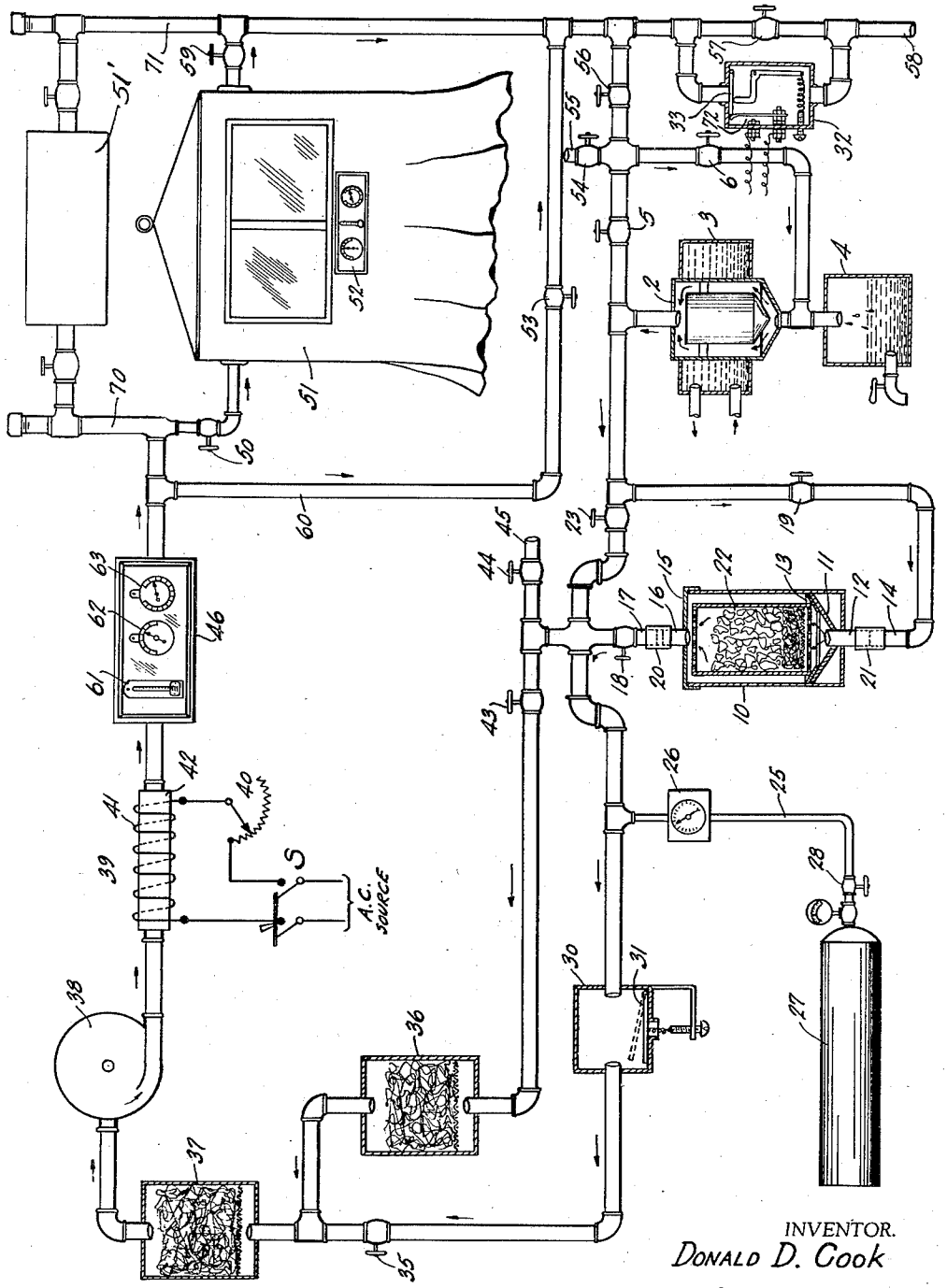
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APPARATUS AND PROCESS FOR TREATMENT OF RESPIRATORY DISEASES

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APPARATUS AND PROCESS FOR TREATMENT OF RESPIRATORY DISEASES

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The present invention relates in general to the treatment of respiratory diseases, and the object of the invention, briefly stated, is a new and improved method for the treatment of such diseases, together with certain novel apparatus by means of which the method may be carried out. The invention is particularly valuable in the treatment of pneumonia, for which it was especially developed, although its utility is not necessarily limited to the treatment of this disease.

There are several different types of pneumonias, but all of them are characterized by an impaired functioning of the lungs caused by a progressive reduction in the effective area of the lung tissue. The function of the lungs is to bring a supply of air into an intimate relation with the blood stream so that the blood can continuously exchange carbon dioxide for oxygen. It is unnecessary to state that if the normal rate of exchange is interfered with or reduced, a serious condition will ensue. This condition, known as anoxemia, is characterized by a shortage of oxygen and an excess of carbon dioxide in the blood; and results in damage to various organs, which will cause death if the condition is not alleviated. This critical stage is reached with various degrees of rapidity in different cases, and may never be reached. At the first onset of the disease, some reduction in the effective or working area of the lungs is compensated for by an increased rate of respiration and by an accellerated heart action, which gives the patient an opportunity to build up a resistance against the infection. Frequently the time thus afforded is sufficient to enable the progress of the disease to be arrested. In other cases, unfortunately, the affected area may continue to increase in size, progressively reducing the capacity of the lungs, and a point may be reached before long where the natural resources of the individual are unable to take care of the situation.

The usual method of relieving anoxemia, or of preventing it, is by the administration of oxygen, this operation being commonly known as oxygen therapy. The patient is enclosed in a so-called oxygen tent, to which oxygen is supplied in sufficient quantity to maintain a saturation of 50% or more. The temperature within the tent is maintained at about 68° F., which is the temperature usually advised. The cooling is accomplished by passing the oxygen, or oxygen enriched air, through a container filled with cracked ice. Since oxygen therapy is in use in many hospitals and is therefore well known, it will not be necessary to enter further into the details.

The theory of oxygen therapy is that by increasing the saturation of oxygen in the air which the patient breathes, the unaffected area of his lungs is rendered more efficient. Stating it another way, the blood can be maintained in normal condition by a smaller unimpaired lung area when working in an atmosphere of high oxygen saturation than is required in a normal atmosphere. This theory seems all right, and undoubtedly some patients are relieved, at least temporarily. The fact is, however, that the mortality rate of the disease has not been greatly lowered by the introduction of oxygen therapy.

The theory on which the present invention is based does not deny that the proper administration of oxygen is beneficial to pneumonia patients, but it predicates the substantial failure of oxygen therapy as practiced at present on the hypothesis that in undergoing the treatment the patient has so many other handicaps imposed on him that any benefit derived from the oxygen is overbalanced by other factors tending to accentuate the progress of the disease. It is believed that only in rare instances does a net benefit accrue to the patient. Of course some cases in which the oxygen tent is used have a favorable result, but it is also true that patients recover after no use of oxygen therapy at all. Suffice it to say here that a distrust of the accepted treatment is arising, but it has not been abandoned because nothing better has been available.

The belief that as commonly used an oxygen tent actually may promote the progress and fatal termination of the penumonia is based on the following reasoning: The oxygen tent maintains the patient in an atmosphere of cool air which has a high relative humidity and frequently is nearly saturated with water vapor. Because of its high relative humidity, the air in passing through the tent cannot take up as much water as is given off by the patient through perspiration and in the process of respiration, with the result that moisture tends to accumulate. This condition, along with the low temperature of the air, produces a climate inside the tent which resembles that encountered on a raw day in March, a season of the year when pneumonia is prevalent. It is logical to contend that a climatic condition which is a predisposing factor of prime importance in contracting the disease is not the correct climatic condition in which to treat the disease successfully.

The theory that the cool damp air of the oxygen tent promotes the progress of pneumonia is not only in agreement with the observed facts

as to the seasonal prevalence of the disease, but is supported by observation of patients undergoing the treatment, with special reference to the tendency to intro-pulmonic precipitation. The air in the lungs is saturated with water vapor which is expelled at every exhalation if normal working is not interfered with. When, however, cool air is drawn into the lungs and comes in contact with the warm saturated air therein, condensation is liable to take place, and especially so when the inhaled air has a high relative humidity. The lungs begin to fill up with water, and the beneficial effect of the increased supply of oxygen is counteracted by the loss in working lung area due to surplus moisture on the tissue surfaces and in time to actual fluid congestion.

The theory of the present invention therefore denies the efficacy of oxygen therapy as practiced at present because the oxygen is administered along with cool air having a high relative humidity, the evil effects of which are so pronounced that the patient is seldom able to derive any net benefit from the additional oxygen.

The new method of treatment evolved from the foregoing and other considerations is based primarily on the idea that far better results can be secured if an artificial climate can be created for the patient which will inhibit the progress of the disease. Instead of subjecting the patient to the malignant influence of a cold damp atmosphere, it is proposed as a fundamental principle to give him the benefit of a warm dry atmosphere, which is known from experience to be highly unfavorable to the development of pneumonia. Thus the new treatment proceeds along lines directly opposite to those which are features of the old treatment. Instead of cold air, warm air is supplied. Instead of moist humid air, dry air is supplied.

By this process there is created for the patient an artificial climatic condition favorable for recovery, and which may alone be sufficient to enable the patient to successfully resist the progress of the disease. If more than the normal amount of oxygen is required, the oxygen is administered without changing the favorable conditions, thereby enabling the patient to utilize it to the fullest extent.

Further details of the treatment will be explained hereinafter in connection with the description of the apparatus which has been designed for practicing it, reference being made to the accompanying drawing, in which there is shown diagrammatically one form of apparatus which may be used.

Referring to the drawing, it will be seen that the several equipment items, conventionally illustrated, are connected together by a system of pipes or tubing to form a closed circulating system. The size of the tubing used will depend on the capacity desired, but in most cases two or three inch tubing will be satisfactory. If the apparatus is to be used for a single patient then a smaller size will be large enough. The fittings such as couplings and valves may be of any suitable type. The arrows show the direction in which the air flows.

The first piece of apparatus which will be pointed out is the dehydrating apparatus or equipment for removing water vapor from the circulating air. This equipment comprises a chamber 2, surrounded by a water jacket 3, in which a circulation of cold water is maintained. The air is cooled on coming in contact with the walls of the chamber, resulting in condensation of the moisture, which accumulates in drops and runs down into the tank 4 from which it may be withdrawn from time to time. In order that the air may be passed through the dehydrating apparatus the valve 5 should be closed and the valve 6 should be open. The apparatus can be bypassed by reversing the position of the valves, that is, opening valve 5 and closing valve 6. Other known means of extracting water vapor may be used.

Next to the dehydrating apparatus there is shown apparatus for removing carbon dioxide from the air. This comprises a cylindrical chamber 10 having a conical false bottom 11 on which rests a rubber ring 13. A pipe 12 extends through the bottom of the container and the false bottom 11. The lower end of pipe 12 is connected with pipe 14 by a tight fitting sleeve 21. The chamber 10 has a cover 15 in which there is set a pipe 16, the latter being connected to pipe 17 by means of sleeve 20. Inside the chamber 10 there is a canister 22 containing soda lime. This canister is perforated at both ends and the lower edge rests on the ring 13, which makes a gas tight connection and forces the air to flow through the canister.

The foregoing apparatus is connected into the system by opening valves 19 and 18 and closing valve 23. It can be by-passed wholly or partially by opening valve 23 to the necessary extent. These valves may also be used when inserting a fresh canister of soda lime, which has to be done from time to time. Valve 23 is opened and valves 18 and 19 are closed. Sleeves 20 and 21 are then slipped down on pipes 16 and 14, respectively, sufficient to clear pipes 17 and 12, whereupon the chamber 10 can be moved out sideways and the cover 15 removed. The used canister such as 22 can then be removed and replaced by a fresh one. The apparatus is then reassembled and the valves are returned to their former positions.

The arrangement for introducing oxygen into the system includes a pipe 25 which is connected to an oxygen tank 27 by way of a valve 28. A flow meter 26 is connected in series with the pipe 25 so that the amount of oxygen being admitted can be observed.

The reference character 30 indicates a valve chamber, provided mainly for purposes of safety. It contains an adjustable intake valve 31. There is another valve chamber 32 which contains a relief valve 33. The function of these valves will be described later.

The reference characters 36 and 37 indicate filters for removing impurities from the air. These filters may be of various types as circumstances require.

A blower for maintaining the circulation of the air is indicated at 38. This blower may be driven in any convenient way, preferably by an electric motor.

Means for heating the air is indicated at 39. The heating device is preferably electrical, and may comprise heating coils such as 41 by means of which a tube 42 through which the air flows is maintained at a high enough temperature to heat the air. Regulation is secured by means of a rheostat 40. It will be appreciated that the showing is more or less conventional and that various known kinds of heating apparatus may be used.

The reference character 46 indicates a box or casing connected in the circulating system. In-

struments such as a thermometer 61, a hygrometer 62, and a barometer 63 may be suspended in the air stream and can be observed through the glass face with which the casing is provided.

The reference character 51 indicates an oxygen tent, which may be of any suitable design. A number of tents which can be used are on the market. As shown herein it comprises a frame work covered by some textile fabric, having windows to light the interior, and adapted to be suspended over a patient lying in bed. The tent is preferably large enough to enclose the head and shoulders of the patient and provide sufficient space above so as to avoid a feeling of confinement by the patient so far as possible. The lower part of the tent is arranged so that it can be folded underneath the mattress and bed coverings in the well known manner to make the enclosure substantially gas tight. An instrument panel 52 is incorporated in the wall of the tent, the instruments being subject to atmospheric conditions inside and being readable from the outside.

The treatment is not limited to the use of any particular kind of breathing apparatus, and it will be understood, therefore, that the tent is shown merely as one convenient type which may be used. Various kinds of face masks are also known and are well adapted to the treatment.

The apparatus described may be permanently installed in a hospital room or ward, or the various equipment items may be mounted in convenient fashion on some kind of wheeled conveyance to make the complete assembly portable, so as to adapt it for use in any place required. In the case of a permanent installation in a hospital ward, the pipes 70 and 71, shown closed by caps, may extend down a line of rooms or beds, so that the system can be used to supply air at any room or bed required without the necessity of moving any apparatus except the tent. The system may even be used to operate several tents in parallel, provided the patients are being treated for non-contagious diseases, or if the necessary filtering means is interposed as at 37 to eliminate bacteria from the air before it is breathed. Heating of the air is also effective to kill many types of bacteria. The drawing indicates a second tent 51^1, which may be separately connected to the circulating system or which may be operated in parallel with tent 51.

The operation of the apparatus will now be described, and for this purpose it will be assumed first that it is to be used in treating a pneumonia patient who requires the administration of oxygen.

While the oxygen tent is being set up, the circulating system may be started so as to get the proper supply of air ready. Assuming that the valves are all open, the system will be filled with air at atmospheric pressure. The motor driving the blower 38 is now started up, and the heat is turned on by means of switch S. Valves 57, 54, 6, 18, 43, and 44 are closed. Valves 50 and 59 may be closed also until the tent is ready. The air now flows in a closed circulating system extending from the blower 38 by way of heater 39, instrument chamber 46, by-pass pipe 60, valve 53, valve 56, valve 5, valve 23, valve chamber 30, valve 35, and filter 37 back to the blower 38. After the circulation has been established for a few minutes, the condition of the air may be observed and the necessary preliminary adjustment of the temperature may be made by means of rheostat 40, the temperature being read from the thermometer 61. The pressure in the system may also be observed on barometer 63 and the humidity on hygrometer 62. The blower is of the proper capacity to maintain a steady flow of air and the barometer should show a slight increase above atmospheric pressure. The humidity may be approximately correct, but if too high may be corrected by connecting in the dehydrating equipment, as will be fully explained shortly. If the humidity is somewhat too low, it may be neglected, as the deficiency will be corrected very soon after the patient starts breathing from the system.

When the tent is ready, it is connected in the system by opening valves 50 and 59, and by partially closing the by-pass valve 53, the latter being used to regulate the supply of air to the tent. The system is now in operation, to the extent that air is being circulated through the tent.

Attention may now be directed to the admission of oxygen to the system, which is accomplished by slightly opening the valve 28 and observing the flow meter 26. Various methods are in vogue for determining the proper concentration of oxygen in the air. This may be roughly estimated from observation of the flow meter in conjunction with empirical flow values obtained from previous use of the system. Samples of air may also be taken and tested from time to time. However, it is usual to regulate the amount of oxygen to a considerable extent from direct observation of the patient. If suffering from oxygen deficiency he will have a characteristic blue color, which changes to the normal color as the deficiency is corrected. It will be unnecessary to go into further details as to this phase of the matter, for the proper oxygen concentration and the effect of the oxygen itself have long been known. It may be stated, however, that with my process of treatment somewhat lower concentrations than are ordinarily deemed necessary may be used.

It will be understood that when the oxygen is first turned on it should be allowed to flow in considerable volume so as to rapidly obtain the desired concentration. When this point is reached the flow is reduced to a value which will just supply the amount consumed by the patient and the losses which occur at the tent. The amount of oxygen expended can be reduced somewhat by using a breathing bag equipped with a face mask, such as has been mentioned hereinbefore.

As soon as the patient starts using the air in the system, carbon dioxide is given off in exchange for the oxygen consumed. This product must not be allowed to accumulate and therefore the apparatus for removing it is connected into the system by opening valves 18 and 19 and by closing valve 23. The circulation of air in the system now takes place through the soda lime in canister 22, with the result that the carbon dioxide is absorbed as fast as it is produced by the patient. Sometimes it is desirable to have the air contain a certain percentage of carbon dioxide to stimulate breathing, and to secure this condition the by-pass valve 23 may be opened partially. The arrangement shown therefore provides for entirely removing the carbon dioxide, or for allowing a regulated part to remain at the discretion of the physician in charge.

The use of the dehydrating apparatus will now be explained. The expired air is saturated with

water vapor, which will accumulate in the system unless removed. This is accomplished by connecting in the dehydrating apparatus. Valve 6 is opened and valve 5 is closed, thereby causing the circulating air to pass through the dehydrating apparatus and give up a portion of its moisture content. The apparatus is of sufficient capacity so that as low a humidity as is necessary can be obtained. Regulation is secured by opening the by-pass valve 5 more or less. Securing the proper humidity is an essential step in my process and will be considered more in detail later on.

As already mentioned, the temperature is controlled, in the arrangement illustrated, by means of the rheostat 40, which increases or decreases the value of the current supplied to the heating coils. The maintenance of the air at the proper temperature is also an essential step in my process and will be more fully discussed in the further explanation thereof.

It will be noted that the instruments in chamber 46 are of value in starting up the system, and they may be used from time to time to check the instruments in the tent, although naturally the temperature and humidity in the tent and at the point where the instrument chamber is located will differ somewhat. The instruments at 46 are used also in case a mask or other simple form of breathing apparatus is used, which it might not be convenient to equip with separate instruments.

The intake valve 31 and the relief valve 33 ordinarily will function only in an emergency such as would arise if the circulation of the air should become impeded or stopped altogether. This might occur through improper manipulation of the valves controlling the carbon dioxide removing or dehydrating equipment, for example, or through the careless insertion of a canister of soda lime without first removing the covers from the perforated ends, although the likelihood of stoppage from these or other causes is remote. Nevertheless it may be considered advisable as a safety measure to provide these valves and when present they function in the following manner. Assuming that the system is stopped up by accidental closing of valves 18 and 23 at the same time, the blower 38 will at once create a suction in the system between the point where it is stopped and the blower, which will open valve 31, allowing air to be drawn into the system. At the same time the pressure will be increased on the other side of the blower, with the result that the valve 33 is opened to allow the air to escape. Valve 31 may take in air from the room, while valve 33 preferably discharges into the outside atmosphere by way of pipe 58. It will be seen, therefore, that circulation through the tent will be maintained notwithstanding the stoppage of the circulating system at any point between the intake and relief valves. These valves are of course adjusted so that they will not open in the normal unimpeded operation of the system. If desired, one or both of the valves may be equipped with an alarm to indicate that trouble has occurred. Thus valve 33 is shown equipped to close an electrical circuit at contact 72, the circuit serving to actuate an electric bell or other signalling device.

The foregoing considers the operation of the apparatus mainly from a mechanical standpoint. I will now go into the physiological features of the treatment with a view to pointing out among other things the essential conditions which are maintained, the effects these conditions produce on the patient, and the underlying reasons therefor, insofar as they are understood.

In the preliminary portion of this specification some of the disadvantages of methods at present in vogue were pointed out, and my new method was contrasted with such old methods in order to emphasize an essential difference between them. This difference is the use in my new method of a characteristically warm dry atmosphere from which the patient breathes, whereas in the old methods of treatment cool air is considered to be a necessity, and the humidity is permitted to be very high, often approaching saturation. The bad effects of cold damp air on the patient have been briefly referred to, of necessity. The beneficial effects produced by the warm dry air will now be discussed more in detail.

First will be explained more particularly what is meant by warm dry air. By this I mean air which at the least is as warm as is encountered at mid-day on a hot day in summer—a temperature of 90° or higher. As to the himidity, the amount of moisture is maintained as low as it can be without causing excessive drying of the air passages. The relative humidity, for example, may be about 50 or 60. Thus the air is not entirely devoid of moisture; in fact, since it is warm it contains considerable, but its relative humidity is such that it can take on additional moisture whenever the possibility presents itself.

The atmosphere in the tent therefore simulates the climatic conditions which statistically are known to be unfavorable to contraction of the disease and favorable to recovery from it. If carried no further than this, my new method of treatment induces very satisfactory results. The patient is kept warm without encumbering him with numerous coverings; but at the same time, and contrary to what might be expected, he is not uncomfortably hot, even though running a considerable fever. The heat of the body is kept down by evaporation of surplus moisture from the lungs and perspiration from exposed portions of the body. Ample amounts of fluids are supplied so that the throwing off of moisture by the patient may be maintained.

The chief effect of breathing warm dry air as defined in the foregoing appears to be, so far as I can determine, to definitely reverse the tendency to precipitation of moisture in the lungs and air passages which is characteristic of the cold damp air treatment. The warm dry air as it enters the lungs is nearly as warm as the air already there and is far below the saturation point. It cannot cause condensation, therefore, but on the contrary it has a large capacity for taking up moisture. In pneumonia the tendency is toward an excess of moisture in the lungs. Any accumulation, being at body temperature, affords a good culture medium for the growth of the bacteria of the disease, and also interferes with or prevents the functioning of that portion of the lungs where it exists. By causing the patient to breathe warm dry air, therefore, which can readily take up water, the formation of areas in which surplus moisture has accumulated is prevented and such areas as may have been formed are gradually dried up. It should be borne in mind that the air should not be too dry, however. Its humidity should be regulated to a value such that it will take away the surplus moisture but will not produce an excessive drying of the membranes of the nose and other air passages.

The warm dry atmosphere is of great value to the patient on various other grounds. Patients in cold air oxygen tents frequently complain of sinus pains, and of muscle pains in the shoulders, arms, and neck. They complain also of chills. These complaints, or rather the climatic conditions which cause most of them, are entirely removed under the influence of the heat and relative dryness of the air supplied in my new treatment.

Conditions inside the tent are vastly improved from several other standpoints. In the cold air oxygen tents the tendency toward accumulation of moisture results in a general condition of dampness, characterized by cold and clammy bed clothing, precipitation of moisture on the tent walls, etc., which is not only uncomfortable to the patient, but is also favorable to the continued life and virulence of bacteria given off by the patient. Danger of reinfection is therefore present, and the active bacteria swarming within the tent obviously are a hazard to the attendants. The warm dry air supplied in accordance with my method of treatment results in rapid evaporation of moisture and keeps the bed clothing and entire interior of the tent dry. Accumulations of moisture in which bacteria can exist are entirely prevented and such bacteria as are thrown off into the air by the patient as he breathes are quickly dried. Thus they progressively lose their virulence and soon die for want of moisture.

Psychologically, the effect of my new method of treatment is excellent, which is a factor of great importance. The patient is not subjected to the depressing effects of high relative humidity which often cause restlessness and inability to sleep. On the contrary, he is made more comfortable by the dry atmosphere, and a better mental condition is inevitable. At the same time the warmth of the air is soothing and tends to produce drowsiness and sleep, which enables the patient to obtain the rest which he requires.

The proper regulation of the oxygen concentration and of the carbon dioxide content of the air is of some importance. Oxygen should be supplied at the start if the disease has progressed to a point where the pulse and respiration rate have sensibly increased. As regards the carbon dioxide, a more rapid clearing up of the disease may frequently be accomplished by periodically allowing the percentage of carbon dioxide to rise sufficiently to stimulate breathing.

The foregoing sets forth the essential principles of my new treatment, as originally developed. The underlying thought was to simulate and improve on as regards constancy, a natural climatic condition known to discourage the development of pneumonia and by administering oxygen in this favorable artificial climate if necessary, give the patient an opportunity for rapid recovery unimpeded by factors tending to prolong his illness.

Since the simulation of ideal natural climatic conditions was one of the principal considerations, it was at first contemplated to use air temperatures on the order of those encountered naturally on hot days, say temperatures between 90° and 100°, and such temperatures indeed give excellent results, when accompanied by the proper humidity regulation as explained hereinbefore. I have found, however, that the temperature may be raised considerably higher, as high as 105° to 110°, or even somewhat more, to great advantage.

The bacteria of pneumonia grow with the greatest rapidity at a temperature of about 98°, or normal body temperature, assuming an adequate supply of moisture is present. The growth is not so fast at slightly higher temperatures, and at a temperature of 105° the bacteria begin to be killed. For example, if a culture of pneumococcus bacteria is subjected to a temperature of 105° for five minutes large numbers of the bacteria are killed. None survive a temperature of 110°. At fever temperatures below 105° the bacteria are adversely affected but of course to a lesser degree. At a temperature of 103°, for example, pneumococci are attenuated and their virulence is decreased. This explains in a measure the effect of a high fever in combating the disease. But when the patient breathes cold air a large portion of the bacteria in his lungs are maintained at a temperature below the body temperature by the inspired air, which tends to cool those surfaces with which it comes in contact. Much of the infected area therefore may be at or near the ideal temperature for the growth of the bacteria even though the body temperature is considerably higher. The natural effort of the individual to combat the disease by raising his own temperature is thus hindered to a great extent.

Now it will be appreciated that if the patient is caused to breathe air which is at least as warm as his body temperature, the cooling effect of the inspired air by direct contact will be entirely eliminated. There has to be considered also, however, the cooling effect of the evaporation of moisture in the lungs. In view of this phenomenon, the inspired air must be somewhat warmer than the body temperature to obtain the desired result. How much warmer it has to be depends somewhat on the individual case, but it will be obvious that in any case the temperature of the inspired air can be regulated to a value which will prevent cooling of the infected areas below the temperature at which the natural forces of the patient are seeking to maintain them.

If the body temperature is as high as 105°, it will usually be inadvisable to heat the air supply any higher than the temperature which is required to maintain the lung areas at the same temperature as the rest of the body. If the body temperature is lower than 105°, however, the temperature of the air supply may be raised high enough so as to produce a substantial heating effect in the lungs, thus producing a more or less localized fever condition which is of great value. In fact, great numbers of bacteria may in this way be subjected to a killing temperature, while the body temperature remains considerably below a dangerous value.

The ability of the patient to stand the high temperatures, on the order of 110° or more, depends on the dryness or low relative humidity of the air, which causes it to rapidly take up moisture and cool the patient by evaporation. The patient may therefore be actually cooler and more comfortable when breathing air at 110° having a low humidity than he is when breathing air at 70° having a high humidity. This fact makes it possible to directly attack the disease bacteria by means of a killing temperature without harm to the patient.

I will now describe a modification of the foregoing treatment which may be used to advantage under certain circumstances. The provision of a closed continuous circulating system is necessary in order to conserve the oxygen. If the condition of the patient is such that he does not require

the administration of oxygen, the apparatus may be operated as an open circulating system, which will be explained by further reference to the drawing.

The tent is set up in the manner before described, the valves **50** and **59** being closed. Valves **35**, **18**, **23**, and **56** are closed, and valves **43**, **44**, **53**, and **57** are opened. Upon starting the blower a circulation of air will be established from the intake at **45**, by way of valves **44** and **43**, filter **36**, filter **37**, blower **38**, heater **39**, instrument casing **46**, by-pass pipe **60**, and valves **53** and **57** to discharge opening **58**. The intake **45** may be in the room where the apparatus is located if the air supply is of satisfactory quality, or it may be extended to reach the outside air. The discharge opening **58** is preferably outside, as stated hereinbefore.

The air circulation having been established as described in the foregoing, the heat may be turned on by closing the switch S. As soon as the air supply reaches the proper temperature, as determined by inspection of the thermometer **61**, the tent may be cut into the circulating system by opening valves **50** and **59** and partially closing valve **53**, the proper supply of air to the tent being regulated by means of valve **53** in the manner previously explained. The patient is now being supplied with warm air.

If the air drawn into the system is of reasonable purity and of the proper humidity, no further adjustments will be necessary beyond the regulation of the temperature which will have to be attended to for a short time until a steady running condition is attained. As regards the purity of the air supply, it will be observed that an additional filter **36** is included in the system. This filter may well be especially designed to intercept dust particles which are usually present in outside air.

In the event that the air should contain some other impurity which would make it desirable to include an additional filter in the system, the circulation can be rearranged so as to include the carbon-dioxide removing chamber **10**. This is accomplished by closing valves **44** and **23** and by opening valves **18**, **19**, and **54**. With this arrangement of the valves air is taken into the system at **55**, which may be located at a point adjacent to intake **45**. The circulation extends from intake **55** by way of valves **54**, **5**, and **19**, the chamber **10** and valves **18** and **43** to filter **36**, from which point the path of the circulation is the same as was previously traced. In the event that carbon-dioxide is to be removed from the air the chamber **10** will contain a canister of soda lime, the same as was described in connection with the closed circulating system. If some other impurity is to be removed, then different chemicals or other filtering materials are used which are suited to the particular impurity which has to be absorbed or removed.

In case the humidity of the air supplied is too high, then the dehydrating apparatus may be connected in. This is accomplished by closing valves **44**, **18**, **19**, and **5**; and by opening valves **23**, **6**, and **54**. With this arrangement of the valves, air will be drawn into the system at intake **55** and will circulate over a path which includes valves **54** and **6**, the dehydrating apparatus, and valves **23** and **43**.

In carrying out my method of treatment with the open circulating system, the temperature and humidity of the air are regulated in accordance with the principles previously explained, and hence these features need not be again discussed. The open circulating system method of treatment is entirely satisfactory in the early stages of pneumonia, when the necessity of supplying additional oxygen is not present, and is highly beneficial at any stage. Thus it may be used to great advantage where oxygen is not available or if the supply is temporarily exhausted.

This method of treatment, using warm dry air unenriched by oxygen, may also be used to advantage in treating other respiratory diseases such as influenza or common colds. It is also of value in treating sinus infections, as the breathing of warm air tends to heat the nasal passages and promotes drainage of the infected sinus. Another application is in the treatment of dangerous post-operative conditions such as shock and threatened post-operative pneumonia. The warm dry air rapidly clears the air passages and lungs of residues of the anesthetic; and at the same time, it has a tendency to raise the patient's body temperature, which is apt to be too low immediately following the operation.

Other applications for the treatment will no doubt become known, and modifications thereof and of the apparatus with which it is performed will be readily apparent. I do not, therefore, wish to be limited to the precise forms of my invention which are shown and described herein, but desire to reserve and have protected by Letters Patent all forms and modifications thereof which come within the scope of the appended claims.

What I claim is:

1. In combination, an air storage reservoir adapted to enclose the external breathing organs of a patient, a closed circulating system for withdrawing air from said reservoir and for returning the air, means in said system for regulating the amount of water vapor and carbon dioxide in the air, air cooling means included in the vapor regulating means, means for introducing oxygen into the system, and means for heating the air in the system before it is returned to said reservoir to compensate for the heat absorbed by said cooling means.

2. In combination, a closed circulating system for air, said system including a tent or other enclosure for enabling a patient to breathe air from the system, means for circulating air in said system, whereby the air is continuously withdrawn from and returned to said enclosure, means for cooling the withdrawn air to precipitate moisture, means for exchanging oxygen for carbon dioxide in the air, and means for heating the air before it is returned to a sufficiently high temperature so that the relative humidity of the air in the enclosure is maintained low enough to prevent precipitation of moisture exhaled by the patient and keep the interior of the tent dry.

3. In combination, a tent or enclosure for a patient, a closed system of piping for circulating air thru said enclosure, means included in said system for extracting products of combustion and for adding oxygen, and means included in said system for cooling the air and for heating it over a temperature range sufficient to maintain the relative humidity of the air within the enclosure low enough to evaporate all water produced by perspiration and respiration of the patient.

4. The method of supplying to a patient air suitable for respiration which consists in confining a quantity of air, causing said air to circulate continuously past the patient in the

proper relation to enable the patient to breathe from and into the circulating air as it flows past him, extracting water vapor from the air after it leaves the patient, extracting CO_2 from the air, adding oxygen to the air, and heating the air before it again approaches the patient, whereby the air at the point of breathing is characterized by relative freedom from CO_2 and moisture, by richness in oxygen, and relatively high temperature.

5. The method of administering oxygen which consists in causing the patient to breathe from a storage device containing air, in withdrawing air from said device, in removing excess water vapor and carbon dioxide from said air, in mixing oxygen with said air, in heating the air and oxygen mixed therewith, and in then returning the heated air to said storage device.

6. The method of creating within a closed space an atmosphere suitable for respiration, which consists in confining a supply of air from which a patient breathes, in treating the confined air to maintain it in proper condition for breathing, in heating the air, in regulating the temperature to a value higher than the patient's body temperature, and in warming the patient's lungs by inhaled air to counteract the loss of heat due to evaporation in the lungs.

7. The method of operating an oxygen tent to supply air to a patient for breathing, which consists in withdrawing air from the tent, in cooling the air to precipitate moisture, in heating the air to lower its relative humidity, in returning the heated air to the tent, thereby establishing a circulation of warm dry air through the tent, in introducing oxygen into the circulating air, and in utilizing the low humidity of the air in the tent to clear up moisture from the patient's lungs and thus enhance the benefit obtained from the oxygen.

8. The combination, with breathing apparatus, of a closed system for circulating air through said apparatus, means in said system for maintaining circulation of the air, means in said system for conditioning the circulating air, and two valves arranged to open automatically if the circulation is obstructed between said valves, one to admit air to the system and the other to permit air to leave the system, whereby circulation through said apparatus may be maintained.

9. The method of operating an air circulating system which includes an oxygen tent for supplying air to a pneumonia patient, which consists in dehydrating the air after it is withdrawn from the tent to lower its humidity, in adding oxygen to the air, in extracting carbon dioxide from the air, in raising the temperature of the air before it is returned to the tent, in utilizing the high temperature and low humidity of the air to facilitate the expulsion of moisture from the patient's lungs, and in preventing excessive rise of the patient's temperature by the cooling which results from the evaporation of perspiration from his body.

10. The method of operating breathing apparatus for supplying air to a patient with a respiratory disease, which consists in circulating air through said apparatus, in heating the air above the temperature of the patient, in maintaining the humidity of the air at a value such that it will readily evaporate excess moisture from the lungs, and in utilizing the high temperature of the air to prevent the evaporation of moisture in the lungs from cooling the lung tissue below the temperature of the rest of the body.

11. The method of operating breathing apparatus for supplying air to a patient with a respiratory disease, which consists in circulating air through said apparatus, in conditioning the circulating air for breathing, in maintaining the air at the point where it is breathed in the range of fever temperatures or higher, and in utilizing the high temperature of the inspired air to reduce the virulence of or destroy the bacteria of the disease.

12. The method of operating an individual oxygen tent for supplying air to a patient for breathing, which consists in continuously withdrawing and returning air to the tent, thereby establishing a circulation of air past the patient, in introducing oxygen into the circulating air, dehydrating the air after it is withdrawn from the tent, in heating the air before it is returned to the tent, and in utilizing the hot dry air to prevent precipitation of moisture in the tent from air exhaled by the patient.

13. The method of administering oxygen to a pneumonia patient, which consists in causing the patient to breathe from a storage device containing oxygen enriched air, in withdrawing air from said storage device, in dehydrating the withdrawn air and extracting products of combustion therefrom, in heating the air, in returning the heated dehydrated air to the storage device, in adding oxygen to replace that consumed by the patient, and in regulating the heating and dehydrating operations so that the air at the point of breathing is dry enough to reverse the tendency to accumulation of moisture in the patient's lungs.

14. The method of operating an oxygen tent for supplying air to a patient for breathing, which consists in continuously withdrawing and returning air to the tent, thereby establishing a circulation of air through the tent, in dehydrating the withdrawn air and in extracting carbon dioxide therefrom, in adding oxygen, in heating the air before it is returned to the tent, in regulating the dehydrating and heating operations to produce a hot dry climatic condition inside the tent, and in utilizing such climatic condition to evaporate all moisture resulting from respiration and perspiration of the patient and keep the interior of the tent dry.

15. In a system for administering oxygen to a plurality of patients from a common source of supply, two main supply pipes, a plurality of breathing apparatus connected between said pipes in parallel, a closed circulating system for withdrawing air from one pipe and for returning it to the other, means in said circulating system for dehydrating the air, for extracting carbon dioxide from the air, and for adding oxygen to the air, and means in the circulating system for destroying organisms of disease in the air to prevent active organisms from being carried from one breathing apparatus to another by the common circulating system.

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