APPARATUS FOR INDUCING
HYPERTHERMIA

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References Cited
UNITED STATES PATENTS
739,612 9/1963 Mohr.......................... 128/256
1,932,122 10/1933 Schulte......................... 128/256 X
3,338,233 8/1967 Grosholz......................... 128/1 B
3,565,072 2/1971 Gauthier......................... 128/212

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ABSTRACT

Hyperthermia can be safely induced in human and other mammalian bodies by exposing the body to an environment at a humidity of at least 97% R.H. and a temperature in the range of 80° to 110°F. It is preferred that the patient should breathe air at a similar humidity and temperature and if necessary a separate supply of breathing air under appropriate conditions may be provided. The invention also provides apparatus in which this treatment can be carried out, the apparatus including a thermally insulating enclosure which can be maintained at the humidity and temperature conditions specified together with an air heater and water evaporator or a steam generator capable of providing saturated water vapour at a controlled temperature containing fine water droplets. The humidifying and/or heating means can be regulated in response to physiological changes in the patient, and a control system may perform a cycle in which a treatment phase under the said conditions for a predetermined period is followed by a cooling phase in which humidity or the temperature is allowed to fall to a lower level.

2 Claims, 11 Drawing Figures
Fig. 7

Fig. 7A

Fig. 4

Temperature Detector

Energy Controller

Controller

Physiological Variable Detector

Set Temperature Desired

Preheat Cooling

Constant

Set Point Desired

FIG. 4

Controller

FIG. 7

Coolant

Waste

Fig. 7A

Controller

Set Alarm Limit

Set Point Desired
APPARATUS FOR INDUCING HYPERTHERMIA

The present invention relates to therapeutic and prophylactic apparatus, and in particular to apparatus for safely inducing hyperthermia of the body, the main application being to induce therapeutic sweating.

It has already been observed that if profuse sweating is induced by subjecting the body to elevated temperatures under humid conditions, numerous substances are eliminated from the body through the skin, among which are salt, cholesterol, toxic amines, acids and histamines. By reason of the elimination of these compounds, therapeutic sweating of this kind has proved highly effective in the treatment of liver and kidney conditions, allergies, glaucoma and other complaints. It has also been noted that under the body conditions set up by such sweating, the effectiveness of antibiotics is enhanced and intensive treatment with antibiotics can thus be carried out using higher dosages of antibiotics than would otherwise be possible, without causing harmful side-effects.

It has further been found that the treatment is valuable not only as a therapeutic measure but also as a prophylactic measure for the prevention of acute medical conditions and the maintenance of bodily health.

It has been discovered that the hyperthermia produced in the body by the conditions used to induce profuse sweating has other important applications. For example, the clotting time, prothrombin time and oxygen content of the bloodstream are increased with beneficial results in the treatment of cardiovascular diseases. The maintenance of hyperthermia can also be used to improve the ability of the body and overcome certain infections by modifying the balance between the natural defences and the rate of growth of infecting organisms or modified cells (e.g. cancer cells).

It has hitherto been thought necessary for inducing this characteristic type of profuse sweating to employ temperatures considerably above normal body temperatures, for example 115°F and above, and under these conditions it is necessary for the patient's brain to be protected from the effects of the high temperatures employed, not only to avoid harmful side-effects but also to maintain the desired physiological balance in the body. Cool air must also be provided for breathing, to avoid damage to the lungs and mucous surfaces. U.S. Pat. No. 740,945 relates to a treatment cabinet equipped to provide such conditions.

In accordance with this invention a new technique of induced sweating has been devised wherein the desired type of profuse sweating or high inner body temperature (hyperthermia) is induced by the use of ambient temperatures close to the inner body temperature instead of 15°-25°F above as previously thought necessary.

This involves reduction of heat loss from the body not only by reducing radiation, conduction and convection losses as achieved in varying degrees by other methods, but by reducing to a low level the heat loss due to evaporation from the skin and also from the mucous surfaces. This makes it possible to approach the desired inner body temperature by utilizing heat generated within the body to continue the warming process and replace any residual losses, with the result that temperature gradients within the body are reduced and the risk of overheating the blood supply to the brain is reduced.

In accordance with this new technique, it has been found that the desired hyperthermia or profuse sweating can be induced by exposing the body to an atmosphere almost completely saturated with water vapour, say, between 97 or 98% and 100% relative humidity (R.H.), without the use of temperatures substantially above normal body temperature. Under these conditions the body eventually breaks out into profuse sweating of the special character discussed above, and the inner body temperature rises to the level associated with such sweating without the application of external high temperature. The humidity levels required are extremely high and are not achieved in previously known equipment. It has been found that even where high humidity has been sought, the level actually maintained is below the value of at least 97% needed for present purposes. The rate of sweating appears to be very sensitive to small changes in relative humidity and it is important to maintain a value as close to 100% as possible. Not only is this new technique more reliable and better suited to home treatment but it can be carried out in much simpler apparatus than formerly, because the necessity for cooling the brain and of providing cool air for breathing is avoided. This is not to exclude the provision of cooling means in all circumstances, since for special purposes this may be desirable.

Furthermore, when necessary for therapeutic purposes it is possible to approach the limiting safety conditions more closely (e.g. brain temperature) owing to the lower temperature gradients and method of control made possible.

In putting the new technique into practice, the patient enters and reclines or sits in an enclosure in a suitable apparatus, such as those described hereinafter, in which the necessary level of relative humidity of at least 97% is achieved in an air/water vapour atmosphere at a temperature slightly above or below the desired body temperature, and usually in the range of 98° to 105°F, while the internal surfaces of the enclosure are warmed to approximately the same temperature to reduce the net heat losses from the body to a negligible level.

After a period of 10 to 30 minutes the patient commences a profuse sweat and it then becomes necessary to reduce the humidity and/or the temperature of the enclosure to allow some dissipation of heat and so avoid an excessive rise of inner body temperature of the patient.

In accordance with another important aspect of the invention, it has been discovered that the onset of sweating of the special character described is accompanied by a number of other physiological changes in the body, and that these can be employed in controlling the operation of the apparatus. For example, when profuse sweating begins the body temperature rises (even where the enclosure is below body temperature), the pulse rate rises, and there are changes in blood pressure, humidity of the skin, pH value of sweat, alpha rhythm of the brain, metabolic rate, eye movement and constituents of bodily excretions through the skin, and changes in one or more of these physiological variables may be employed to control the humidity and/or the temperature in the enclosure by the provision of suitable instrumentation. The most convenient of these physiological variables, however, is the pulse rate, which exhibits a sharp rise at the onset of sweating, for example from a normal value of around 70 to between
In treatment by the method and in apparatus according to this invention, an atmosphere of 99–100% R.H. within the enclosure and a temperature of only 105°F achieved a similar rate of sweating in 20 minutes, the mouth temperature rising to 103°F and the pulse rate to 120–135. At 99–100% R.H. a temperature of only 98°F sufficed to sustain the high rate of sweating.

The apparatus of the present invention arises directly from these new observations and the necessity of providing means for carrying out the treatment indicated. The apparatus according to this invention comprises an enclosure adapted to enclose the body of a patient, means for maintaining either the walls of or the atmosphere within the enclosure at a temperature within the range of 80°F to 110°F, and preferably at 98°F to 105°F and means for maintaining the atmosphere within the enclosure or for supplying air to be breathed by the patient at a humidity of at least 97% R.H.

The means for maintaining the desired level of humidity may include a water vapour generator or a circulatory system in which the air is withdrawn, humidified and returned. The operation of either system may be controlled in dependence upon the temperature and/or relative humidity within the enclosure or by physiological changes in the patient.

The walls of the enclosure are preferably insulated to reduce the loss of heat from the enclosure. The walls may be fitted with heating elements to maintain their inner surfaces within the range 80°F–110°F. Alternatively or in addition, provision may be made for heating the interior of the enclosure to maintain the atmosphere therein at a temperature in the said range. Introduction of water vapour in the form of steam will itself result in some heating of the atmosphere within the enclosure, and it is possible by appropriate design to use steam to provide all the heat required, while maintaining the desired level of relative humidity. The temperature of the walls or the atmosphere in the enclosure may be controlled by means of appropriately located thermostat equipment.

For the most effective treatment the air breathed by a patient, and to which his lung surfaces are exposed, should be at substantially the same humidity and temperature as the atmosphere in the enclosure, and to which his body is exposed. It is therefore desirable to provide means for supplying air at correspondingly high humidity (i.e. at least 97% R.H.) and at a temperature in the range 95°F to 110°F to be breathed by the patient, in order that heat losses due to evaporation from the lungs and other mucous surfaces should be reduced as far as possible. Where the apparatus includes an enclosure into which a patient can enter completely there is no need to make further provision for the supply of humid air for breathing. In cases where the enclosure contains only the body and limbs of the patient leaving the head free, it is preferable that means such as a mask or an air curtain should be provided to conduct air to the patient's face at a humidity and/or temperature controlled in dependence upon physiological changes in the patient. The humid air exhausted from a mask or air curtain for one or more patients may be used to supply the atmosphere in the enclosure surrounding the bodies of the patients.

In some circumstances it may be found possible to induce hyperthermia by supplying air under the above condition to be breathed by a patient, while the environment surrounding his body is maintained by an insu-
lating wrap to retain naturally generated heat and humidity.

The invention will be further described by way of example with reference to the accompanying drawings in which:

FIG. 1 is a perspective view, partly cut away, of one form of apparatus in accordance with the invention, FIGS. 1A and 1B being partial sections of the wall and floor respectively of the apparatus of FIG. 1;

FIGS. 2 and 3 are respectively vertical cross-section and top plan views of a further form of apparatus embodying the invention;

FIG. 4 is a schematic diagram of humidifying equipment employing recirculation, which can be used in apparatus according to this invention;

FIG. 5 is a schematic vertical section through one form of equipment for supplying a recumbent patient with humidified air, for example from the equipment of FIG. 4;

FIG. 6 is a schematic sectional view of a steam generator which can be used in apparatus according to this invention, for example that shown in FIG. 1;

FIG. 7 is a schematic diagram of equipment for cooling the neck and head of a patient in treatments embodying this invention where such cooling is desirable, FIG. 7A being a top plan view of the cooling pad shown in FIG. 7, and

FIG. 8 is a block diagram showing one example of a control system suitable for use in apparatus according to this invention.

FIG. 1 shows a typical unit in the form of a cabinet with inside dimensions 8 X 6 X 7 ft. high with a door 10 and having walls 11, roof 12 and floor 13 constructed of heated insulating materials and preferably having a U-value of about 0.3. Too low a U-value is undesirable because if the need for special cooling facilities is to be avoided it is necessary for losses to exceed the net heat output of the patient or patients being treated once the profuse sweating condition has been achieved, plus a margin to allow for any excess heat fed in through the humidifying system. A section through a wall is shown in FIG. 1A and is made up of a rigid outer surface layer 14, an insulating layer 15, for example of expanded synthetic resin, and an impermeable lining 16. The internal surfaces of the cabinet, especially those which come into contact with the patient, are preferably lined or coated with smooth, impermeable and easily cleaned material which does not readily promote condensation.

The floor is shown in section in FIG. 1B and may be constructed from two layers 17 of a rigid material, such as concrete, separated by a layer of insulating material 18, such as expanded polystyrene, and covered with an impervious material 19 which does not promote condensation. The floor slopes towards a gutter 21 leading to a drain 22. A cold shower 23 controlled by a tap 24 and disposed over a drainage depression 25 are also provided, waste water being led away through the same drain 22. Electric lights 26 in sealed fittings are provided in the roof. Chairs, reclining chairs or couches (not shown in the drawing) of materials which do not readily absorb water such as tubular aluminium and synthetic fibre webbing, are provided as required.

An electric fan heater (not shown) is arranged to supply heated atmospheric air through a closable aperture 27, and a second closable aperture 28 is provided for the discharge of air from the cabinet. A humidifying unit, for example a steam generator, indicated at 30 supplies moisture to a perforated distribution pipe 31 whence the moisture passes into the atmosphere within the cabinet. The perforations are preferably disposed at a level in the pipe wall greater than a distance equal to half the radius of the pipe above the inner bottom surface of the pipe, and the pipe may be laid with a fall to the point of entry into the cabinet so that excess water will run back to the humidifying unit 30. Alternatively, there may be a fall to the far end of the pipe, where means are provided for draining off excess water. A further opening 32 in the wall of the cabinet permits the passage of cables from instrumentation within the cabinet, which will be described below.

A typical cycle of operation in this apparatus proceeds through the following steps under control of a control unit such as that described below with reference to FIG. 8:

a. A start button outside the unit is pressed.

b. The fan heater blows heated air into the cabinet through the aperture 27 for the period necessary to warm up the inner surfaces to about 105°F, the air being allowed to leave by the aperture 28. This pre-warming period is not essential, but has advantages in reducing the time needed to achieve the desired humidity and reducing the extent of condensation during the warming up period. After a predetermined period, or when a thermostat indicates that the wall or floor temperature is adequate, the fan heater is switched off and the humidifying unit 30 is switched on and supplies water vapour and water droplets through the distribution pipe 31. When the humidity in the cabinet has reached about 95%, or at an approximate predetermined time after the humidifying unit has been switched on, the apertures 27 and 28 are almost fully closed to restrict the entry of less humid air from outside. In some versions of the equipment, to simplify the control system, they may be closed completely by hand because the air in the cabinet is sufficient for a normal period of sweating and condensation within the cabinet allows further steam to enter without increase in pressure. When the temperature has risen to the desired level a signal indicates that the unit is ready and the patient enters.

c. A device for sensing that physiological variable in the patient which has been selected as the control variable (e.g. a pulse detector) is connected to the patient, and if desired a "brain temperature" sensor (i.e. a sensor fitted, for example, in the outer ear to give some indication of effective brain temperature) providing overall safety control and also control of cooling facilities for the head and neck where provided and used. The control unit may then be switched to automatic control for the required cycle of high humidity treatment in accordance with this invention. The humidity generator continues to supply water vapour, and therefore energy, at the desired temperature until the physiological control variable approaches the predetermined desired level. The energy fed into the humidity generator is thereupon reduced by a conventional controller with the result that, owing to heat losses from the cabinet, condensation takes place and temperature falls. In practice the relative humidity also falls. With the fall in temperature and/or humidity the physiological control variable moves away from the desired level and the energy fed to the humidity generator is thereupon increased by the controller to restore the conditions within the cabinet.
d. After the prescribed period of high humidity treatment the control unit may be switched manually or by a timer to another mode in which the humidity generator is turned off, or controlled by a thermostat set at a temperature below body temperature. During this phase the patient is cooled off by a cold shower to reduce loss of carbon dioxide, and rests before leaving the unit or starting another cycle of high humidity treatment.

c. On completion of the treatment the humidity generator is switched off; the apertures 27 and 28 are opened fully, the floor is washed down with a germicide and the fan heater run for sufficient time to dry out the inner surfaces. The apertures are then closed to conserve heat until the cabinet is required again.

Apart from an insulated cabinet completely enclosing one or more patients, as already described with reference to FIG. 1, other forms of enclosure can be used. Examples of such alternative enclosures include an insulated cabinet enclosing the body only of one or more patients with the head and neck protruding, as will be described below with reference to FIG. 2, and a flexible enclosure in the form of an insulating plastic wrap.

Any of these forms of enclosure may be combined with other necessary or desirable devices to provide a complete apparatus according to the invention and the combination selected depends on the purpose for which the unit is to be used and the economics of those combinations which would be suitable. Such additional devices include:

- means for generating water vapour and/or very small water droplets at the desired temperature and controlling the energy input in response to the humidity within the enclosure or a selected physiological variable of the patient and including either a steam generator adapted to supply steam containing water droplets (as in FIG. 6) or an air heater and an evaporating surface wetted by water and/or means for generating a spray or mist of very small water droplets (as in FIG. 4);
- a mask or air curtain for supplying air at approximately body temperatures and between 97 and 100% R.H. (as in FIG. 5);
- means for cooling the neck and/or head of a patient (as in FIGS. 7 and 7A);
- means for heating the cabinet prior to humidification and/or drying it after use, for example the heated air system already described; and
- means for heating the inner surfaces of the walls of the cabinet to the desired temperature and for controlling the energy input to such heating means by reference to the humidity within the enclosure or a selected physiological variable of the patient.

When several patients require treatment at the same time some economy in cost can be achieved by arranging to use identical conditions for all patients except the supply of atmosphere for breathing, which is preferably individually controlled by the selected physiological variable of each patient both as to temperature and humidity. The individual supplies of atmosphere for breathing may be supplied by a conventional mask or preferably by an air curtain.

In a simple form of multiple apparatus patients are seated in a cabinet such as that shown in FIGS. 2 and 3. The patient enters the insulated cabinet 35 through a door 36 and sits with the body inside and head outside the cabinet, the face resting against a padded aperture 37 past which a slow flow of humidified air under individual control is carried from a humidity generator (not shown) through ducts 38 and 39. The gap at the back of the neck is closed by a flap 40 of plastics film. The lower part of the cabinet, which is common to several patients, is humidified through ducts 41 and 42 from a separate source. A clear window 43 is provided in front of the patient's head.

Alternatively, a number of patients may be treated completely within a large enclosure of the type shown in FIG. 1 but with individual air curtains of the type shown in FIG. 6, which can be used in conjunction with recirculation humidity generators such as that shown in FIG. 5 as described heretofore.

For home treatment, where precise control is unnecessary, it is equally possible to design a unit which achieves higher humidities (up to 99% R.H.) than hitherto possible. Such a unit may be of the general form of that shown in FIG. 1, with a steam generator such as that shown in FIG. 7 and the energy input controlled by reference to the temperature within the cabinet rather than a selected physiological variable of the patient. The control system can also, if desired, be greatly simplified. In designing such a cabinet a balance must be struck between the various relevant factors and in particular a suitable level of heat losses from the cabinet should be provided for, in order that the desired temperature and high humidity can be maintained by the simplified control system adopted.

In turning now to the provision of suitable humidifying equipment, it may be observed that, whereas it is relatively easy to achieve relative humidities of up to 95%, as measured by the difference between wet and dry bulb temperatures, considerable research and development work has proved necessary to achieve at a closely specified temperature between 98° and 105°F controlled humidities in the range 97 to 100%.

If the heat losses from the cabinet are to be balanced partly by the latent heat of condensation of water vapour, and the inner surfaces and atmosphere of the cabinet are to be held at a specified temperature within narrow limits the design of the humidity generator is critical. It is not only necessary to produce water vapour at approximately the desired temperature but also essential to have present in the atmosphere surface with a small radius of curvature (e.g. very fine wetted fibres or very small droplets) if relative humidities closely approaching 100% are to be maintained.

The reason for this is not yet completely clear, but a possible explanation is that with the low temperature gradients required for the process it is necessary to make use of the fact that even under conditions of substantially 100% R.H. small droplets will evaporate more readily than larger droplets on a plain water surface, part of the energy being provided by the surface tension rather than heat energy, as a means of ensuring consistent achievement of the very high relative humidity desired.

It is important to remember also that if steam generated at, say, 212°F is used to provide water vapour, additional small droplets are necessary to take up the heat made available as the partial pressure and temperature are reduced to those of the water vapour in the cabinet.

Ideally the humidity generator should produce water vapour at the temperature to be maintained in the cabinet. The quantity of water vapour should be such that the latent heat is equal to the heat loss of the cabinet.
less heat supplied from other sources including the patient.

One type of humidity generator — employing recirculation — is illustrated in FIG. 4. With this type of unit it is possible not only to allow for introduction of fresh air, but also to achieve greater precision of control because the rate of energy input and the output temperature of the humidified atmosphere are independently controlled. A duct 45 is connected to the enclosure of apparatus according to the invention: the high humidity atmosphere of air, water vapour and water droplets from the enclosure can be extracted by a fan 46. A duct 47 is provided for fresh air. Dampers or throttles 48 and 49 are provided to control the proportion of fresh air to recirculated atmosphere. The rate of flow may be controlled by modifying the motor speed of the fan or, as shown, another damper or throttle 51 may be provided downstream of the fan. The damper 51 in the drawing is controlled by a controller 52 in response to a temperature detector 53 in the output duct 54 of the unit and the desired enclosure temperature set on the controller.

From the fan the atmosphere is passed through an electrical heater 55 the energy input to which is controlled by a controller 56 in response to a signal from a detector 57 of the selected physiological control variable sensed by a transducer 58 connected to the patient in the enclosure.

The heated atmosphere is then passed through a layer of fine wet fibres 59 and a spray 60 of very small water droplets which may be produced by conventional mechanical means, such as a nozzle or spinning disc atomiser. The evaporation of water and finally of small droplets enables a relative humidity closely approaching 100% to be achieved. The temperature of the humidified atmosphere is kept at the desired level by controlling the rate of flow as described.

No attempt is made to control the supply of water droplets, a surplus being provided and the excess run off through waste outlets 61 or carried with the humidified atmosphere back into the enclosure through the duct 54.

On the other hand the very high degree of humidity in the cabinet tends to fall (from condensation and reduced supply of very small droplets, even though water remains present) and at these very high levels the humidity within the cabinet seems to depend on the rate of supply of further water vapour and very small droplets.

It will be noted that any reduction of energy input to the heater 55 will result in a reduction of the rate of flow by the controller 52 since it acts to maintain the output temperature constant at the sensor 53. This will reduce the flow of both water vapour and droplets.

Any excess in the supply of air, due to fresh air brought into the system through the duct 47 or due to expansion, is released through a vent 62 which is kept closed by a flap 63 with a slight weight bias.

With this type of humidity generator it is possible to conduct the pre-warming period by arranging the controls so that no water is supplied to the humidifier spray 60, the damper 49 is closed and damper 48 opened, the controller 52 keeps the damper 51 open and the controller 56 is set to a predetermined energy level. Air from the cabinet is then extracted through the duct 45; reheated and returned through the duct 54 for the time necessary to heat up the inner surfaces of the cabinet to about 105°F.

This type of humidity generator can also be used after completion of treatment to dry out the cabinet for a predetermined time sufficient to dry the inner surfaces, by arranging the controls so that no water is supplied to the humidifier spray 60, the damper 49 is opened, the damper 48 is closed, the controller 52 keeps the damper 51 open and the controller 56 is set to a predetermined energy level. Fresh air is then drawn in through the duct 47, heated, passed through the duct into the cabinet, and released outside the cabinet through the duct 45 and the vent 62.

The design of the generator shown in FIG. 4 is such that condensate and droplets not carried through to the cabinet are able to fall to the lowest part of the system and be drained off through the waste pipes 61.

The type of humidity generator just described with reference to FIG. 4 can be applied with slight modification to supply a humidified atmosphere to a patient by means of an air curtain, as shown in FIG. 5. The air curtain device includes a supply duct 65 leading to a spreader unit 66 which has peripheral lips 67 and a drip tray 68 to catch condensate. A clear plastic dome 69 is provided to improve the air flow, and if desired, clear plastic curtains 70 may be hung around the spreader unit 66 to minimise escape of the moist atmosphere.

The artificial atmosphere is collected from below by an extractor funnel 71, and an extractor fan 72. The fan 72 may be linked mechanically to the circulating fan of the humidifier (as at 46 in FIG. 4) but should be of about 15% greater capacity and connected to the normal inlet duct (45 in FIG. 4). The controls are arranged so that the damper 48 is open and damper 49 closed and any atmosphere collected by the fan 72 in excess of that accepted by the humidifier fan 46 is discharged through the vent 62. The energy input is controlled as before by reference to the selected physiological variable.

Where the body is separately enclosed the body enclosure may be fed from a separate unit, or from humidified atmosphere bled off from the duct 54 (FIG. 4), and extracted using the spare duct 47 and appropriate adjustment of the dampers 49 and 48.

An alternative type of humidity generator is shown in FIG. 6, namely a steam generator. The unit shown is only an approximation to the ideal generator because only the energy input is controlled directly and not the rate of flow of water vapour and droplets. However by careful design it has proved possible to ensure that water vapour and sufficient small droplets are supplied at approximately the correct temperature. In this unit a water boiler 75 is provided with an electric immersion heater element 76 into which the energy input is controlled by a controller 56 (analogous to that in FIG. 4) in response to a signal from a detector 57 of the selected physiological variable sensed as before by a transducer 58 connected to the patient in the enclosure. A pipe 77 to convey water vapour and droplets formed in the boiler passes through the insulated wall of the apparatus enclosure and is connected to the perforated distribution pipe 31 inside the enclosure (as shown in FIG. 1).

As water is evaporated in the boiler the fall in level is sensed by a conventional level controller 78 which controls a water valve 79. Great attention must be paid to the design of the boiler in terms of the water surface
area, the height above the water level and the depth of water over the elements if humidities in excess of 97% are to be ensured in the enclosure. The precise reasons are not known but are probably related to the size and proportion of small water droplets carried by the steam into the cabinet.

As the steam and water droplets approach the perfrations in the distribution pipe 31 and passes through them it meets cooler air and water vapour in the atmosphere of the enclosure and its vapour pressure is reduced to the partial pressure of water vapour in air. In the process a new balance is reached in which, if an excessive rise in temperature is to be avoided within the enclosure, sufficient water droplets must be present to evaporate quickly and take up the heat which would otherwise contribute to raising the temperature of the atmosphere in the enclosure, but at a lower humidity than desired.

It can be shown that the proportion by weight of small droplets to steam required to prevent a temperature rise is at least 5%. This requirement for water droplets is additional to the need for small water droplets in the atmosphere of the cabinet mentioned above in the general discussion on humidification.

A further possible alternative where low cost is the primary consideration, rather than precision of control, is the generation of very high humidities within a cabinet with heated walls by the use of a spray of very fine droplets on a large surface area provided by wet fibres of small diameter. Such a system would have the disadvantage of a longer time constant, but might be acceptable for home treatment.

Another possible simple technique is to use an electric fan heater fitted within a cabinet to heat the atmosphere and blow it through a mist of small droplets to maintain the humidity level. The energy input in this case can be controlled by reference to the selected physiological variable. This is really an equivalent of the recirculating type of humidity generator but one in which the elements of the generator are located within the cabinet itself.

When a treatment is prescribed which may result in a brain temperature approaching the maximum safe limit, a cooling collar or pillow should be placed in contact with the neck and head of the patient. Suitable equipment is illustrated in FIGS. 7 and 7A. A double walled collar 81 of plastic material is supplied with coolant through a valve 82. A sensor 83 is provided to detect the temperature in the inner part of the outer ear. This temperature is close to the actual brain temperature and is referred to as 'brain temperature' in this description. The sensor 83 is connected to a controller 84 on which the desired brain temperature may be set and which operates a valve 85. In the simplest version the coolant is cold water and when cooling is required the valve 82 is opened to fill the collar 81. When the collar and the sensor 83 have been attached to the patient the flow of water is adjusted by the controller and the valve 85 so that the higher the sensed brain temperature above the desired brain temperature the greater the flow of coolant. An upper safety limit can be set and an alarm system operated if the brain temperature rises above it.

The design of the cooling unit should be such that valve 85 when fully open restricts the flow of coolant sufficiently to keep the collar 81 adequately filled.

FIG. 6 is a block diagram of a typical control system for the treatment cycle described above, but using a recirculation type of humidity generator. Items which correspond to those discussed in connection with other drawings are indicated by identical numerals. It is believed that this diagram is in most respects self-explanatory.

The control system is built from conventional devices and control system components. For many applications it is both practical and more economical to undertake much of the control programme manually except for the control of energy input to the humidity generator. In practice two term controllers are used instead of proportional controllers where greater precision is necessary for treatment closely approaching human safety limits. Near these limits safety measures are important, and if the selected physiological variable goes outside pre-set limits or if the sensed brain temperature exceeds the specified level an alarm is given and if not answered within a specified period switches the programme to the cooling part of the cycle.

The timer indicated in FIG. 8 is adapted to establish three separate periods, shown as A, B and C, and these correspond to the pre-heating period, the high humidity treatment period and the drying out period of the cycle, as described respectively under (b), (c) and (e) above.

As an ultimate safety device a thermostat cut out 88 is provided to over-ride the energy controller 56 and interrupt the power supply to the heater 55 if the temperature in the cabinet, as indicated by a wall temperature sensor 89 rises above a pre-set temperature, normally 115°F. The sensor 89 may be mounted alongside another sensor 87 (see an earlier FIG. 4) which through its associated detector 86 controls the heater in relation to the wall temperature during the pre-heat and cooling periods.

What is claimed is:

1. Apparatus for safely inducing hyperthermia comprising:

an enclosure adapted to enclose at least the major portion of the body of a patient;

means for maintaining the enclosure at a temperature within the range of 80°F to 110°F;

means for maintaining the atmosphere within said enclosure and supplying air to be breathed by the patient at a humidity of at least 97% R.H. and at a temperature within the range of 80°F to 110°F;

means for sensing the pulse rate of a patient; and

means for controlling at least one of said humidity and temperature in response to a change in said pulse rate.

2. Apparatus for safely inducing hyperthermia comprising:

an enclosure adapted to enclose at least a major portion of the body of a patient; an air heater for maintaining the atmosphere within said enclosure at a temperature in the range of 80°F to 110°F, humidifying means for generating saturated water vapour at a predetermined temperature within said range containing fine droplets of water, said humidifying means being disposed downstream of said heater and between said heater and said enclosure; means for sensing the pulse rate of a patient enclosed by said enclosure; control means for regulating at least one of said heater and humidifying means in response to changes in said pulse rate and means supplying air to be breathed by said patient at a humidity of at least 97% R.H.

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