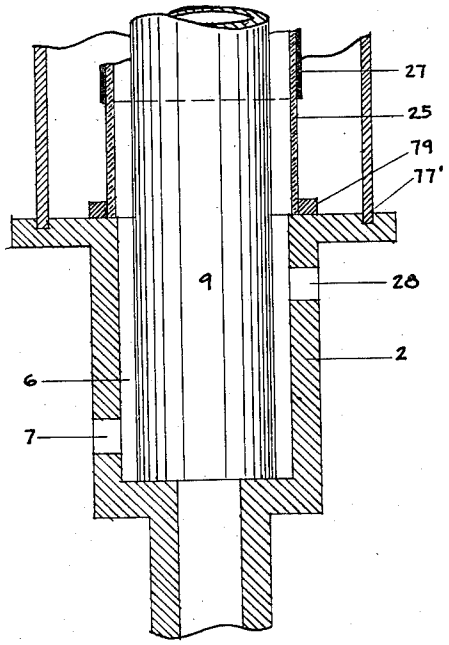
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1 FIGURE 3



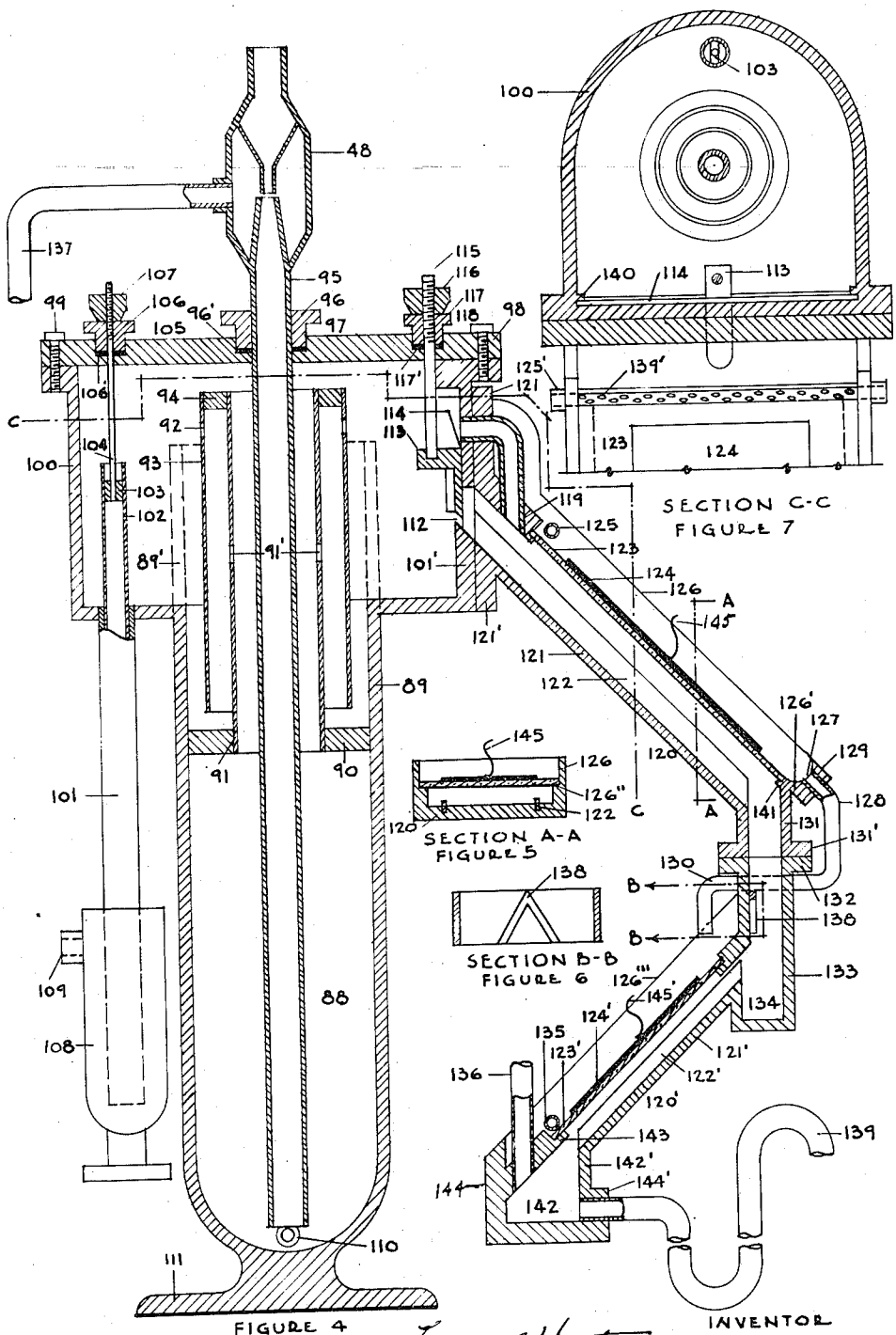
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Filed July 22, 1936 3 Sheets-Sheet 3



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2,271,895

APPARATUS FOR TREATING LIQUIDS WITH ELECTRICAL DISCHARGES

Frank E. Hartman, Highland Park, Ill., assignor to George H. Bergman

Application July 22, 1936, Serial No. 91,935

4 Claims. (Cl. 204—314)

This invention relates to improvements in apparatus and method for the treatment of liquids by the use of electric discharges in the presence of a liquid and a gas and/or vapour, and is a continuation in part of my copending application, filed January 4, 1934, Serial Number 705,202, which issued as United States Letters Patent No. 2,089,793.

One of the objects of this invention is the provision of apparatus which readily lends itself to economic manufacture over a wide range of sizes and capacities. It is also an object to provide an apparatus which permits of a protracted single treatment of a liquid. Another object is the provision of means for artificially cooling the dielectric. A further object is the provision of means for recirculating the gas employed to react with the liquid, together with means for conditioning the gas thus recirculated, for the purpose of increasing the effectiveness of the action of the gas on the liquid.

A still further object is the provision of positive control means for cutting off the electricity to the apparatus, in the event of rupture in the dielectric. Other highly important objects are means for controlling the thickness, uniformity and homogeneity of the film of liquid to be treated. Other objects, advantages and novel features will become obvious to those skilled in the art as these specifications proceed.

Before passing on to a description of the apparatus, methods and improvements comprehended by this invention, it may be well to deal briefly with some of the practical advantages which they offer. In my copending application, Ser. No. 705,202, which issued as United States Letters Patent No. 2,089,793, glass coated steel was specified for use as combined dielectric and electrode. This is desirable, both for convenience and durability where the potential difference between the electrodes is relatively low (ca. 4,000 to 5,000 volts) and the energy density is correspondingly low. However, when higher potential differences are employed with accompanying higher energy densities, or high frequency is employed, which yields higher energy densities without the need of so great a potential, pin holes tend to show up in the glass coating, which, on continued operation, soon burn through, exposing the bare metal beneath, a condition which is to be avoided. In the present invention solid glass dielectrics are specified, and dielectric coverage is confined to only one of the electrodes of the apparatus, since any thickness desired may be obtained in a solid glass dielectric.

In carrying out a treatment with the apparatus of this invention very thin films of liquid are presented to the discharge, of the thickness of from one to two millimetres. It becomes obvious then, if this film is also to act as the dielectric of the circuit, that it must be both uniform and homogeneous. By homogeneity is meant freedom from physically entrained gas; uniformity refers to cross section. This invention provides very special means for obtaining these ends, as will be presently seen from the description of the apparatus. It may be added, however, that in obtaining uniformity and homogeneity, the initial formation of the film, before it passes under the influence of the discharge, is of paramount importance. Contrary to opinion, the action of the discharge on the liquid surface is that of maintaining the uniformity of the film. Film rupture rarely initiates in the zone of the discharge, this inevitably occurs prior to passage of the film under the discharge area, hence the utmost importance of the initial formation of the film.

It is also interesting to point out that the presence of the film on the electrode surface offers complete protection to the electrode from "etching." When a brush or corona discharge impinges against bare metal, even so hard a metal as steel, the surface becomes roughened with time. For a surface on which it is desired to form and maintain a thin film of liquid, such condition would be a decided handicap. However, even with so soft a metal as aluminum, very prolonged action of the discharge on a film of water no more than one to two millimetres thick, failed to noticeably affect the original mirror polish of the metal; whereas, no more than one half hour's action on the bare metal produced a roughening which gave the metal a satiny finish. With water, aluminum is affected chemically, in time; the ozone in solution attacking it to form aluminum oxide. Stainless steel has not been noticeably effected, even with water, over the period of my experiments.

It has been found that pre-saturation of the liquid with the gas it is to react with greatly increases the amount of action between them. It has further been found that maintaining the gas phase in active motion is a further advantage, but this is probably tied up with some effect resulting from washing the gas repeatedly with the liquid to be treated. Provisions are made in the present invention for recirculating the gas, through "injector action," utilizing the flow of the liquid to be treated for both saturating the

liquid with the gas and maintaining the gas in active motion through the discharge area.

It is thought that the action of the apparatus is two-fold: action resulting, on one hand, through the formation of ozone, when oxygen is contained in the gas, and, on the other hand, there is a more direct action due to the migrating electrons, causing an activation of, perhaps, both of the liquid and gaseous phases, with the formation of ionized and excited molecules, and also, perhaps, the rupture of valency bonds direct—all of which would not properly involve passage of the gas through the ozone state.

In some cases ozone formation alone is the prime object. This is exemplified in the formation of ozonides with the fatty oils. It is further exemplified in the treatment of a "carrier" liquid, when ultimate chemical action is to be accomplished outside of the apparatus. For instance, very dilute solutions of ozone in water bleach both animal and vegetable fibers rapidly, and require much less "excess oxygen" for the same rate and degree of bleaching than is required when chlorine is used to produce the oxygen for the bleach; or even when hydrogen peroxide is employed, or hydrogen peroxide producing agents, such as sodium peroxide, furnish the active oxygen for the bleach. Such being the case the apparatus of this invention may be employed to produce bleaching liquors of high activity. Whilst such liquors are not stable over a long period of time, they may be produced as used, with excellent results and great economy.

For this purpose water may be used as the inert, ozone carrying liquid and it then becomes the object to produce as high a concentration of ozone as possible, in contact with the water film within the apparatus, since the amount of ozone that will enter solution in the water is governed by the partial pressure of the ozone in the gas in contact with it. "Active oxygen," which would enter into reaction with oxidizable substances of the liquid film, whilst highly desirable when oxidation in situ is the object, is of little importance here, hence every effort is made to increase the ozone production of the discharge.

Now it is found that when oxygen supplied to a discharge, with the view of producing ozone, contains some ozone, there is a tendency for the concentration of ozone thus produced to be lower than when the supplied gas is totally free from ozone. In the apparatus of this invention the repeated washing of the gas with the liquid to be treated is important as contributory to the utilization of all the ozone formed, as well as maintaining the highest possible ozone production. During the washing operation the ozone contained in the residual gas is taken up by the liquid through chemical reaction therewith. But this is true only when there are reaction possibilities between the liquid and the ozone. Water will not react chemically with ozone, it simply dissolves it, and it will never dissolve all of the ozone, due to the equilibrium obtaining between gases in solution and the atmosphere in contact with the liquid. Thus, when water is the liquid, there always remains some traces of ozone in the gas, after washing with water. Presence of these traces of ozone causes a significant decrease in the ozone produced by the discharge. To overcome this the recirculated gas is conditioned by passing it through a decomposer, which destroys the remaining ozone content, thus maintaining conditions for the production of the maximum ozone concentration in contact with the water within the apparatus.

As a decomposing substance, most adsorbents answer the purpose very well, when the concentration of ozone is low. Glass wool suffices when only traces of ozone are present, the surface effect alone being sufficient to adsorb the ozone. With higher concentrations, adsorbents, such as the carbons, silica and aluminum gels, etc., serve the purpose very well indeed. For higher concentrations I have found that catalytic decomposition of the ozone is best resorted to. Such agents offer a greater convenience, since they display neither "saturation" nor "fatigue." Manganese dioxide, either more-or-less pure, or in the form of minerals of high manganese dioxide content, such as pyrolusite or the amorphous psilomelane, serves to catalytically destroy the ozone very effectively. It is preferably employed in granular form, placed in a bed, after the well known fashion of employing gas adsorbents.

The electrical characteristics of the apparatus are unusual, when considered with the more general applications of electricity to industrial usage. On inspection of the circuit, as illustrated in Figure 3, it is obvious that the apparatus, or activator proper, is nothing more than a leaky condenser. Major electric damage occurs only on rupture of the dielectric. Now dielectrics rupture in a variety of ways. When only a minor pin hole, or slight crack occurs in a dielectric, although conditions of what might be called a "short-circuit" obtain, in most cases the actual current, occasioned by this so-called short-circuit, assumes a value lower than that of the normal operating current. On formation of a short circuit, in the usual way, the current rises to a very high value. Through this pin hole, or slight crack, a localized sparking discharge occurs, with a total disappearance of the over-all corona discharge, which obtains when the apparatus is operating properly. Naturally, under such conditions, the liquid is not receiving the proper treatment. Further, if this condition is allowed to endure the slight rupture develops into a large one, giving rise to an arcing discharge, the heat of which is destructive of both product and apparatus. When the dielectric is the enclosing cylinder, a rupture, if allowed to become large, would admit the outside atmosphere, which, in some cases, may cause an explosion. From these remarks it is seen that it is important to de-energize the apparatus immediately upon rupture of the dielectric. It is also seen that electric fuses, in the ordinary way, offer no protection. Attempts have been made to employ constant current relays for handling this condition, but they are unsatisfactory, since it is frequently desirable to purposely reduce the current of the circuit. Matters go beyond this, however, for one can not always be sure of what direction the change in current may take, on dielectric rupture. If the initial rupture is large the rupture current may be greater than normal, hence protection actuated by current change is very limiting in the commercial practice of the apparatus.

There is, however, in all cases, a decided change, always of the same character, in the spectral characteristics of the luminosity within the apparatus, on rupture of a dielectric, regardless of magnitude of the rupture. Sheer intensity of light, measured in lumens, at any fixed point within the apparatus cannot be counted on, since a small rupture, remotely located with

respect to the fixed point, may give an even lower lumen intensity than the properly operating discharge. On the other hand, even a very small rupture in the immediate proximity of the fixed point will give a decided increase in lumens at the point. Any large rupture, regardless of location, will increase the lumens falling on any point within the activator. When the discharge is properly operating its spectrum is characteristically blue-to violet, extending, of course, into the ultra-violet. There is very little green light, practically no yellow, an ill defined orange and a very low intensity red. When the dielectric is ruptured, and a metal to metal discharge occurs, which is of the nature of a sparking discharge, the light in the red region becomes very much intensified, well defined orange and yellow appear, with a good intensity in the green. The spectrum thus becomes preponderdantly green to red. If the rupture is large a hot arc occurs, which, while containing a great deal of blue to violet light is, never-the-less, exceeding rich in red. The distinguishing difference then, between the several types of discharge is: low intensity from green to red with the corona discharge and high intensity in this region with either the sparking or arcing discharge.

It is seen, therefore, that a photo-electric cell, sensitive to the red end of the spectrum, may be effectively employed to operate a relay, immediately upon the formation of an improper discharge, and this, in turn, employed to disconnect the apparatus from the source of power. A cell, highly sensitive from yellow to red, will operate, on even a very small rupture, almost before the entire corona discharge disappears and long before any damage may occur. Cracks in a glass dielectric, which still retain gas pressure without showing a lowering of the operating gage, may be detected and repaired before a clean-cut sparking through occurs. This is of highest importance when a liquid film is employed as the dielectric, since the rupture of the film is detected and the power shut off before any appreciable quantity of untreated liquid can pass through.

Having set forth the objects of the invention and dealt, in some detail, with the practical value of such objects, it is now proposed to describe how the desired objects are achieved. Several embodiments of my invention are illustrated by the attached figures, of which:

Figure 1 represents a cross section of one form of the apparatus in elevation

Figure 2 is a plan view of the activator proper, illustrated in Figure 1, looking from directly above it

Figure 3 shows an elevation, partially in section, of an adaptation of the activator proper, illustrated in Figure 1, together with a complete wiring diagram

Figure 4 represents a cross section of another form of the apparatus in elevation

Figure 5 represents a sectional view, in elevation, along the line A—A of Figure 4

Figure 6 represents a sectional view, in elevation, along the line B—B of Figure 4

Figure 7 represents a plan view, in section, along the line C—C of Figure 4.

Like numerals designate like parts throughout the several figures and the description thereof.

Referring to Figure 1, the activator proper is designated generally as 1. It comprises a base section 2, provided with an inlet tube 3 and an outlet tube 7, same either forming or terminating in any suitable form of trap, having an outlet to atmosphere, as indicated at 8.

To the base section is secured the centre tube, or electrode 9, the counter bore receiving same being enlarged over a portion of its depth to provide the well 6, for receiving the liquid which flows down the outer wall of 9. The base section 2 is also bored, as at 4, to receive the outer, or dielectric, tube 25. A gasket 5 is provided between 25 and 2 for rendering their junction both gas and liquid tight.

The centre tube, or electrode, 9 is provided with a head casting 10, same being closed at the bottom, as indicated at 11, excepting for a small opening into which the upright tube 12 is secured. Tube 12 extends upward to a distance slightly beyond the plane occupied by the apertures 15 and 15'. Head 10 is preferably of the shape shown, being provided with the radius 10' for the dual function of assisting in the formation of the liquid film which flows down the outer wall of 9, and the prevention of edge effects, or intensified discharges, which tend to form when the end of an electrode terminates with a sharp edge. The top 10 is closed with the plug 13, which carries the baffle tube 14, which extends downward into the head, sufficiently to leave only an adequate passageway for the liquid between the lower end of 14 and the closure 11. Plug 13 also contains an opening into which is fitted the gas escapement tube 23, same being closed at its top and provided, in the wall, with a series of apertures 24.

A cap member 16 is provided for closing the top of the activator proper, same being bored to receive the gasket 26 against which 25 is secured to make a gas tight seal. Cap member 16 also carries the stuffing box 17, into which is threaded the packing gland 18, to operate against the packing 19, thus providing a gas tight seal for the film control shaft 20. Shaft 20 is hollow, but closed at its upper end and is threaded internally to receive the upward extending and threaded portion of 23, about which 20 may be revolved by turning the knob 20', thus raising and lowering it on 23.

At the lower end of 20 the film control skirt is secured. This comprises the plug 22, which is secured to 20 and further carries the tube 21, which is the film control skirt proper. Plug 22 is provided with a series of apertures 22' for connecting the interior of tube 21 with the interior of the activator proper.

The dielectric tube 25, which is of glass or other suitable dielectric material, is provided, over a portion of its outer surface, with a closely adhering metallic film 27, said film being confined to the medial portion of 25, terminating sufficiently back from both ends to provide ample electrical insulation between 27 and the remaining metallic parts of the apparatus.

The activator is secured together with the tie rods 50, which may be covered with insulating tubes 51, to prevent sparking between the rods and 27, without the necessity of spacing the rods too remotely from 27.

A gas outlet tube 28 is provided in the wall of 25, and connects with an enlarged tube 29, which serves as a connecting chamber between the interior of the activator proper and certain auxiliary apparatus. The bottom of 29 is provided with a downward extending tube 30, which dips into a trap tube 31. Trap 31 is provided with an outlet 32 which may be connected with any suitable receiver or reservoir. This trap func-

tions to prevent accidental overflow from the activator entering the lines leading to either the injector or the decomposer.

A tube 33 is taken from 29 and leads, through the stop cock 35, to the bottom of the decomposer 41, as indicated at 37. A further tube 34 is taken from 29 and leads, through stop cock 36, to the gas inlet port of the injector 48. It is obvious that one three way valve may be used to replace these stop cocks; however, single cocks have been used to make the drawing more clear. A tap 44 is taken from tube 34, as indicated at 46, and leads through the stop cock 45, to the top of the decomposer 41, as indicated at 43. Tube 44 is further provided with a tap 52, which leads through the shut-off cock 53 to a source of gas or gases.

The figure illustrates only one source of gas, 55. However, a mixture of gases may be employed, in which case any suitable means for providing the activator with mixed gases may be employed. Gas is admitted to the activator, preferably through a pressure control valve, as indicated by 54, as it is important to maintain a constant supply of gas to the activator, under some constant and predetermined pressure.

The decomposer 41 consists of a chamber 38, provided with an inlet 37. Located at the bottom of the chamber is a screen 39, permeable to gas but of such mesh as to retain the material 40, which fills the body of the chamber. A removable top section 42 is provided, carrying the outlet port 43. The material 40 which fills the chamber may be any suitable adsorbent or catalytic material, as has already been discussed.

The base 2 of the activator is electrically connected with earth, and any suitable source of high tension electric current, at any suitable frequency, when alternating current is employed, may be used to energize the activator, such, for example, as furnished by the transformer 56. One side of the high tension is connected with the base 2, and, in consequence, earthed, and the other side is connected to electrode 27, as indicated at 57 and 58 respectively. The transformer 56 may have its primary energized from any suitable source of electric power.

In Figure 1 the dielectric tube 25 serves also to enclose the activator against the atmosphere. For this reason it is essential that it be secured tightly between 2 and 16. When the dielectric is of large diameter, and relatively high gas pressures are employed, the clamping essential to effective sealing, places a considerable mechanical strain on the dielectric, which is not desirable, since it predisposes the dielectric to rupture under electrical stress. For large apparatus, therefore, it is desirable to relieve the dielectric of mechanical strain and provide a separate tube for enclosing the activator. Figure 3 illustrates one way of accomplishing this. Note that here, 25 is free from any clamping action. It is positioned and centered by the bottom centering ring 79, a similar ring, 78, serving a similar purpose at the top. The dielectric slips snugly but freely into these rings. A metallic tube 63 is provided for enclosing the activator. Grooves 77 and 77' are provided in the top and bottom sections respectively, for receiving 63, and a gasket, not shown, may be provided for ensuring a tight seal. The activator is again secured together by suitable tie rods as illustrated by Fig. 1.

It is necessary, however, to convey the high tension lead to 27, and as 63 is earthed, along with the remaining metallic parts of the apparatus, this must be done through a suitable insulator. Such an insulator is designated generally as 59. A skirt 59' may be secured with a gasket and bolts, not shown, to provide an air tight connection between the insulator and the tube 63. Inserted into the insulator and sealed therein, is the metallic stud 60. To this stud the high tension lead 85 is connected as indicated at 58. A spring 61 co-operates with the stud 60 and the metallic rod 62, the rod having at its inner end an enlarged portion or plate 87, which is held in pressure contact with 27, by the action of 61, and thus good electric contact is ensured for 27, and insulated from the remaining metallic parts of the apparatus.

The gas outlet tube 28, secured to 25 of Figure 1, is, in this case, removed from the dielectric and provided in the base casting, as indicated by 28, the base casting being sufficiently elongated to provide proper depth of the well 6.

Figure 3 also illustrates a means for protecting the apparatus against damage from dielectric rupture. A photoelectric cell, sensitive to the red end of the spectrum, and relatively insensitive to the blue-violet end, is made in annular construction and positioned at the top of the annulus formed by 9 and 25, as indicated at 64. From this position the cell scans the entire depth of the discharge annulus and any luminosity within same will impinge on the active surface of the cell. A stuffing box 65 is provided in 16 to admit passage for the cell leads 66 and 66'. These leads are brought out and connected with an amplifying unit 67, the output from the amplifier being conducted through leads 68 and 68' to the relay 69.

The contacts 70, of relay 69, are in series with the solenoid circuit of the main contactor 71, hence when the relay functions, the electric supply to the activator is cut off. Since contactor 71 is controlled by a three wire circuit, or "no-voltage-release," electric supply cannot be reestablished to the activator until same is purposely done by hand. This necessitates the pushing of the start button 82, of control switch 74. The forces which cause cell 64 to function to offer the desired protection have previously been described.

The main electric circuit of the apparatus is as follows: Power, at low tension, from any suitable source, is conveyed through L_1 and L_2 to the service studs of contactor 71. From the load side of the contactor the leads 75 and 75' conduct power to the primary of the transformer 56. In one lead, as in 75', a reactance or choke coil 76 is connected in series, said coil may have a movable core, or otherwise the iron may be adjusted, and thus the coil be made to control the current in the circuit, thus controlling the energy in the activator. A reactance is more desirable for this purpose than a resistance, such as is offered by a rheostat, since it is more sharply current limiting, especially at high frequencies, and further aids in tuning the over-all circuit. The action of the activator, being that of a condenser, introduces a considerable capacity reactance into the circuit. The inductive reactance of the transformer, even when same is of the high reactance type, is rarely sufficient to yield a good power factor for the operation of the activator. The use of further inductance is therefore indicated. A further aid to tuning, when high frequency is employed, is the spacing of the high frequency leads. Due to the magnitude of the mutual reactance of parallel leads at the higher

frequencies, this factor cannot be neglected and when convenient it may be employed as a source of additional inductive reactance. A well tuned circuit is essential to hold within reason the size of the electrical equipment.

The contactor 71 is controlled by the momentary contact, push button switch 74. The start button 82 is connected directly with L_2. The stop button 83 is connected in series with the contacts of the cell relay 69 and thence to one side of the solenoid 72. The opposite side of the solenoid is connected directly to L_1. An extra contact is provided on 71 and short-circuited on the load side to L_2 and the service side of this contact is connected with the common connection 84 of switch 74. This constitutes a hold-in tip necessary to the "three wire, momentary contact" control of the contactor, which is required in order to render the functioning of the cell 64 effective for complete shutdown. If such control was not employed, when the circuit was first broken by the cell the actuating light would be extinguished and the cell would no longer feed current to relay 69 and the contacts of 70 would again close. In the absence of momentary control of 71, this would produce a condition of "chattering," with repeated cutting off and on of the activator. However, with the control as shown, once the control circuit has been broken it can only be re-established by hand.

Figure 4 illustrates what may be termed "flat plate construction," as opposed to the tubular construction of Figures 1 and 3. This comprises a saturating column, designated generally as 88. This column is provided with an enlarged top section 100, which is closed with the removable top 98, secured by the bolts 99, and a gasket, not shown, may be provided for rendering the top gas tight.

Top 98 is provided with the stuffing box 97, through which the tail pipe 95 of the injector 48 is introduced. A packing gland 96 screws into this stuffing box and compresses the packing 96' to seal the passage of the tail pipe. Pipe 95 extends downward into the saturating column to within a short distance of the bottom. Column 88 is provided with a partition 90, containing an opening into which the upright tube 91 is fitted. Tube 91 is provided with a series of apertures 91' as shown. A ring 94 is pressed on the top of 91, serving to close the top of the annulus formed by tubes 91 and 93. A baffle tube 93 is pressed onto 94 and extends downward to within a short distance of the partition 90. The wall of 93 is provided with a series of apertures 92 as shown. This assembly of tubes constitutes a gas separating device, the operation of which is later described.

The enlarged top section 100 is provided with a downward extending pipe 101, which dips into a trap or liquid seal 108, same having an outlet 109, which may be connected with any suitable receiver. The tube 102 is slip-fitted inside of 101, and is provided with an interior web 103 to which is secured the rod 104, same being threaded near its top and passes outwards through 98. Stuffing box 105 is provided as a passageway for the rod, the packing gland 106 and packing 106' serves to render the passageway gas tight. A nut 107 screws onto the extending portion of 104 and may be manipulated to raise and lower 102 in 101 and secure 102 in position.

At one side of section 100 the discharge chamber, designated generally as 120, is attached and secured to 100 by the flange 121'. Discharge chamber 120, which is conveniently constructed of metal, comprises a bottom 121, side walls 126, a ledge 126'' being provided in the side walls for supporting the plate dielectric 123. Dielectric 123 also serves to close the top of the discharge chamber 120, and may be luted into place, or otherwise secured to make a gas tight seal. This construction is clearly shown in the transverse section, Figure 5.

The wall 101' is slotted, as at 112, for connecting the interior of 100 with the interior of 120. This slot does not extend the full width of 101' but is made only sufficiently long to fall within the space described by the film inserts 122, as shown in Figure 5. This slot is covered with a sliding door 114, which is secured in sliding relation with the wall 101' by the guides 140. Door 114 is provided with a boss 113 to which is secured the rod 115, same serving to raise and lower 114 across the slot 112. Rod 115 passes out through 98, the stuffing box 116 being provided for this purpose and into which the gland 117 is screwed to compress the packing 117' and thus render the passageway gas tight. Nut 118 is provided for the manipulation of 114 and securing same in place. As only liquid must pass through slot 112 and as a gas must also be supplied from 100 to 120, tube 119 is provided for making the gas connection between them.

The lower end of 120 is provided with a downward extending throat 131. A ledge 141 is provided in the discharge chamber 120 for supporting the dielectric plate 123, and to which it may be luted or sealed. A boss 129 is provided on the end wall 126', the opening, 127, in this boss, receiving pipe 128, which connects the trough formed by the walls 126—126' and the dielectric 123, with the similar trough formed in the lower, attached discharge chamber 120'. An opening 125 is provided in walls 126, at both sides, as shown, and a perforated pipe 139' connects these openings, bosses 125' being provided on the exterior of the walls for receiving externally connected pipes which supply cooling liquid to perforated pipe 139'.

To the flange 131' a second discharge chamber 120' is secured by the companion flange 132. At the upper end of this chamber a well section 133 is provided, said section being continuous with a discharge chamber substantially identical with 120. It consists of a bottom 121', side walls 126''' and end wall 144. A ledge is provided in walls 126''' to support the dielectric plate 123', and film inserts 122' are provided in 121', all similar to chamber 120. The lower end of this discharge chamber is provided with a well section 142, covered, in part, by the top wall 143, which is cut back to form the bottom support of 123', as shown. A boss 144' is provided in wall 142' and to which is secured the U-trap liquid outlet tube 139. In wall 143 a gas outlet tube 136 is provided.

In the throat section 133 one wall is provided with an inverted V-shaped boss 138, as shown, for the purpose of dividing the liquid stream, which flows over this wall, into two streams, and thus provide a passage way for gas, as will be described in detail under "Operation."

Dielectrics 123 and 123' are provided with metallic films, which serve as electrodes, over part of their external surface, as indicated by 124 and 124'. Wire connections 145 and 145' are provided for making contact between the electrodes and an external source of electricity.

Having described in detail the construction of

the several adaptations of the activator and its auxiliary apparatus, a description of their operation will now be given.

Operation of apparatus Figure 1

The operation of the activator is as follows: The liquid to be treated is introduced through the liquid inlet 49 of the injector 48, under sufficient pressure to force the liquid through the injector tail pipe 56 and elevate it within 9 to the point of overflow through the apertures 15, of head 10 and further entrain gas against the head of liquid in 9 and compress it against such internal gas pressure as the activator may be operated under.

The liquid thus introduced flows out of the head 10, through the apertures 15, filling the annulus formed by 10 and 21. Skirt 21 is elevated sufficiently to permit the liquid to pass out about its periphery and in so doing it runs as a thin film down the wall of 9. The film control skirt 21 serves to evenly distribute the liquid about the periphery of the radius 10', so that a film of uniform thickness is maintained on the outer wall of 9. It further serves to quickly establish a uniform film on starting up. There is a tendency with liquids which do not readily wet surfaces to run in rivulets along 9. When this occurs, 21 is lowered to shut off the flow of liquid and then quickly raised, an increased flow of liquid, evenly distributed about 10' is established, and by repeating this operation, if necessary, an even film on 9 is readily established.

In maintaining the uniform feed of liquid about 10' it is important that no gas bubbles accompany the liquid. Since the film to be maintained is exceedingly thin, upwards of a millimetre, the presence of bubbles tends to break the film. In order to ensure against this contingency all physically entrained gas is separated from the liquid before it passes out of apertures 15.

The stream in pipe 56 contains gas and liquid finely dispersed as exceedingly small bubbles and globules. Due to the high velocity of this stream very little coalesence of the gas occurs. It is here that good saturation of the gas with the liquid is obtained. When this stream discharges into 9 the velocity is greatly reduced and the gas tends to separate almost at once. By the time the stream approaches the top of 9 the gas has condensed into a stream of rather coarse bubbles, and in this condition both gas and liquid pass through tube 12. Here, however, the velocity is again increased, but the gas, having already condensed will not again become finely dispersed throughout the liquid, since the original dispersion is characteristic of the action of the injector employed.

The gas escapment tube 23 is positioned immediately over 12, thus, the gas leaving 12 passes rapidly out through 23, via the apertures 24, and finally enters the activator proper, first passing through the apertures 22' of the film control plug. The liquid, however, after leaving 12, must pass again downward through the annulus 12—14, to pass upwards, in turn, through the annulus 10—14. This reversal of the flow of the liquid ensures the disengagement of all bubbles during its downward course, this being sufficiently slow to prevent the gas following the liquid.

The gas introduced with the liquid fills the activator and surrounds the film of liquid flowing down the outer wall of 9. The liquid film from 9 collects in the well 6, but cannot flow out of the activator until its head is sufficient to overcome the trapped outlet 7. When the head reaches the height determined by 8, which is preferably slightly below the gas outlet 28, the liquid may then flow from the activator into any suitable reservoir or receiver.

The gas which follows the liquid film cannot escape through 7, due to the trapping arrangement. The gas pressure at which the activator is operated is determined by the height of the column of liquid in 7, which may be anything desirable within reason. It should be pointed out that should higher gas pressures be desirable, than can be obtained conveniently with a liquid trap, any suitable type of pressure valve or escapement valve may be employed in place of the trap shown. The gas leaves the activator through the gas outlet 28, and may be either directly recirculated, or recirculated through the decomposer, as conditions may demand.

If it is desired to directly recirculate the gas, cocks 35 and 45 are closed and cock 36 opened. The gas then passes out of the activator through 28, upwards through 29, trap 31 being previously filled with liquid to prevent escape at that point, through cock 36, tube 47 and re-enters the gas inlet of the injector at 57, to be again entrained in the liquid for another cycle of circulation. In this way the only gas escaping from the activator is that held in solution in the liquid, together with that which enters into chemical reaction with the liquid. These actions would cause a deficiency in gas volume but for the fact that gas is continuously fed into the system from reservoir 55 to replace that used up. A pressure regulating valve 54 is employed for the introduction of the gas, and this is set to just deliver gas against the head occasioned by the traps 7 and 31, thus maintaining the gas volume of the activator under a constant and predetermined pressure.

If it is desired to recirculate the gas through the decomposer, cocks 35 and 45 are opened and cock 36 is closed. In this case gas leaves the activator at 28, passes through 29, enters 33, en route to the bottom of the decomposer at 37, upwards through the decomposer, out through 43, cock 45, tube 44 and enters the gas tube 47 of the injector 48. Deficiencies in gas volume are made up in precisely the same way as previously described.

The activator may be energized with electricity through any suitable switching arrangement, such as contactor 71, when the photo-electric cell control of the apparatus is employed. The photo-electric cell control should properly be considered in the operation of the device, but since this has elsewhere been described in detail it will not be repeated here. When the transformer is energized, a potential difference is established between the outer electrode 27, on the outer wall of dielectric 25 and the inner electrode or tube 9. When the potential difference is sufficient, a brush, corona, or so-called silent electric discharge occurs throughout the entire area described by electrode 27, filling the annulus formed by 25 and 9. When the liquid film is flowing down 9 the discharge impinges on the film, thus obtaining intimate contact between gas, liquid and discharge.

Operation of the activator under somewhat elevated gas pressure offers several advantages. In the first place it increases the chemical efficiency, since there are more gas molecules to become activated for the same flow of energy. In addition to this, elevated pressures appear to stabilize the discharge and discourage any

tendency for the discharge to creep. It may also be here noted that the energy density within the apparatus may be suitably controlled, by any suitable arrangement, such as the reactance coil illustrated in Figure 3.

Operation of apparatus, Figure 4

Essentially the operation of the plate construction apparatus, illustrated in Figures 4, 5, 6 and 7, is the same as that just described for the tubular construction.

The liquid to be treated is introduced through the liquid inlet of the injector 48. Here gas is drawn into the liquid, and the mixture delivered to 88 through 95. This mixture passes upward in 88, the gas quickly condensing into large bubbles. Gas and liquid pass through the annulus formed by 95 and 91. When the liquid reaches the apertures 91' it passes outwards through same and flows down through the annulus formed by 91 and 93. The gas, however, continues upwards and ultimately out at the top of 91 and into 100.

After the liquid has filled the annulus 91—93, below the apertures 91', it flows upward again through the annulus 93—89, ultimately reaching 100. This tortuous gas separating trap is required only when the liquid is viscous and tends to hold entrained bubbles. If complete separation of the gas does not occur in 91—95, it will continue to separate in 91—93, and such gas as there separates passes into 100 through apertures 92. When a non-viscous liquid is treated, gas separation is more easily accomplished. In this case the wall 89 may be extended upward into 100, as indicated by the broken lines 89' and as this delivers the gas-liquid mixture above the level of the liquid in 100, adequate gas-liquid separation is obtained, so that no gas passes out through 112.

The liquid entering 100 must pass out through slot 112, and thus enter the discharge chamber 120. Door 114 is adjusted to give the required film thickness, then the rate of liquid supply to the apparatus is maintained so that there is always a slight head acting to cause flow through 112. This will maintain a film flow of uniform thickness at all times. If the liquid is reluctant to wet the entire width of the film passage way on 121, slowly lowering 114 quickly raising it will greatly aid in obtaining a uniform initial wetting.

To aid in maintaining the head constant, the tube 102 may be adjusted at the required level and the rate of supply made just a little greater than is required. A slight excess is then bled out through 102 and trap 108, from whence it may be collected and returned to the main reservoir. This further compensates for minor variations in flow, as will frequently occur with pumps, etc.

The accompanying gas passes from 100 into 120 through tube 119, and thus follows the course of the liquid film, precisely as with the tubular construction. Gas tubes 136 and 137 may be connected with the remaining external apparatus of the gas circulating system, precisely as illustrated in Figure 1. Tube 136 connects with 28 and 137 with 34 of Figure 1.

When the liquid film reaches the bottom of 120 it passes downward through the throat 131, accompanied by the superimposed layer of gas. Although the liquid film does not cover the entire width of 121, being confined to the path described by guides 122 of Figure 5, there is a tendency for the film to spread. The spreading film being exceedingly thin, the passage of the gas from the throat into the second discharge chamber tends to blow the film about. An effective way of avoiding this, as well as the tendency for the thin film to hug the top of the casting, is offered by the spreader 138, illustrated in Figure 6, which divides the film into two relatively thick streams, with an open space between them for the passage of the gas. These streams enter the well 134, and thence overflow in a film, downwards along 121' and ultimately into the outlet well 142, out through trap 139 and to any suitable reservoir set to receive it.

The gas also passes over the liquid through the second discharge chamber and re-enters the circulating system through 136. Only two discharge chambers are shown, by way of illustration, but obviously as many may be employed as is required to give the liquid the proper time of treatment.

The electric discharge takes place from the electrodes 124, 124' to the bottom plates 121, 121' in precisely the same way as described for the tubular construction. One decided advantage of the plate construction, apart from the greater facilities for obtaining large plates of glass of proper thickness, is that the plate may be sloped at any desired angle, and thus the rate of flow through the discharge area is brought under control. With perpendicular, tubular construction, this is not possible, the rate of flow down the electrode being governed by gravity and the viscosity of the liquid.

It should be pointed out that electrode 124 does not completely cover the outer surface of dielectric 123, but a margin is left all around. This margin should be of sufficient width to properly insulate 124 from the metallic parts of the apparatus. It should also be noticed that the film inserts or guides, 122, are so located in plate 121 as to confine the boundary of the liquid film to immediately beneath the electrode area, thus all of the flowing liquid is subjected to the discharge. These inserts extend the full length of plate 121. At the upper end they are so arranged that no liquid can pass down outside of them. For electric reasons the inserts are best made from insulating material. Glass and maple wood serve excellently.

When very high energy densities are employed it may become desirable to liquid cool the dielectric. The cooling liquid is introduced through ports 125 and distributed uniformly across the dielectric by the perforated pipe 139'. It then flows downward along the trough formed by walls 126 and the dielectric, through pipe 128, which conveys it to the top of the second discharge chamber. It passes along this chamber and is ultimately discharged from 135. The cooling liquid is preferably a good insulating oil, which may be recirculated through an inter-cooler, employing water for cooling the oil.

A drain is provided at the bottom of the saturating column, as indicated at 110, through which the column may be drained for any purpose desired.

It should be pointed out that the apparatus and means herein disclosed are by way of illustration only, and must not be construed as limiting the invention in any way. It is obvious that many variations may be employed without departing from the spirit of the invention.

For instance, an injector is shown as a means of circulating the gas. It is obvious that this may

be replaced by any suitable gas pump, forcing the gas into the liquid at any suitable point, and under conditions which give a fine dispersion, such as a porous cup or body. It is also obvious that gas may be dissolved in the liquid in an entirely separate apparatus, such as a pressure chamber wherein the liquid supplied to the treating chamber is maintained under gas pressure, and, if desired, agitated to facilitate solution of the gas. It is equally obvious that separation of the phyiscally entrained gas may be accomplished in a variety of ways, that films may be otherwise formed, such, for instance, as allowing jets to impinge on the surface. In such manner, together with the manner disclosed, I have produced a film on the outer tube, which, in such case was a bare metal electrode, whilst the inner electrode was covered by the dielectric.

It should also be pointed out that the liquid supply to the treating chamber may be controlled through a solenoid valve, or other electric control means, and thus, when the photo-electric cell functions to cut off the current from the apparatus it also serves to arrest the flow of liquid. Numerous adaptations and variations are possible with the elements of this invention, and what I wish to secure to myself by Letters Patent is given by the appended claims.

I claim:

1. In an apparatus having a chamber for treating liquids with electric discharges in the presence of gas, means to presaturate the liquid with gas before subjecting it to electric discharge, means for liberating the excess gas from the liquid previous to subjecting the liquid to electric discharge, means to pass the liquid to be treated in a thin film through the treating chamber, means to cause a positive flow of gas through said chamber and means for passing an electric discharge through said treating chamber.

2. In a liquid treating apparatus, a treating chamber, means for passing the liquid under treatment through said chamber in thin films, means for subjecting the liquid to electric discharge while passing through said chamber, means to introduce a gas into said liquid prior to the entry of the liquid into said chamber, whereby to pre-saturate the liquid with the gas, a gas and liquid separation chamber between said pre-saturation means and the treating chamber, separate gas and liquid outlet connections from the separation chamber to the treating chamber, and suction means for drawing the free gas from said treating chamber.

3. In a liquid treating apparatus, a treating chamber, means for passing the liquid under treatment through said chamber in thin films, means for subjecting the liquid to electric discharge while passing through said chamber, means to introduce a gas into said liquid prior to the entry of the liquid into said chamber, whereby to pre-saturate the liquid with the gas, a gas and liquid separation chamber between said pre-saturation means and the treating chamber, separate gas and liquid outlet connections from the separation chamber to the treating chamber, and suction means for drawing the free gas from said treating chamber, said suction means comprising an injector actuated by the incoming liquid.

4. In an apparatus having a chamber with an inlet and an outlet for treating liquids with electric discharges in the presence of gas, means for passing an electric discharge through said treating chamber, means to presaturate the liquid with gas before subjecting it to electric discharge, means for liberating the excess gas from the liquid previous to subjecting the liquid to electric discharge, means to pass the liquid to be treated in a thin film through the treating chamber and gas recirculating means operatively connected to the inlet and outlet of said treating chamber to cause a positive flow of gas through said chamber, said recirculating means including an ozone decomposing chamber and means to draw the gas from said treating chamber through the decomposing chamber and again deliver it into the liquid to be treated.

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