

Sept. 29, 1959

C. J. TABOR

2,906,513

APPARATUS FOR NEBULIZING LIQUID AND HUMIDIFYING INHALANT GASES

Filed Sept. 17, 1953

3 Sheets-Sheet 1

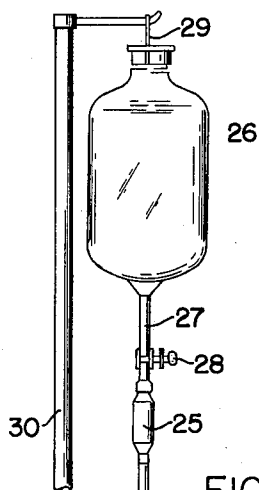


FIG. 1

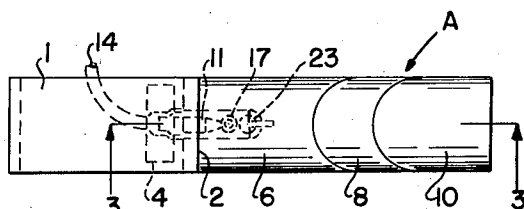


FIG. 2

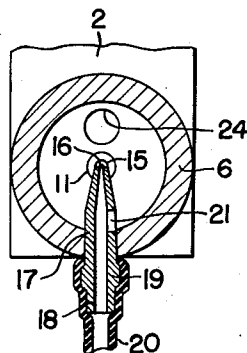
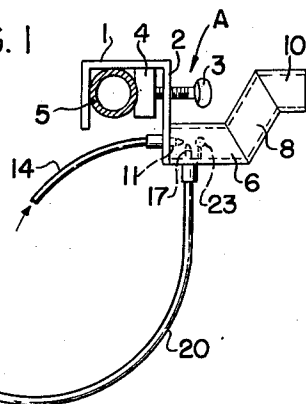


FIG. 4

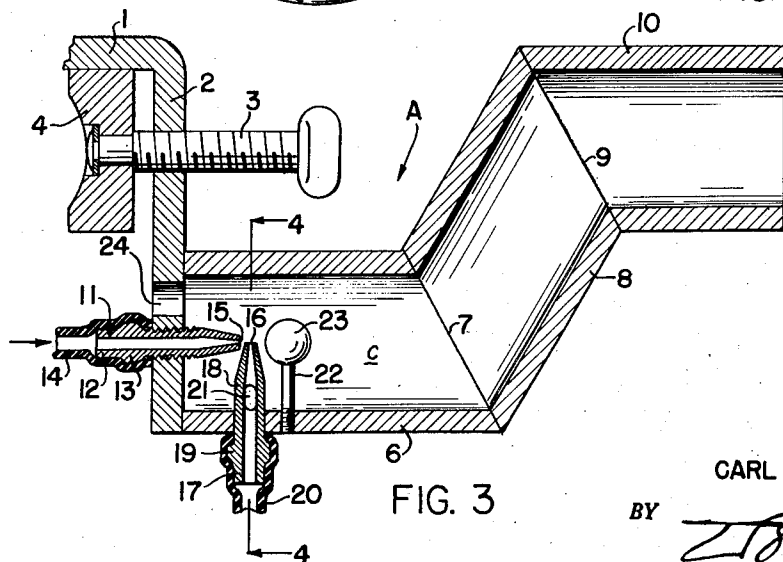


FIG. 3

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3 Sheets-Sheet 2

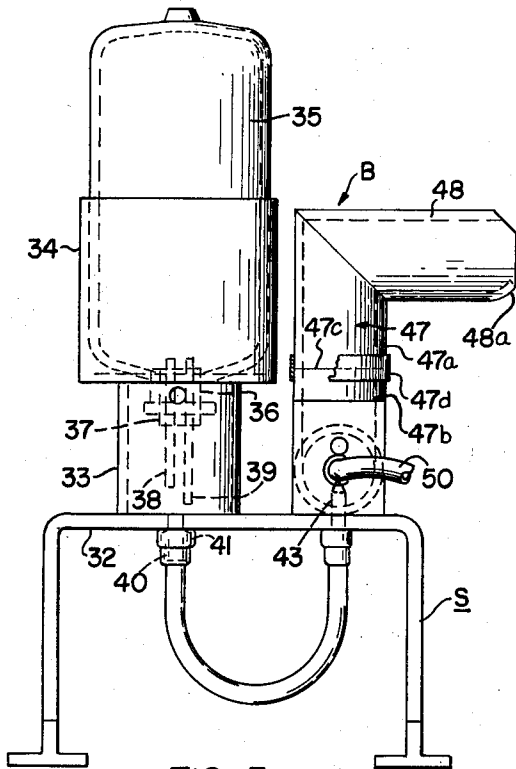


FIG. 5

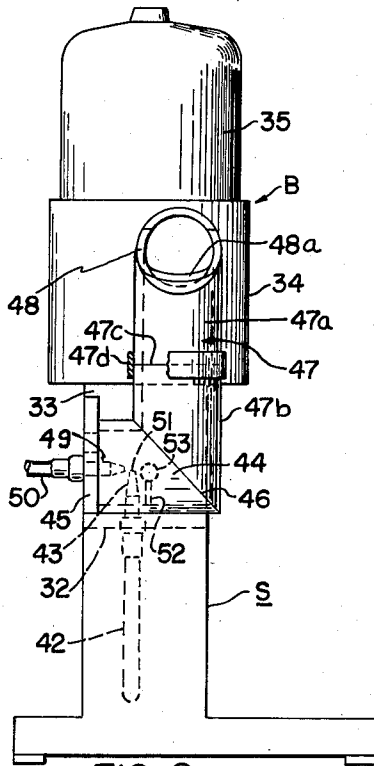


FIG. 6

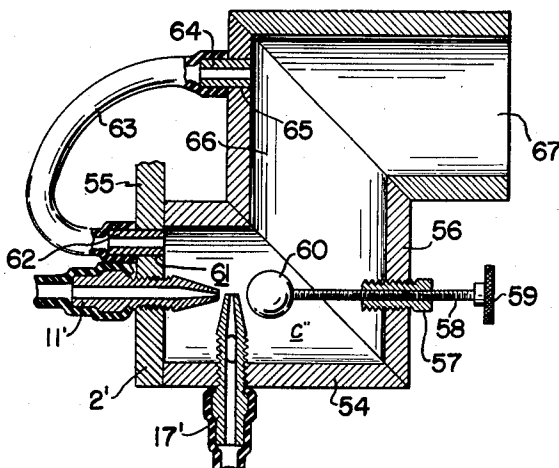


FIG. 7

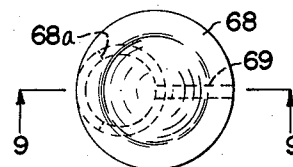


FIG. 8

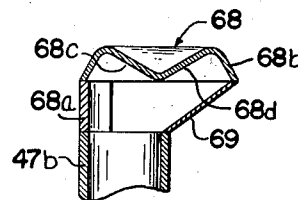


FIG. 9

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3 Sheets-Sheet 3

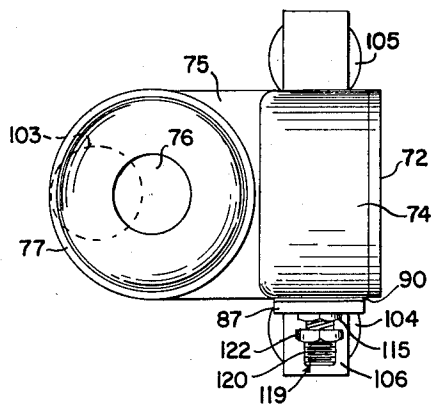


FIG. 13

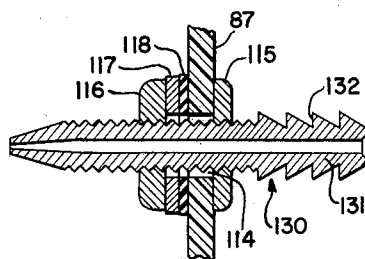


FIG. 14

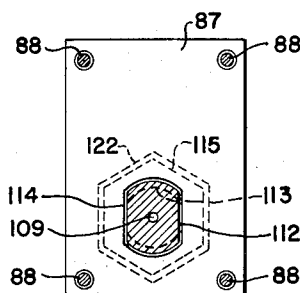


FIG. 12

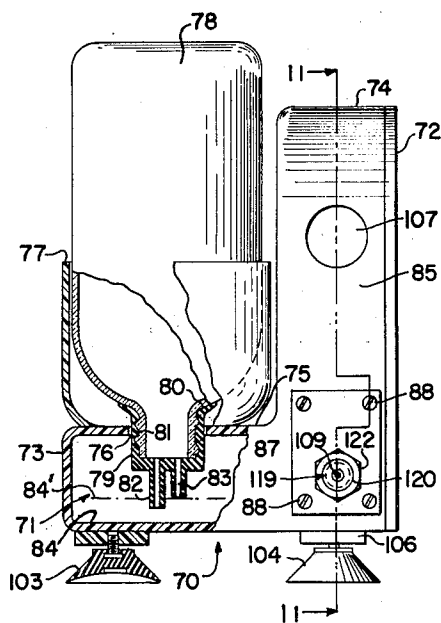


FIG. 10

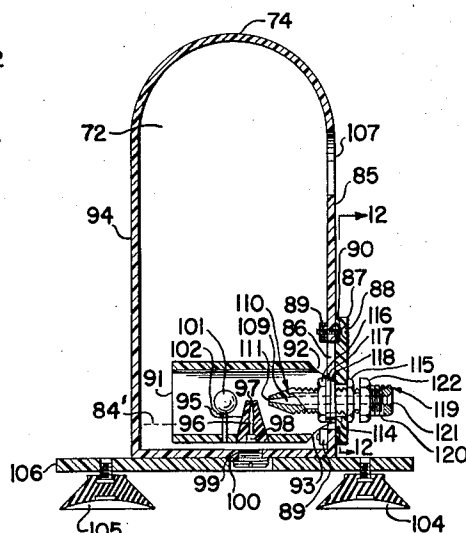


FIG. 11

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2,906,513

APPARATUS FOR NEBULIZING LIQUID AND HUMIDIFYING INHALANT GASES

Carl J. Tabor, Afton, Mo.

Application September 17, 1953, Serial No. 380,686

2 Claims. (Cl. 261—78)

This invention relates in general to nebulization of liquids and more particularly to an apparatus for nebulizing a liquid and humidifying gases such as oxygen for therapeutic purposes, in an economical and efficient manner.

The practice of inhalation therapy has become widespread in recent years and no doubt oxygen and gas mixtures with oxygen are the principal gases administered. Gases so administered are usually required to meet U.S.P. standards and, in the case of U.S.P. oxygen for example, the gas in addition to being pure will also be substantially dry. Unfortunately, if the dry gas is inhaled for any length of time, moisture supplied by the body will be insufficient and the mucous membranes of the respiratory passages become desiccated with the result that the natural processes of gas exchange between the alveoli and blood stream are impeded if not thwarted with resultant injury to the patient. As a person is seldom subjected to administration of oxygen unless in a serious health condition, it is not improbable that such drying of the mucous membranes might result in the death of the patient. It is expedient therefore that the gas administered be humidified, that is, as nearly as possible saturated with liquid particles of microscopic size.

Heretofore, the practice in administering oxygen has been to bubble the oxygen through a bottle of water on the theory that the bubble of oxygen will pick up enough moisture vapor to counteract the desiccating effect normally resulting from the administration of dry oxygen.

This expedient of bubbling oxygen through a bottle of water and other expedients, which have hitherto been employed, have all been found to be highly unsatisfactory. The oxygen still remains comparatively dry and is still capable of desiccating the mucous membranes of the patient's nose, throat, and lungs. Even the method of bubbling the oxygen through a large volume of water does not introduce any appreciable quantity of moisture vapor into the stream of gas, because the gas passes through the water bottle rather rapidly and in fairly large bubbles so that very little moisture can actually be picked up by the gas.

The desideratum is achieved in the smallest moisture particle sizes which are more readily carried by the gas carrier to the smallest bronchial tubes and thereby into the alveoli. The larger are the particles of liquid borne in the gas carrier, the more rapid will become their deposition in the upper air passages, the mouth and pharynx. This is to be avoided as the benefit to the patient occurs in the achievement of substantial saturation of the gas with small particle size moisture delivered to the alveoli, and not in a virtual drowning of the patient by, for example, a concentration of liquid droplets of comparatively large size in the mouth and throat.

It is accordingly the principal object of this invention to provide an apparatus for nebulizing a liquid and humidifying an inhalant gas to a degree whereby the inhalant is substantially saturated with liquid in minute particles size that may penetrate to the tiniest and inner-

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most of the bronchial tubes, with or without the inclusion of drugs, such as antibiotics, antispasmodics, secretion liquifaction agents, and the like.

It is another object of the present invention to provide an apparatus for introducing a precisely controlled and therapeutically effective quantity of moisture vapor into the stream of oxygen or other dry gas in continuous, regulatable, and efficient manner.

It is also an object of the present invention to provide a device of the type stated which is capable of introducing moisture into a stream of gas, such as oxygen, without materially increasing the temperature of the gas.

It is another object of the present invention to provide a device of the type stated which is capable of producing a steamlike stream of moisture laden gas in which the moisture is so finely dispersed and is suspended in the gas stream under such conditions that it will not readily separate or condense out of the gas, but will remain completely intermingled therewith for a substantial period of time.

It is another object of the present invention to provide a device of the type stated which is capable of producing a moisture laden stream of gas in which the moisture content will remain relatively constant and unchanged over comparatively wide ranges of variations in temperature, thereby making it possible to provide a humid atmosphere irrespective of temperature changes.

These objects and additional features and advantages will become more readily apparent as the following description of the invention, which is substituted and is a continuation in part of my copending application Serial No. 191,043, filed October 19, 1950 and now abandoned, proceeds, taken in conjunction with the accompanying drawings in which:

Figure 1 is an elevational view of oxygen humidifying apparatus constructed in accordance with and embodying the present invention;

Figure 2 is a top plan view of the oxygen humidifying apparatus;

Figure 3 is a longitudinal section view taken along line 3—3 of Figure 2;

Figure 4 is a transverse sectional view taken along line 4—4 of Figure 3;

Figure 5 is a side elevational view of a modified form of oxygen humidifying apparatus constructed in accordance with and embodying the present invention;

Figure 6 is a front elevational view of the modified form of oxygen humidifying apparatus;

Figure 7 is a fragmentary sectional view of a further modified form of oxygen humidifying apparatus constructed in accordance with and embodying the present invention;

Figure 8 is a plan view of a hood or deflector for apparatus such as illustrated in Figures 5 and 6;

Figure 9 is a diametral section on line 9—9 of Figure 8;

Figure 10 is a side elevation, partly in section illustrating another embodiment of apparatus by which this inventive method may be carried out;

Figure 11 is a sectional view taken on line 11—11 of Figure 10;

Figure 12 is a sectional view taken on line 12—12 of Figure 11;

Figure 13 is a plan view of the device shown in Figure 10 with the bottle removed; and

Figure 14 is an elevation of a gas injector as shown in Figure 11 but having an alternative hose connection means.

Referring now in more detail and by reference characters to the drawings, which illustrate practical embodiments of the present invention, A (Figures 1—3) designates, generally, oxygen humidifying apparatus compris-

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ing a U-shaped clamp member 1 constructed preferably of Lucite or other transparent plastic material and having a main leg 2 threadedly provided with a thumb screw 3 which projects therethrough and is swivelly seated in a sliding clamp block 4 adapted for engagement with any suitable supporting structure, such as a tubular bed rail 5, for example.

Cemented or otherwise rigidly secured upon the front face of the clamp leg 2 and extending horizontally outwardly therefrom is a tubular member 6 adapted to form a diffusion chamber *c* and being cut off at its outer end at an angle of approximately 30° and adhesively mitered, as at 7, to an angularly upwardly extending intermediate tube 8, which is, in turn, angularly cut off and mitered, as at 9, to a forwardly projecting horizontal discharge tube 10. It will, of course, be understood that the tubular members 6, 8, 10, may be molded or otherwise unitarily formed if desired.

Threadedly mounted in, and extending horizontally through, the lower portion of the clamp leg 2 in approximate axial alignment with the center line of the tubular member 6 is a gas inlet nozzle 11 provided at its rearwardly extending outer end 12 with a diametrically enlarged collar portion 13 for retentive engagement with a rubber gas line 14 connected at its remote end to a conventional oxygen supply (not shown). At its inner end, the nozzle 11 is drawn down to a discharge orifice 15 and terminates slightly rearwardly of, and in approximate alignment with, the upwardly presented orifice 16 of a water induction nozzle 17, which is removably mounted, by means of a tapered fit, in, and extends vertically through, the bottom portion of the tubular element 6 and is similarly provided on its downwardly projecting end 18 with a diametrically enlarged collar 19 for retentive engagement with a water conduit or tube 20. Just above the level of the inner face of the tubular member 6, the water induction nozzle 17 is provided with a laterally opening water-return aperture 21, as best seen in Figure 3, and for purposes presently more fully appearing.

Also threadedly mounted in the bottom portion of the tubular element 6 and extending vertically upwardly therefrom in forwardly spaced parallel relation to the water induction nozzle 17 is a post member 22 integrally provided at its upper end with a water dispersion ball or spherical target 23, the latter being located with its center approximately along the projected axis of the gas inlet nozzle 11. Just above the gas inlet orifice 15, the clamp leg 2 is provided with an aperture 24 opening into the diffusion chamber *c* so as to permit a certain amount of air to be drawn into the chamber *c* by the force of the oxygen discharging through the nozzle orifice 15. Under certain circumstances it may be desirable to provide a substantially pure oxygen stream, in which case the aperture 24 may be closed by the insertion of a suitably sized rubber stopper or cork, the latter being conventional and, therefore, not being shown.

The water conducting tube 20 extends downwardly and bends upwardly in a U-shaped loop and is, at its upper end, connected to the lower end of a drip tube 25, which is, in turn, connected to a water flask 26 by a short section of flexible rubber tubing 27 equipped with a screw clamp 28. Preferably, though not necessarily, the flask 26 is filled with distilled water and suspended or hung by means of a wire bail 29 from a conventional transfusion stand 30. It will, of course, be understood in this connection that the transfusion stand 30 is in no sense a part of the present invention and that the flask 26 could be hung from any convenient hook or similar support.

In operation, the stream of water flowing downwardly from the flask 26 is regulated by suitable adjustment of the screw clamp 28, so that it will drip drop by drop into the drip tube 25 and then run through the supply tube 29 up into the nozzle 17. Thereupon, the oxygen control valve is conventionally manipulated to permit oxygen to

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flow through the oxygen supply line 14 at any desired pressure which may be determined upon any conventional pressure gauge (not shown). The stream of gas issuing from the restricted orifice 15 flows at high velocity across the water orifice 16 setting up a venturi effect causing an area of lower pressure adjacent the water orifice 16 which draws the water upwardly into the gas stream. Because of this suction effect, the latter will not flow outwardly through the aperture 21 and the particles of the water which are thus drawn up out of the orifice 16 will be blasted at high velocity, that is, at substantially the velocity of emergence of the gas stream from the gas nozzle against the spherical target 23 and broken up into extremely finely divided particles of the order of 6 to 10 milli-microns. These particles are then further impinged upon the walls of tubular members 6 and 8. In other words, the water is reduced to almost colloidal size and is thus suspended in the gas stream as a substantially non-condensable fog or mist. It is therefore possible to introduce a relatively high percentage of moisture content into the gas stream.

The humidified gas stream then flows upwardly through the intermediate tubular element 8 and outwardly through the discharge tube 10. The angularly upwardly deflected leg, through which the humidified gas must travel as formed by the tubular elements 8 and 9, serves to change the direction of the flow of the gas twice in a short length of its travel, thereby causing any oversized or relatively large particles of water to be precipitated out of the gas stream in case accidentally oversized water particles may escape intact from impingement against the spherical target 23 and walls of members 6 and 8. The humidified gas stream issuing from the discharge tube 10 will be similar to a fog or mist and will not contain large-sized particles. It has been found in this connection that the resulting humidified gas or fog can be projected for relatively long distances before it disappears into the atmosphere and when the hand is held up in the path of this humidified gas stream, the fog will flow around the hand and pass on without depositing any very appreciable amount of moisture. Of course, if the hand is held in such position for any great length of time, a film of moisture will be deposited out of the gas stream, but the slowness of which this film is deposited establishes that the moisture is intimately dispersed in the gas stream and is not readily condensable therefrom.

Once the oxygen has been turned on, the operator can then further manipulate the screw clamp 28 so as to increase or decrease the rate of flow of water until the amount of moisture, which is being dispersed into the gas stream, will reach any desired or predetermined concentration. Any unvaporized moisture or water particles, which tend to collect in the bottom of the chamber *c*, will immediately be sucked back into the water stream through the aperture 21, thereby preventing the collection of any substantial quantity of liquid in the bottom of the chamber *c*. It is, of course, obvious that if the screw clamp 28 is open too widely, so that the rate of flow of water is excessive, the excess water, which is not drawn out of the nozzle due to the suction effect set up by the gas stream issuing from the nozzle orifice 15 will flow outwardly through the aperture 21 and tend to build up a liquid level within the chamber *c*. Since the tubular elements 6, 8, and 10, are preferably formed of transparent Lucite, this water-level can be readily observed by the attendant nurse and the flow of water through the tube 20 cut down by appropriate manipulation of the clamp 28. Finally, if through inadvertence or negligence, the device should fill up with liquid until the liquid level reaches or tends to cover the gas inlet orifice 15, a violent gurgling noise will issue from the apparatus immediately calling attention of the operator to such liquid logged condition and the operator may correct the situation, almost instantaneously, by removing the nozzle 17 momentarily and allowing the excess

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water or liquid to drain outwardly through the hole in which the nozzle 17 was inserted. When the device has been completely drained the nozzle 17 can be reinserted and the introduction of water resumed. Since this latter operation can be performed very quickly there will be substantially no interruption in output of humidified gas. This features furthermore, makes it possible to remove the liquid induction nozzle 17 for cleaning if it should become stopped up during use with accumulation of calcium deposits or suspended foreign matter as sometimes occurs where water with medicinal additives or other than distilled water is being used. Of course, if distilled water is being used the apparatus would not ordinarily become stopped up unless flying particles in the air should accidentally become included in the water stream. This latter accidental result sometimes occurs in hospitals where lint from the bandages, bed linens, or the like may be in the air and may settle on the apparatus, if the operator is not careful. All of these results, of course, are highly accidental and do not occur frequently, but the present invention is capable of simple operation and is relatively fool-proof even under such abnormal circumstances.

If desired, it is also possible to provide a modified form of oxygen humidifying apparatus B, as shown in Figures 5 and 6, comprising a stand *s* integrally including vertical leg members connected by a horizontal member 32, which is, in turn, provided with an upstanding cylindrical well 33 having a diametrically enlarged open-topped cylindrical receptacle 34 into which a suitably sized water bottle 35 can be placed. The height of the receptacle 34 is such that it will support the water bottle 35 adequately and the water bottle 35 is, in turn, provided with a relatively short neck 36 of such length that, when the water bottle 35 is disposed in inverted position within the receptacle 34, the neck 36 will extend downwardly a short distance into the well 33. The bottle neck 36 is further provided with a stopper 37 having two spaced parallel tubes 38, 39. It will be noted that the tube 38 is somewhat shorter than the tube 39 and that both tubes terminate at their lower ends in substantially upwardly spaced relation to the bottom wall of the well 33. Secured in and extending through that portion of the horizontal member 32, which forms the bottom wall of the well 33, in a short outlet tube 40 externally provided on its lower or downwardly projecting end with a diametrically enlarged collar 41 for retentively holding in place one end of the U-shaped length of flexible rubber tubing 42, which is, in turn, bent upwardly and similarly retained at its other end upon the downwardly projecting end of a nozzle 43 substantially similar in all respects to the previously described nozzle 17. The nozzle 43 is removably mounted in and projects upwardly through the horizontal portion 32 of the stand *s* and into the interior of a diffusion chamber *c'* formed by a horizontally disposed length of transparent tubing 44 which is cut off vertically at one end and sealed with an upstanding wall 45 and at its other end is miter-cut, as at 46, for adhesive juncture with a complementarily mitered end of a vertical section of transparent tubing 47, the latter being, in turn, mitered at its upper end for adhesive juncture to an outwardly extending horizontal section of tubing 48, which is open at its outer end and serves as a vapor discharge duct. Mounted in, and extending horizontally through, the end wall 45 is an oxygen nozzle 49, which is connected at its outer end by means of an oxygen line 50 to any conventional source of oxygen under high pressure, the nozzle 49 being substantially identical in structure and function to the previously described oxygen nozzle 15.

It should be noted that the nozzles 43 and 49 are disposed at right angles to each other with their respective longitudinal axes lying in a vertical plane and the orifices located in the same position as previously de-

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scribed, so that the oxygen blast issuing from the nozzle 49 will produce a venturi effect across the orifice end of the nozzle 43.

The nozzle 43 is, of course, provided with a lateral orifice 51 which is substantially similar in construction, arrangement, and function to the orifice 21 of the nozzle 17. Rigidly mounted in, and extending vertically upwardly from the lower interior face of the tubular member 44 and disposed in forwardly spaced parallel relation to the nozzle 43 is a post member 52 provided at its upper end with a water dispersion ball or spherical target 53, which, again, is substantially identical in construction and function to the previously described target 23.

The oxygen humidifying apparatus B functions substantially in the same manner as the previously described apparatus A, except that the water in the bottle 35 will dribble into the well 33 until the liquid level within the well 33 has just barely covered and closed the downwardly presented opening 38, whereupon the admission of air into the bottle will cease and a sort of hydrostatic equilibrium will be reached. The water will then be drawn through the nozzle 43 and intermixed or dispersed in the same manner as previously described in connection with the oxygen moisturizing apparatus A. As the water is withdrawn from the nozzle 43 the water level therein will drop slightly and as soon as the lower end of the tube 38 becomes unblocked a bubble of air will pass upwardly through the tube 38 and into the bottle 35, disturbing the hydrostatic balance and allowing a compensating quantity of water to flow downwardly through the tube 38 into the well 33 to restore the water level therein. This process will continue automatically as long as any water is left in the bottle 35. Since the more or less repetitive admission of air bubbles through the tube 38 will produce a slight bubbling noise, the attendant or nurse will become accustomed to such regularly repeated sound and will immediately be subconsciously warned when the bottle 35 is completely empty because the regularly repeated or rhythmic sound will cease.

It should be noted that instead of the tube 42, connecting the well 33 and the chamber *c'*, a continuous integral chamber could be provided as well, such as is shown in the embodiment illustrated in Figures 10 and 11. In such case the liquid would be drawn directly into the liquid induction nozzle 43 through the opening 21 in the nozzle adjacent the bottom of the chamber *c'*.

The oxygen humidifying apparatus B is uniquely suitable for placement on a bedside table where a stream of moisturized oxygen is to be directed toward the general vicinity of the patient's nose and mouth where only moderate breathing assistance is required, or for placement upon a shelf or other suitable support in proximity to an incubator for blowing humidified oxygen through a suitable aperture or window with which incubators are ordinarily equipped. It will, of course, be understood in this connection that the oxygen humidifying apparatus B may be used in the same manner as the previously described moisturizing apparatus A, in which case the outlet duct 48 may be connected by suitable tubing or conduit to an oxygen tent or any other conventional type of hospital apparatus employed in oxygen administration.

In certain instances it is advantageous to have the tubing 47 and 48 dirigible so as to enable the direction of the outcoming humidified gas in a particular direction rather than having to orient the entire device to accomplish this objective. To this end, the upstanding tubing section 47 may be divided into two sections 47*a* and 47*b* along a line of division 47*c*. A collar of material 47*d* having an inside diameter substantially equaling the outside diameters of the two sections 47*a* and 47*b* is then affixed to the end of one or the other of sections 47*a* or 47*b* in a manner so as to telescope the end of

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the nonaffixed section. It is apparent that in this manner, sections 47a and 48 may be rotated relative to section 47b.

It has been found additionally advantageous to provide a lip 48a at the lower outer end of tubing section 48 and to cut away a small portion of the overlying upper edge 48b of tubing section 48. This has been found helpful to prevent any condensed droplets of liquid formed during prolonged operation of the device from dropping for example into an incubator or canopy into which the humidified inhalant gas is being directed.

In certain instances where for example, the entire apparatus is suspended or placed within an enclosure or area in which the patient is being treated, it has been found desirable to dispense with the dirigible tubing sections 47a and 48 described above and instead of the collar 47d, a hood or deflector 68 such as illustrated in Figures 8 and 9 is affixed to the upper end of tubing section 47b. The deflector or hood 68 has a semi-cylindrical supporting section 68a which is affixed in any suitable manner to the upper edge of tubing section 47b. To this supporting section 68a, circular hood member 68b is affixed. The hood or deflector member 68b is of larger diameter than the tubing 47a and so overlaps same in the manner shown. Additionally, the deflector member 68b is contoured so as to have a rather flattened M shaped diametral cross section. Any condensate formed which might rise through tubing section 47b will be returned into the chamber c' by means of the downwardly directed portion 68c which overlies the opening of tubing portion 47b, whereas the humidified gas is deflected downwardly and outwardly by contoured section 68d. For additional support, the overlapping section 68d has affixed thereto a strap or bar 69 affixed at its other end to the upper end of tubing 47a opposite the support 68a.

It is also possible to provide a further modified form of oxygen humidifying chamber c'', as shown in Figure 7, which comprises a chamber-forming element 54 having a vertical end wall 55 and a vertical discharge tube 56, the latter being set into the upper wall of the member 54 and opening downwardly thereinto. Mounted in the member 54 and end wall 55, respectively, is an oxygen induction nozzle 11' and a water induction nozzle 17' substantially identical in all respects to the previously described nozzles 15, 17, respectively, and functioning in substantially the same manner. Threadedly mounted in, and extending horizontally through, the opposite end wall 56 of the chamber-forming element 54 is a tubular sleeve 57 which is internally threaded and provided with a horizontal screw 58. On its outer end, the screw 58 is provided with a diametrically enlarged knob 59 and at its interior ends with a ball-shaped or spherical target element 60, which is substantially similar to the previously described spherical targets 23 and 53 and is located in the same position of alignment with the orifices of the nozzles 11', 17'.

The back wall 2' of the humidifying chamber c'', which is substantially similar to the back wall forming main leg 2 of the previously described oxygen humidifying apparatus A, is provided with an aperture 61 located in upwardly spaced relation to the induction nozzle 11' and is provided with a rearwardly projecting tube 62 which is connected by means of a short section of rubber tube 63 to a similar rearwardly projecting tube 64 which is inserted through the rearwardly presented portions 65 of the vertically extending tubular passage 66, preferably adjacent the upper end thereof where it is enjoined to the upwardly projecting horizontal discharge pipe or tube 67.

The tube 63 permits a recycling of a small amount of moisture laden oxygen vapor from the region of the discharge tube 67 back to the rearward zone of the moisturizing chamber c'' so as to break the vacuum which tends to build up in this zone. This expedient is extremely convenient and desirable where it is necessary to administer a substantially pure stream of oxygen to

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the patient and the admission of air to break the vacuum in this zone would consequently be undesirable.

By turning the knob 59, the screw 58 may be threaded inwardly and outwardly, so that the target 60 may be adjusted toward and away from the orifices of the nozzle 11', 17'. The amount of moisture which will be suspended in the outflowing stream of gas can be varied and controlled within fairly precise limits by adjusting the position of the spherical target 60. The closer the ball is to the orifices of the nozzles 11', 17', the greater will be the concentration of moisture in the gas stream, and, contrariwise the further away the spherical target 60 is, the lower will be concentration of moisture in the gas stream.

The moisture which is introduced into the gas stream by the humidifying apparatus of the present invention is so finely divided that it will impart to the otherwise colorless gas stream an appearance of fog or smoke having a light gray or almost white color. By actual experiment and practice, it has been found that the concentration of moisture in the gas stream can be observed with a surprisingly high degree of accuracy by merely noting the density of the fog-like or smoke-like gas stream which is produced by the apparatus and the spherical target 60 can be adjusted inwardly or outwardly until the desired density is visible. Even relatively unschooled operators can learn to judge the moisture density of the gas stream quite precisely with relatively short experience and training.

Referring now particularly to Figures 10-14 of the drawings, a preferred embodiment of apparatus for carrying out the method of this invention is illustrated. Numeral 70 represents a housing somewhat L shaped when viewed in side elevation defining within its confines a pair of communicating chambers 71 and 72 in the legs of the L shaped casing. The lower, horizontally disposed chamber 71, is water tight and constitutes a well or liquid reservoir, one end 73 of which is rounded. The other end of the reservoir section 71 is merged into chamber portion 72 of the housing 70 which is upwardly or vertically disposed with respect to reservoir chamber 71 and generally of uniform rectangular horizontal cross section except for its curved or rounded top 74 which is of progressively decreasing rectangular cross section. It should be understood therefore, that the entire housing 70 constitutes a continuous hollow enclosure defining principally two chamber sections.

A deck 75 for the horizontal reservoir chamber 71 of the housing 70 is provided with an aperture 76 about which and extending flaringly outwardly and upwardly therefrom is a receptacle holder 77 which may conveniently be of cup shape. The purpose of the holder 77 is to removably secure an inverted liquid containing receptacle such as the bottle illustrated at 78. The neck of the bottle 78 is preferably covered by a shaped closure member 79 of a resilient material such as rubber. The closure member 79 is provided with a flaring portion 80 which snugly adjoins the curved portion of the bottle and sealingly engages the aperture 76 in the deck member 75. The seal so effected with aperture 76 may be a tight press fit or may merely be a seating closure dependent upon the weight of the bottle 78 and/or its contents. The cap 79 may be secured to the bottle 78 by a press fit or by large internal threads 81 and is further provided with a pair of tubular outlets 82 and 83 of slightly dissimilar length and internal diameter. The longer tube 82 is of the larger internal diameter and is adapted to extend nearly to the base or floor 84 of the reservoir chamber 71 and acts as the outlet for discharging the liquid contents of bottle 78 into said reservoir chamber. The tube 83 is shorter than the outlet tube 82 by a predetermined amount and determines the level 84' to which liquid may rise in the reservoir chamber 71 by acting as an atmosphere vent for receptacle 78. This tubing arrangement operates such that a substantial and

constant volume of liquid is always maintained in the reservoir chamber 71 and thereby provides an adequate reservoir supply during brief periods when the contents of bottle 78 must be replenished or a new bottle with a fresh supply of liquid is substituted.

Adjacent the lower end of a side wall 85 of the up-standing vaporizing and circulating chamber 72 of the housing 70, there is located an access opening 86 which in turn is provided with a door or closure 87 secured to the wall 85 of the housing 70 by any suitable means such as screws 88 which extend through aligned bores in the closure 87 and the wall 85 and terminate in threaded ferrules 89 secured by any suitable means to the inside of the wall 85. A suitable gasket 90 having apertures for the screws 88 is provided between the closure 87 and the wall 85 to maintain the housing 70 liquid and gas tight.

Secured to the inside of the door or closure 87, and extending substantially normal therefrom is a tubular member 91. An upper and a lower portion, 92 and 93 respectively, of tubular member 91 adjacent the closure 87 are cut away as best illustrated in Figure 11. The lower cutaway portion 93 of the tubular member 91 permits the tubular member to lie closely adjacent the floor or base 84 without interference with the lower threaded ferrules 89 when inserted through the opening 86 and positioned in place, when the closure 87 is secured to the wall 85 by the screws 88, also as best illustrated in Figure 11. The purpose for the upper cutaway portion 92 will be referred to hereinafter. The other end of the tubular member 91 when in place, extends to within a short distance of the other side wall 94 of the vaporizing and circulating chamber 72 and its function will also appear hereinafter.

Within the tubular member 91 and extending upwardly and centrally from its bottom wall portion is a liquid induction nozzle 95 having a central bore 96 terminating in an orifice 97 which is located substantially at the longitudinal axis of the tubular element 91. In order that liquid in the reservoir supply defined by level 84' be accessible to the liquid induction nozzle 95, a slot 98 such as might be cut by a saw, extends transversely across the bottom of tubular member 91 and through the lower portion of the liquid nozzle 95 such that the nozzle bore 96 is in free communication therewith.

Immediately below the liquid induction nozzle 95, there is provided a tapped hole in the base 84 for the purpose of ready access to the nozzle 95 in order to run a cleaning rod therethrough in the event that the bore 96 becomes clogged by foreign matter, formation of crystals or the like. This convenient clean out port is normally closed by a short screw 99 having a wide flat head, and sealed by means of a suitable washer type gasket 100. In this manner, if any difficulty should be encountered in the liquid induction nozzle bore 96, the situation can be readily remedied without necessity of removal of the closure 87 and entire vaporizing unit.

Adjacent nozzle 95 within tubular member 91 and toward the wall 94, there is positioned a spherical target member 101 by means of a leg 102 also secured to the bottom of the tubular member. As was the case with the orifice 97, the center of the spherical target 101 should be positioned substantially on the longitudinal axis of the tubular member 91.

Completing the fully removable and accessible vaporizing unit, a gas injection nozzle 110 is mounted in and extends perpendicularly through the closure 87, with its longitudinal or injection axis and bore 109 substantially coincident with the axis of the tubular member 91. In order for the orifice 111 of the gas injection nozzle 110 to be longitudinally adjustable with respect to the liquid orifice 97, but to prevent its being twisted or turned out of adjustment, the central portion of the nozzle and forward thereof to where the orifice taper commences is

provided with flat parallel sides 112 and threads 113 for the curved portions between said flat sides as best seen in the sectional view of Figure 12. The opening 114 in the closure 87 is correspondingly shaped to prevent twisting or rotation of the gas jet or nozzle 110 therein.

Longitudinal adjustment of the gas orifice 111 with respect to the liquid orifice 97 is achieved by means of a pair of lock nuts 115 and 116 operable on the threads 113 to lock the gas injection nozzle 110 to the closure 87. In order to obtain a suitable gas seal and proper bearing, a gasket and washer, 118 and 117 respectively are interposed between the inner lock nut 116 and the closure 87.

The outer end 119 of the gas injection nozzle 110 is provided with threads 120, preferably of larger size than the threads 113, for engagement with any conventional gas messenger coupling member (not shown). For this purpose a conventional female seat 121 is provided and a large hex grip 122 integral with the nozzle 110 proper, permits the application of a wrench to hold the nozzle 110 in conventional manner while the coupling member is being attached to the threads 120 by means of a second wrench.

The inhalant gas, oxygen for example may be supplied from any suitable source under pressure (not shown) such as cylinders, bank supply or the like through conventional pressure reducing regulators, and flowmeters (also not shown).

In Figure 14, there is shown an alternative form of gas injector nozzle 130 in all respects similar to nozzle 110 except that instead of having outer gas supply coupling threads 120, it is provided with a conventional slip over gas hose fitting 131 having annular serrations 132. As no tools would be required to turn a gas supply hose in place on a fitting such as 130, the large integral hex wrench grip 122 may be eliminated.

It will be understood that an entirely removable and replaceable vaporizing unit has been illustrated and described. This facilitates servicing or replacement in the field, particularly where liquids other than distilled water may be used to humidify the inhalant gas or where medicinal preparations are added to the water or other liquid used and the residues, often crystalline in nature are permitted to remain through failure to rinse out the device with clear or distilled water after such usage. On the other hand, where only distilled water is to be used for humidifying the inhalant gas, the vaporizing unit need not be made removable and may be fixedly installed to the base 84 and wall 85 before the rear plate 108 is fixed in place to complete the housing 70.

The entire assembly is provided with a tripod suction cup footing arrangement whereby the device can be held in place by application of a small hand exerted pressure. A single cup 103 is positioned on the underside of the base 84 adjacent the curved end 73 and for greater stability, a pair of cups 104 and 105 are spaced on either end of a support bar 106 affixed to the underside of base 84 beneath the chamber portion 72 and extending slightly beyond either side thereof.

The operation of this preferred embodiment of apparatus according to the inventive method herein involved is as follows: Liquid from the inverted bottle 78 flows intermittently from tube 82 at a steady rate into the reservoir chamber 71 as atmosphere, in bubbles is permitted entry into the bottle through the shorter vent tube 83. This continues until the liquid in the reservoir chamber 71 reaches a level even with the end of the shorter vent tube 83 preventing its further venting action and thus automatically stopping the flow. As gas is admitted through nozzle 110, it passes at high velocity over the liquid induction orifice 97 creating an area of diminished pressure and thereby drawing liquid through the slot 98 below the liquid level into the passage 96. The liquid thus drawn up is blasted against the spherical target 101 and broken into fine particles. The distances between the gas jet orifice 111 and the liquid orifice 97 and be-

tween the liquid orifice 97 and spherical target 101 are critical and are preferably factory adjusted to correlate with the orifice size of the gas jet 111 for producing the desired fog or vapor cloud. For this reason, it is felt preferable to fixedly mount and adjust at the factory all these elements to the closure 87 and tubular member 91 respectively so that no maladjustment may subsequently occur. To obtain ultimate particle sizes down to a range of a few millimicrons, the particles are further impinged and literally blasted against the lower portion of the flat wall 94 adjacent the opening of tube 91 as well as the walls of the tubular member 91 itself. The ultimate particle size of the liquid is also directly related to the length and diameter of the tubular member 91, smaller sizes being achieved as the tube is lengthened and narrowed.

Since the gas injection orifice 111 is fixed, gas flow and velocity can only be increased by increasing the pressure. Such increases account for a range in particle sizes as greater gas velocities also tend to produce the smaller particle sizes.

The gas stream and newly entrained moisture particles are confined to the path provided by tubular member 91 and secondarily blasted against the adjacent lower portion of the wall 94 of the upstanding housing chamber 72 opposite closure 87 and gas nozzle 110. As previously stated, this further tends to break up the liquid particles and abruptly changes the direction of the gas entrained liquid particle flow to a verticle direction. The moisture laden gas is then directed through a circuitous path with additional changes in direction around the curved topside of the upstanding circulation chamber 72 until the exit opening 107 is reached from whence it is discharged. Prior to its discharge from opening 107 however, and during its circuitous course of travel through a plurality of changes of direction each of which is at least 90°, all of the larger, heavier and undesirable moisture particles will have had an opportunity to coalesce and gravitate downwardly into the liquid reservoir at the bottom where this liquid then becomes available for reuse through the liquid induction tube 95. Moreover a portion of the humidified gas will be drawn, without outward passage, through the discharge opening 107, back into tubular member 91 through the upper cutaway portion 92 thereof to be carried by the freshly issuing gas stream and recirculated through the aforementioned circuitous path aiding in achievement of substantial saturation with moisture particles of microscopic size.

From exit opening 107, the properly humidified gas may now be transmitted through suitable tubing (not shown) to the particular type of apparatus for its administration prescribed by the physician, such as a canopy or mask for example.

It will be seen therefore that each of the many embodiments of apparatus constitutes means wherein moisture is finely divided and entrained in an inhalant gas by blasting the particles consecutively, that is, in rapid succession against dissimilar surfaces, one spherical, the other curvilinear and at different pressures to obtain maximum diminution of particle size within a heretofore unachieved range of a few milli-microns, thereafter immediately passing and repassing or recirculating the moisture particle laden gas over a sufficiently circuitous path with a plurality of changes of direction to coalesce, wipe and drop out any undesirable larger particles of moisture, reusing said released larger particles, and delivering the properly humidified gas to the prescribed therapy devices.

It will also be seen from the foregoing description and each embodiment of my invention illustrated in the drawings, that apparatus is provided wherein two dissimilar surfaces are placed directly in the path of the liquid entrained gas stream for finely dispersing the entrained liquid in rapid succession. Moreover, in each instance illustrated, one of these surfaces is conveniently provided in the form of a wall of the device which causes an immediate and abrupt change of direction of the moisture

laden gas stream of at least ninety degrees, and subsequently at least another such abrupt change of direction, again of at least ninety degrees whereby any larger particle sizes are eliminated prior to discharge.

It is thought that inasmuch as the chief novelty of this invention appears to lie in the several forms of apparatus for nebulizing and humidifying an inhalant gas with moisture particles of extremely small and effective size, all such modifications in apparatus for carrying out the process disclosed as will be hereby suggested to those skilled in the art and which fall within the spirit of the invention are intended for inclusion within its scope as best defined by the appended claims.

I claim:

1. Gas humidifying apparatus which comprises, in combination, a source of gas under pressure, a source of liquid, a housing forming an elongated chamber having a bottom wall portion, said chamber being provided at one end with a discharge passage the longitudinal axis of which is disposed at an angle to the longitudinal axis of the chamber and has a discharge opening laterally displaced with respect to the chamber, a gas nozzle extending into the housing, means for connecting the gas nozzle to the gas-source, said nozzle having an orifice for admitting a high pressure stream of gas into the chamber, a liquid induction nozzle mounted in and extending upwardly through the bottom wall portion of the housing, means for connecting the liquid induction nozzle to the liquid source, said liquid induction nozzle having an orifice disposed at a level substantially below the liquid level in the liquid source so that the liquid will flow to the liquid induction nozzle under a hydrostatic pressure, means for controlling the rate of liquid flow to the liquid induction nozzle, said orifice also being positioned adjacent to and in line with the orifice of the gas nozzle so that the high pressure stream of gas issuing from the gas nozzle will flow directly across the orifice of the liquid induction nozzle and produce a venturi effect which will draw liquid into the gas stream, said nozzle also having a laterally presented opening located between the bottom wall portion and the orifice and communicating with the chamber, and a target element mounted in the chamber directly in the path of the gas stream and on the opposite side of the liquid induction nozzle in relation to the gas nozzle so as to be interposed directly in the path of the liquid carrying gas stream whereby to break up into a very finely divided state the liquid particles carried by the gas stream.

2. Gas humidifying apparatus which comprises, in combination, a source of gas under pressure, a source of liquid, a housing forming an elongated chamber having a bottom wall portion, said chamber being provided at one end with a discharge passage the longitudinal axis of which is disposed at an angle to the longitudinal axis of the chamber and has a discharge opening laterally displaced with respect to the chamber, a gas nozzle extending into the housing, means for connecting the gas nozzle to the gas-source, said nozzle having an orifice for admitting a high pressure stream of gas into the chamber, a liquid induction nozzle mounted in and extending upwardly through the bottom wall portion of the housing, means for connecting the liquid induction nozzle to the liquid source, said liquid induction nozzle having an orifice disposed at a level substantially below the liquid level in the liquid source so that the liquid will flow to the liquid induction nozzle under a hydrostatic pressure, means for controlling the rate of liquid flow to the liquid induction nozzle, said orifice also being positioned adjacent to and in line with the orifice of the gas nozzle so that the high pressure stream of gas issuing from the gas nozzle will flow directly across the orifice of the liquid induction nozzle and produce a venturi effect which will draw liquid into the gas stream, said nozzle also having a laterally presented opening located between the bottom wall portion and the orifice and communicating with the cham-

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ber, and a target element adjustably mounted in the chamber directly in the path of the gas stream and on the opposite side of the liquid induction nozzle in relation to the gas nozzle so as to be interposed directly in the path of the liquid carrying gas stream whereby to break up into a very finely divided state the liquid particles carried by the gas stream.

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