(12) PATENT ABRIDGMENT (11) Document No. AU-B-18676/88
(19) AUSTRALIAN PATENT OFFICE (10) Acceptance No. 608863

(54) Title
METHOD OF AND MEANS FOR CONTROLLING THE CONDITION OF AIR IN AN ENCLOSURE

International Patent Classification(s)
(51)[4] **F24F 005/00** **A01G 009/24**

(21) Application No. : **18676/88** (22) Application Date : **01.07.88**

(30) Priority Data

(31) Number (32) Date (33) Country
069091 **02.07.87** **US UNITED STATES OF AMERICA**

(43) Publication Date : **05.01.89**

(44) Publication Date of Accepted Application : **18.04.91**

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(56) Prior Art Documents
US 4259849
US 4819447

(57) Claim

1. Apparatus for conditioning air in an enclosure comprising: a direct contact air/brine heat exchanger; means for passing air in the enclosure through said direct contact heat exchanger; a reservoir of concentrated brine; means for establishing a first brine loop in which brine from said reservoir is passed through said direct contact heat exchanger so that water vapor in the enclosure is condensed into the brine to form dilute brine which flows into said reservoir; a brine boiler; means for establishing a second brine loop in which heat contained within said dilute brine from said first loop is exchanged with heat within brine flowing from said boiler, said boiler evaporating water from said dilute brine and producing steam, and flow control means for maintaining a smaller flow rate in the second loop than in the first loop.

608863

S & F Ref: 62721

FORM 10

COMMONWEALTH OF AUSTRALIA

PATENTS ACT 1952

COMPLETE SPECIFICATION

(ORIGINAL)

FOR OFFICE USE:

Class Int Class

Complete Specification Lodged:
Accepted:
Published:

Priority:

Related Art:

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This document contains the amendments made under Section 49 and is correct for printing

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Complete Specification for the invention entitled:

Method of and Means for Controlling the Condition of Air in an Enclosure

The following statement is a full description of this invention, including the best method of performing it known to me/us

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METHOD OF AND MEANS FOR CONTROLLING THE CONDITION OF AIR IN AN ENCLOSURE

ABSTRACT

Apparatus for conditioning air in an enclosure includes a direct contact air/brine heat exchanger constructed to exchange air in the enclosure with the direct contact heat exchanger, and a reservoir of brine. A first brine loop is established by which brine from the reservoir is exchanged with the direct contact heat exchanger for condensing water vapor in the enclosure air onto the brine to form dilute brine that flows into the reservoir. The apparatus also includes a brine boiler constructed and arranged for establishing a second brine loop in which dilute brine from the first loop is exchanged with the boiler for evaporating water from the dilute brine and producing steam. Finally, a flow control is provided for maintaining a smaller flow rate in the second loop than in the first loop.

DESCRIPTION

METHOD OF AND MEANS FOR CONTROLLING THE CONDITION OF AIR IN AN ENCLOSURE

TECHNICAL FIELD

This invention relates to a method of and means for conditioning air in an enclosure, and more particularly for controlling the temperature and humidity of air in an enclosure such as a greenhouse.

BACKGROUND OF THE INVENTION

U.S. Patent ~~Application Serial~~ No. 4,819,447 discloses an apparatus for conditioning the air in an enclosure by utilizing a direct contact air/brine heat exchanger in which enclosure air is directly contacted with brine from a reservoir for condensing water vapor in the enclosure onto the brine to form diluted brine. The diluted brine is regenerated in a fuel fired boiler producing steam that may be piped into an indirect contact heat exchanger located in the enclosure for the purpose of heating the air in the enclosure. Dilute brine from the direct contact heat exchanger is piped to the boiler through a counter-flow heat exchanger in which the dilute brine absorbs heat from, and thus cools, the concentrated brine extracted from the boiler. The resultant cooled concentrated brine is transferred to a reservoir from which brine is applied to the direct contact air/brine heat exchanger. With this arrangement, the temperature of the concentrated brine entering the direct contact air/brine heat exchanger is kept as low as possible. That is to say, vapor pressure at the air/brine interface of the brine entering the direct contact air/brine heat exchanger will almost always be less than the vapor pressure of the air in the enclosure with the result that the brine entering the direct contact heat exchanger will be hygroscopic and will thus absorb moisture from the air.

An object of the present invention is to minimize the physical size of the apparatus described above, and to improve its efficiency by minimizing fuel consumption, and by increasing the amount of heat returned to the enclosure.

BRIEF DESCRIPTION OF THE INVENTION

Apparatus for conditioning air in an enclosure comprises a direct contact air/brine heat exchanger, and means for exchanging air in the enclosure with the direct contact heat exchanger. A reservoir of concentrated brine is provided to establish a first brine loop in which brine from the reservoir is exchanged with the direct contact heat exchanger for condensing water vapor in the enclosure air onto the brine to form dilute brine which flows back into the reservoir. The apparatus also includes a brine boiler, and means for establishing a second brine loop in which dilute brine from the first loop is exchanged with the boiler for evaporating water from the dilute brine and producing steam. According to the present invention, flow control means is provided for maintaining a smaller flow rate in the second loop than in the first loop. In the preferred construction, the flow control means is constructed and arranged to maintain at least an order of magnitude difference between the flow rates in the first and second loops, and preferably the flow rate in the second loop is about 1/20 of the the flow rate in the first loop. Experience has shown that this leads to the most efficient and compact system.

BRIEF DESCRIPTION OF THE DRAWINGS

An embodiment of the present invention is disclosed in the accompanying drawings wherein:

Fig. 1 is a block diagram showing the general environment of the present invention;

Fig. 2 is a schematic diagram showing the preferred construction of the direct contact air/brine heat exchanger and the boiler shown in Fig. 1;

Fig. 3 is a psychrometric chart for illustrating the operation of the present invention; and

Fig. 4 is an alternative embodiment of the invention shown in Fig. 2.

DETAILED DESCRIPTION

Referring now to the drawings, reference numeral 10 designates an enclosure in the form of a greenhouse containing agricultural products 12 that absorb carbon dioxide during daylight hours and produce water vapor. At night, products 12 are quiescent. Associated with greenhouse 10 is apparatus 14 which comprises direct contact air/brine heat exchanger 16 to which concentrated brine is supplied by conduit 18 from brine reservoir 20, and from which dilute brine is obtained by conduit 22. Dehumidifier 16 may comprise a felt pad or mat of jute material and provides a large surface area over which the concentrated brine is fed to form a thin film of brine exposed to the air. Thus, dehumidifier 16 operates as a thin film, direct contact air/brine heat exchanger as described below.

Duct 24 contained within greenhouse 10, and within which brine dehumidifier 16 is located, provides means for recirculating air in the greenhouse through the dehumidifier. Specifically, duct 24 contains fan 26 which draws humid air in the greenhouse through the dehumidifier and causes the air to pass through heat exchanger or radiator 28 before the air is reintroduced to the greenhouse.

Boiler 30, associated with brine reservoir 20, is heated by fuel burned in burner 32 which is connected to source 34 of fuel. Dilute brine from conduit 22 is pumped, or flows by gravity, through counter-flow heat exchanger 36 and enters boiler 30 where the brine is regenerated. The boiler concentrates the dilute brine by evaporating water therefrom producing steam. Conduit 38 carries the steam to valve 40 which selectively directs the steam into radiator 28 (if the greenhouse must be heated), or into water tank 42 when the heat and the steam must be stored for use at a later time.

Boiler 30 thus concentrates the dilute brine; and the concentrated brine passes through heat exchanger 36 into brine reservoir 20. The hot, concentrated brine produced by the boiler is cooled in heat exchanger 36 before being delivered to brine reservoir 20; and heat extracted from the concentrated brine is transferred to the incoming dilute brine.

Preferably, the fuel burned in boiler 32 is liquified petroleum gas or natural gas in order to limit the products of combustion to carbon dioxide and water. The products of combustion produced by the burned fuel associated with burner 30 may be piped by ductwork 44 into greenhouse 10 such that the products of combustion, namely carbon dioxide and water, are transferred into the greenhouse. This arrangement, however, is optional.

During daylight hours, when the agricultural products such as flowers or vegetables are growing, they actively absorb carbon dioxide from the air in the greenhouse. The active agricultural products also give off water vapor which adds to the water vapor introduced into the greenhouse by the products of combustion. In the absence of steps to the contrary, an almost saturated condition will occur in the greenhouse. The purpose of dehumidifier 16 is to dehumidify the air within the greenhouse and thus maintain the humidity at an appropriate level. Additionally, dehumidifier 16 serves to increase the temperature of the air in the greenhouse in a manner explained below. Effectively, dehumidifier 16 is designed to maintain a humidity within the greenhouse below a level typically 85%, and preferably between 80% and 85%. As explained below, the humidity air will be a function of the concentration of brine in the dehumidifier, the effective area of the brine dehumidifier and the mass flow therethrough.

If it is desirable, steam from boiler 30 can be introduced into heat exchanger 28 for purposes of further increasing the temperature of the air in the greenhouse, or valve 40 can be selectively operated to direct the steam into water tank 42 for the purpose of storing the heat produced during the brine regeneration process. At night, when excess carbon dioxide is not needed in the greenhouse, the operation of boiler 30 can be suspended; and the heat stored in water tank 42 is a consequence of daytime operation of the boiler is available for heating the enclosure by supplying the stored hot water to a radiator 28. Alternatively, the steam produced by the boiler can be directed to a network of pipes buried in the ground beneath the greenhouse thus storing the heat in the ground. When the greenhouse is based on hydrophonic operation, the steam produced by the boiler can be used to heat the liquid that are used in the hydrophonic process.

Dehumidifier 16 may be conventional in the sense that it is a direct contact heat exchanger in which concentrated brine is applied to a felt, jute, or paper mat as a thin film. Alternatively, the mat may be a capillary web through which the brine flows slowly. The flow rate of the brine can be reduced to a level that just keeps the mat wet. To obtain the high concentration required for the brine, calcium chloride is the preferred salt; but other salts such as magnesium chloride, lithium chloride, sodium hydroxide or mixtures of salt can be used. Dead sea end brine can also be used. The vapor pressure of concentrated brine is small compared with the saturated vapor pressure of water at the same temperature. When concentrated brine is exposed to the air in the greenhouse, the water vapor in the air condenses on the brine. The latent heat of condensation supplied to the brine during condensation of water vapor heats the brine film; and the heated brine transfers its heat to the air flowing over the brine. This is an isentropic process in which the temperature of the brine remains substantially constant as the air is warmed and dried in passing through the dehumidifier. This process is described in greater detail below.

The fuel required to regenerate the brine and provide carbon dioxide during the day would be about 15-20 mg/1000 m^2 of greenhouse area which will provide about 10 hours of operation per day. In some environments, the operation need be carried out for only 3 to 4 hours during the day because the temperature of the greenhouse will become excessive insofar as the agricultural products are concerned. This requires either a shutdown of the system or the introduction of outside air into the greenhouse.

To provide suitable control over the operation of the system shown in Fig. 1, duct 44 may be provided with an adjustable butterfly valve 48 for controlling the rate at which the products of combustion are admitted into greenhouse 10, and a suitable valve (not shown) may be provided in duct 24 and in the greenhouse itself for the purpose of controlling the flow of air into the duct and into the greenhouse, respectively.

If desirable, it is possible to use the apparatus described above to moisten the air in the enclosure rather than dehumidify it. This can be achieved by using brine in reservoir 20 and dehumidifier 16 of such a concentration so that its vapor pressure in dehumidifier 16is large compared with the saturated vapor pressure of water at the same temperature. Thus, when such brine is exposed to the air in the greenhouse, water vapor will be given off from the brine into the air in the greenhouse. Alternatively, steam from boiler 30 can be introduced directly into the air in the greenhouse.

The preferred construction of the present invention is illustrated in Fig. 2 to which reference is now made. Apparatus 100 shown in Fig. 2 comprises direct contact air/brine heat exchanger 16A which includes header 102 for receiving brine from reservoir 20a located below the header, and air permeable cylindrical sleeve 104 interposed between header 102 and the reservoir. Sleeve 104 may be a mat or woven mesh suspended by a metal reinforcing screen for the purpose of providing structural rigidity in maintaining a cylindrical form in the face of drag forces exerted on the cylinder by reason of the flow of air described below.

Header 102 includes spray heads (not shown) for distributing brine to sleeve 104 whereby the brine falls in a film from the header to the reservoir.

The operation of blower fan 106 located above header 102 draws air from enclosure 10A through sleeve 104 in the manner shown by arrows 108 thereby contacting the air in the enclosure with the film of brine flowing downwardly over cylinder 104. Demister 107 suspended from header 102 below blower fan 106 separates any droplets of brine entrained in the air as it passes over the film of brine on sleeve 104 before the air is returned to the enclosure.

Adjacent to cylinder 104 is vertical standpipe 110 extending vertically from a region slightly lower than reservoir 20A to a point just higher than header 102. Standpipe 110 is closed at its bottom end but open to the air in enclosure 10A at the top. Conduit 112 connects the top region of standpipe 110 to header 102. Pump 114 located below reservoir 20A and connected by conduit 116 to the reservoir pumps brine from the reservoir into the bottom of standpipe 110 through conduit 118. The output of pump 114 is adjusted such that standpipe 110 is filled with brine from reservoir 20A as indicated by reference numeral 120, to a level just slightly above conduit 112 through which concentrated brine flows into header 102.

As shown in Fig. 2, a first brine loop is defined by reservoir 20A, conduit 118, standpipe 110, conduit 112, and sleeve 104. When pump 114 operates, brine contained in reservoir 20A flows into the bottom of standpipe 110, rises in the standpipe to a level just above conduit 112, and then flows into the header. From the header, the brine is circumferentially deposited onto sleeve 104, flows downwardly, and returns to the reservoir.

As indicated above, fan 106 is effective to exchange air between the enclosure and heat exchanger 16A with the result that the hygroscopic brine flowing downwardly in a film over sleeve 104 is contacted by the air flow produced as a consequence of the operation of fan 106, and interacts with the air. Because the brine is hygroscopic, moisture in the air in the enclosure is absorbed by the brine which becomes more dilute as the brine flows downwardly into the reservoir.

Brine concentrator 122 for reconcentrating the brine in reservoir 20A is a part of a second brine loop that includes brine boiler 30A, dilute brine conduit 124 for conveying brine from pump 114 to brine tank 126 inside boiler 30A, and concentrated brine conduit 128 for conveying brine from tank 126 back to reservoir 20a. Indirect heat exchanger 36A interconnects conduits 124 and 128 such that these conduits are in heat exchange relationship. Preferably, heat exchanger 36A is in the form of a closed cylinder containing coil 129 connected to conduit 124, and with conduit 128 being attached at one end of the cylinder. The other end of the cylinder is connected to reservoir 20A by conduit 132. In this manner, dilute brine from reservoir 20A pressurized by pump 114 flows in one direction essentially through cylinder 130 while warm brine from boiler 126 flows oppositely outside coil 129 connected to conduit 124.

Boiler 30A also includes burner 32A which burns fuel from tank 34A. Valve 138 controls the rate at which fuel is supplied to burner 32A. The operation of valve 138 itself is controlled by level sensor 109. Flue gases produced by the burning fuel pass upwardly though a jacket that surrounds tank 126, and then are exhausted at flue 44A. Preferably, tank 126 is constructed of enamelled coated, porcelainized normal steel, stainless steel, titanium or nickel. In a preferred embodiment, cathode protection methods are used in boiler 30A with cathode 127, preferably zinc, being attached to tank 126. In order to reduce possible corrosion in boiler 30A, it is important to minimize the amount of oxygen present in the brine contained in tank 126. This is achieved in the present embodiment by providing means (not shown) for impeding the brine flow in the second loop when burner 32A stops operation. Operation of burner 32A is controlled by level sensor 109, the burner being stopped when the brine level in reservoir 20A drops below level sensor 109, only to be restarted when the brine once again reaches the level of level sensor 109.

Finally, tne top of tank 126 is connected by conduit 142 to heat exchanger 140 located inside enclosure 10A at the outlet of shroud 144 that provides a venturi-like arrangement in connection with fan 106. Heat exchanger 140 contains fins 146 which provide a large area for transferring heat from steam flowing into the heat exchanger from the boiler. The condensate produced by the condensation of steam in heat exchanger 140 is carried off by conduit 148 and collected or otherwise disposed of as indicated.

In order to increase the efficiency of the operation of the apparatus shown in Fig. 2, constriction 150 in the form of a selectively operable valve is provided in conduit 124 for the purpose of ensuring that he flow of brine in the second brine loop is small as compared to the flow of brine in the first loop. Preferably, flow control means 150 is constructed and arranged to maintain at least an order of magnitude difference between the flow rates of the first and second brine loops. Preferably, the flow rate in the second loop is about 1/20 of the flow rate of the first loop.

The present invention provides for the return to the enclosure of practically all of the heat added to the dilute brine in boiler 122 by the burning of fuel. That is to say, the sensible heat added to the dilute brine in the boiler, the heat of vaporization by which water is evaporated from the dilute brine, and the latent heat of condensation by which steam produced by the boiler is condensed to water vapor, are all returned to the enclosure by the operation of heat exchanger 36A, and heat exchanger 140. Furthermore, this heat is returned to the air in the enclosure rather than to the brine and then to the air. Consequently, the temperature of the concentrated brine applied to the sleeve 104 on direct contact heat exchanger 16A is kept as low as possible with the result that the brine is as hygroscopic as possible. As a result, the system will operate at maximum possible efficiency.

Preferably, the brine flow rate in the first loop should be about two orders of magnitude (about 100 times) greater than the rate of at which water is removed from the air in the enclosure. In typical enclosure applications (i.e., in greenhouses, enclosed swimming pools, etc.), the rate of removal of water will be about 10-20 Kg/h, so that the flow rate of brine in the first loop will be in the range 1-2 m^3/h. In such case, the heat of condensation absorbed by the brine as water vapor from the air in the enclosure condenses on the brine in the direct contact heat exchanger is almost immediately returned to the air in the enclosure because under the conditions indicated, the dehumidification process is carried out under conditions of constant enthalpy as described below. Thus, virtually all of the water vapor present in the air is converted into heat which is almost immediately returned to the air in the enclosure with little heat being stored in the brine itself. Also, in systems where cool conditions are required such as enclosures where mushrooms are grown or food or vegetables are stored, the present apparatus may be used to prevent the load on the existing systems from increasing.

If the flow rate of brine in the second loop (which is associated with the boiler) were the same as the flow rate in the first loop (which is associated with the enclosure), then large quantities of heat would be required to heat the brine in the boiler. The amount of heat necessary could be reduced, of course, by the use of a preheater, but this approach would require a physically large preheater to provide the necessary heat exchange area. Therefore, the present invention involves minimizing the flow rate of brine entering and exiting the boiler and flowing through the preheater (i.e., the brine flow in the second loop) in order to minimize the physical size of the system and provide the most efficient operation from an energy standpoint.

That the approach according to the present invention leads to these results is demonstrated below. Consider first what is termed the adiabatic conversion efficiency (ACE) of the system:

(1) $ACE = (\ )(C_{pa})(M_a)(\ T_{ba})$

where $= (\ T_{air})/(\ T_{ba})$, the approach parameter;

M_a = air flow rate (Kg/h)

C_{pa} = specific heat of air

T_{ba} = temp. diff. btwn. brine and inlet air.

Consider now the psychrometric chart shown in Fig. 3. Point I represents the starting condition of the air in the enclosure at the inlet to direct contact heat exchanger 16A, and gives the temperature and humidity of the air. Point II represents the end condition of the air at the outlet of the direct contact heat exchanger. Point III represents condition of the brine at the air/brine interface when the heat load on the brine is zero and the system is functioning adiabatically. Point V represents the condition of the brine when the heat load is large. The vapor pressure of the brine at point V is larger than the vapor pressure of the brine at point I. Finally, point IV represents the condition of the brine at the air/brine interface when the temperature of the brine has dropped due to evaporation. At point IV, the vapor pressure of the brine is the same as the vapor pressure at point I.

Point II' represents the condition of the air at the exit of the direct contact heat exchanger when the heat load is so large that the air exiting from the heat exchanger has the same absolute humidity as the air entering the heat exchanger (i.e., the heat exchanger is operating diabatically).

Relating the expressions in Eq. (1) to Fig. 3:

$$T_{ba} = T_{III} - T_I$$
$$T_{air} = T_{II} - T_I.$$

The closer approaches unity, the closer is the approach of the temperature of the exit air to the temperature of the brine at the air/brine interface. However, when the heat load is large, evaporation of water from the brine can exceed the condensation of water from the air onto the brine causing the direct contact heat exchanger to act as a humidifier instead of a dehumidifier.

If the heat load on the brine is Q_b, the efficiency of the direct contact heat exchanger can be expressed as:

(2) $EFF = ACE\ [\ 1 - (v)(Q_b)/ACE)]$ where

v = is the fraction of Q_b which is released as vapor. Thus, the more concentrated the brine, the smaller v becomes. On the other hand, as the brine becomes more concentrated, saturation may be reached; and salt precipitation may result which is undesirable for obvious reasons. Therefore, if the brine concentration and ACE have been maximized, the only way to increase the efficiency is to minimize the heat load Q_b. Possible ways to achieve this end are examined below.

Referring to Fig. 1, the heat transfer that occurs in preheater 36A can be expressed as follows:

(3) $h[(T_{132}-T_{124})+(T_{128}-T_{125})] = (2)(C_{pb})(m)(T_{125}-T_{124}).$

On the other hand, applying heat conservation considerations to preheater 36A yields:

(4) $m(T_{125}-T_{124}) = (m-m_o)(T_{128}-T_{132})$ where

h = heat transfer rate (watts/^oC)

m = flow rate of brine entering preheater and boiler (Kg/h)

m_o = evaporation rate in the boiler (Kg/h)

C_{pb} = specific heat of the brine

T_{124}, T_{125}, T_{128}, and T_{132} are the temperatures at the inlets and outlets of preheater 36A in ^oC.

Solving Eqs. (3) and (4) yields:

(5) $T_{125} = [T_{132}+T_{128}+T_{124}\{(mC_{pb}/h) - 1\}]/\{(2mC_{pb}/h)+1\}$

(6) $h = X/Y$

(7) $X = 2mC_{pb}[(m-m_o)(T_{128}-T_{132})/m]$

(8) $Y = T_{132}+T_{128}+2T_{124}-[(m-m_o)(T_{128}-T_{132})/m]$

The following chart was obtained using actual values measured from an actual system constructed in accordance with the present invention:

T_{124}	T_{125}	T_{128}	T_{132}	m	m_o	h	Q_b	ACE	EF
^oC	^oC	^oC	^oC	Kg/h	Kg/h	Kg/h	Kg/h	Kg/h	
15	74	120	40	97	19	116	1.4	13.3	0.95*
15	85	120	40	194	19	332	3.8	13.3	0.86
15	90	120	40	388	19	759	6.4	13.3	0.75
15	92	120	40	772	19	1640	14	13.3	0.52
15	94	120	40	2000	19	4530	36	13.3	-0.32
15	62	120	65	194	19	116	7.0	13.3	0.74

* optimum condition

From an analysis of the above chart, the efficiency (EF) of the direct contact heat exchanger becomes negative if all of the brine flowing through the heat exchanger also flows through the preheater and the boiler even if a preheater some forty times larger than the optimum preheater were used (based on on the fact that h is about forty times greater). In such case, the direct contact heat exchanger will humidify, rather than dehumidify, the air in the enclosure.

Reducing the brine flow rate m from 2000 Kg/h to 772 Kg/h will produce a positive efficiency. However, the level of efficiency is still rather low even though the preheater size (based on the values of h) is some fourteen times larger than the size of the optimum preheater. Only by reducing the brine flow in the second loop to 97 Kg/h is a high efficiency level (0.95) obtained. Thus, the above chart shows that the smaller the brine flow rate m, the smaller the size of preheater required, and the higher the operating efficiency of the direct contact heat exchanger.

However, it can be shown that:

(9) $(S_d - S_i)/S_d = m_o/m$ where

S_d = salt concentration of the brine discharged from the boiler (Kg salt/Kg solution)

S_i = salt concentration of brine entering the boiler (Kg salt/Kg solution).

From inspection of Eq. (9), the smaller the brine flow m, the higher the salt concentration S_d of the brine discharged from the boiler. Thus, precipitation of salt may occur. Consequently, even though reducing the brine flow rate in the second loop is desirable for increasing the efficiency, care must be taken not to reduce the flow to a level at which the brine exiting the boiler will be saturated bringing about precipitation of salt.

The most efficient practical system would therefore use a relatively high flow rate of brine in the first loop (through the direct contact heat exchanger), and a relatively low flow rate of brine in the second loop (through the preheater and the boiler). In a practical embodiment of the invention, the flow rate in the first loop is in the ranger 1-2 m^3/h, and the flow rate in the second loop is in the range 60-70 liters/h. The provision of restriction 150 in conduit 124 provides an adjustable flow control means for controlling the flow of brine in the second loop. Generally speaking, the constriction in conduit 124 would not have to be adjusted in an actual system. However, provision may be made for varying the flow in the first loop by incorporating a valve in conduit 118 or controlling the speed of rotation of pump 114; and in such case, valve 150 would be of use in relating the flow in the second loop to the flow in the first loop.

The provision of standpipe 110 establishes a hydrostatic head that, in addition to effecting proper operation of header 102, also stabilizes the brine flow in the second loop ensuring that the proper amount of brine is in boiler 122. Note also that the level of the brine in boiler 30A is above the level of brine in reservoir 20A, thus ensuring that the hydrostatic head of brine in the boiler is sufficient to maintain the required flow of brine through preheater 36A without the need for an additional pump. While this is the preferred configuration, concentrated brine may be returned either to header 102 or to standpipe 120 of the direct contact head exchanger. In such case, either a pump would be used or, boiler 30A could be elevated to a position at which the brine level in the boiler is higher than the header. The latter modification is shown in Fig. 4.

The advantages and improved results furnished by the method and apparatus of the present invention are apparent from the foregoing description of the various embodiments of the invention. Various changes and modifications may be made without parting from the spirit and scope of the invention as described in the claims that follow.

The claims defining the invention are as follows:

1. Apparatus for conditioning air in an enclosure comprising: a direct contact air/brine heat exchanger; means for passing air in the enclosure through said direct contact heat exchanger; a reservoir of concentrated brine; means for establishing a first brine loop in which brine from said reservoir is passed through said direct contact heat exchanger so that water vapor in the enclosure is condensed into the brine to form dilute brine which flows into said reservoir; a brine boiler; means for establishing a second brine loop in which heat contained within said dilute brine from said first loop is exchanged with heat within brine flowing from said boiler, said boiler evaporating water from said dilute brine and producing steam, and flow control means for maintaining a smaller flow rate in the second loop than in the first loop.

2. Apparatus according to claim 1 further comprising an indirect heat exchanger in said second brine loop.

3. Apparatus according to claim 2 wherein said heat exchanger is in the form of an inner coil carrying dilute brine from said reservoir, and an outer cylinder carrying concentrated brine from said boiler.

4. Apparatus according to claim 2 wherein said second brine loop includes a conduit carrying dilute brine from said reservoir to said boiler, and said flow control means includes a constriction in said conduit.

5. Apparatus according to claim 4 wherein said constriction is adjustable.

6. Apparatus according to claim 4 further comprising means for controlling the size of said constriction.

7. Anparatus according to claim 2 wherein said flow control means is constructed and arranged to maintain at least an order of magnitude difference from the flow rates in the first and second loops.

8. Apparatus according to claim 7 wherein the flow rate in the second loop is about 1/20 the flow rate in the first loop.

9. Apparatus according to claim 1 wherein said direct contact heat exchange includes a header located above said reservoir for distributing brine from said reservoir; and said first loop includes a vertically oriented standpipe extending from said reservoir to said header, a conduit connecting said standpipe to said header, and a pump for pumping liquid from said reservoir into the bottom of said standpipe.

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10. Apparatus according to claim 9 wherein the top of said standpipe is open to the air in said enclosure.

11. Apparatus according to claim 10 wherein concentrated brine from said boiler is returned to said reservoir.

12. Apparatus according to claim 10 wherein concentrated brine from said boiler is returned to said standpipe.

13. Apparatus according to claim 10 wherein said concentrated brine from said boiler is returned to said header.

14. Apparatus according to claim 11 wherein said apparatus is constructed and arranged so that gravity returns concentrated brine from said boiler to said reservoir.

15. Apparatus according to claim 14 further comprising an auxiliary indirect contact heat exchanger associated with the air in the enclosure, and a steam conduit for applying steam from said boiler to said auxiliary heat exchanger.

16. Apparatus according to claim 14 wherein said steam conduit slopes upwardly from said boiler to said auxiliary heat exchanger.

17. Apparatus according to claim 1 wherein said boiler includes an enamelled steel shell for containing the brine in the boiler.

18. Apparatus according to claim 1 wherein the direct contact air/brine heat exchanger includes a header for receiving brine from a reservoir located below the header, an air permeable cylindrical sleeve interposed between said header and said reservoir, said header including means for distributing brine to said sleeve whereby the brine falls in a film from the header to the reservoir; and a fan located above said header for drawing air from said enclosure through said sleeve thereby contacting said air with brine on the sleeve and a standpipe extending vertically from said reservoir to said header and being open to the air in said enclosure at the top thereof, a conduit connecting said standpipe to said header, a pump for pumping brine from said reservoir to the bottom of said standpipe, and brine concentrator means for reconcentrating brine in said reservoir.

19. Apparatus according to claim 18 wherein said brine concentrator means includes a brine boiler, a dilute brine conduit for conveying brine from said pump to said boiler, and a concentrated brine conduit for carrying brine from said boiler to said reservoir, the dilute and concentrated brine conduits being in heat exchange relationship.

RLF/1250h

20. Apparatus according to claim 19 further comprising control means for limiting the flow in said dilute and concentrated brine conduits to less than 10% of the flow in the conduit connecting the standpipe to said header.

21. Apparatus according to claim 1 wherein said brine boiler includes a burner.

22. Apparatus according to claim 21 wherein said reservoir of concentrated brine includes a brine level sensor.

23. Apparatus according to claim 22 wherein the operation of said burner and flow of brine in said second loop is controlled by said level sensor.

DATED this EIGHTH day of JANUARY 1991

Geophysical Engineering Company

Patent Attorneys for the Applicant
SPRUSON & FERGUSON

AUSTRALIAN PATENT OFFICE LS

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FIG. 1

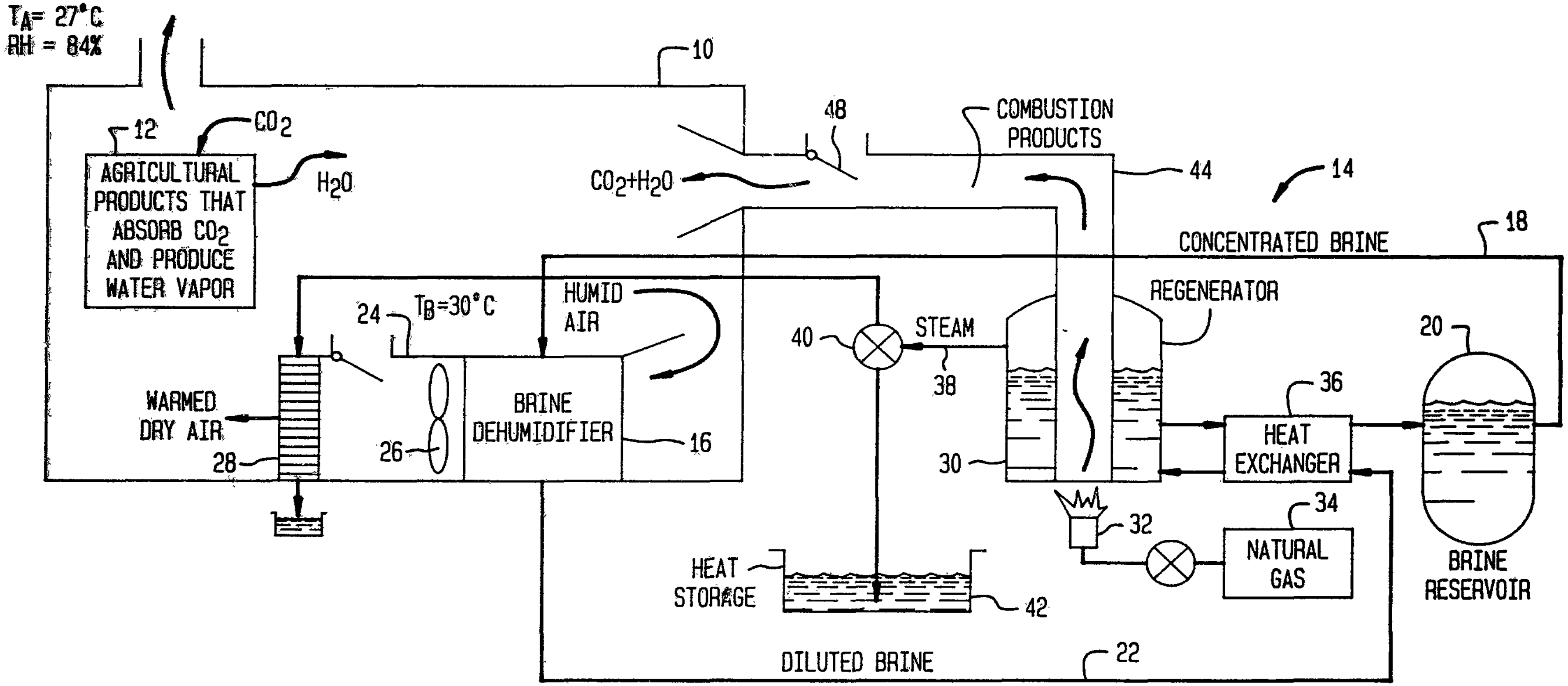

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FIG. 2

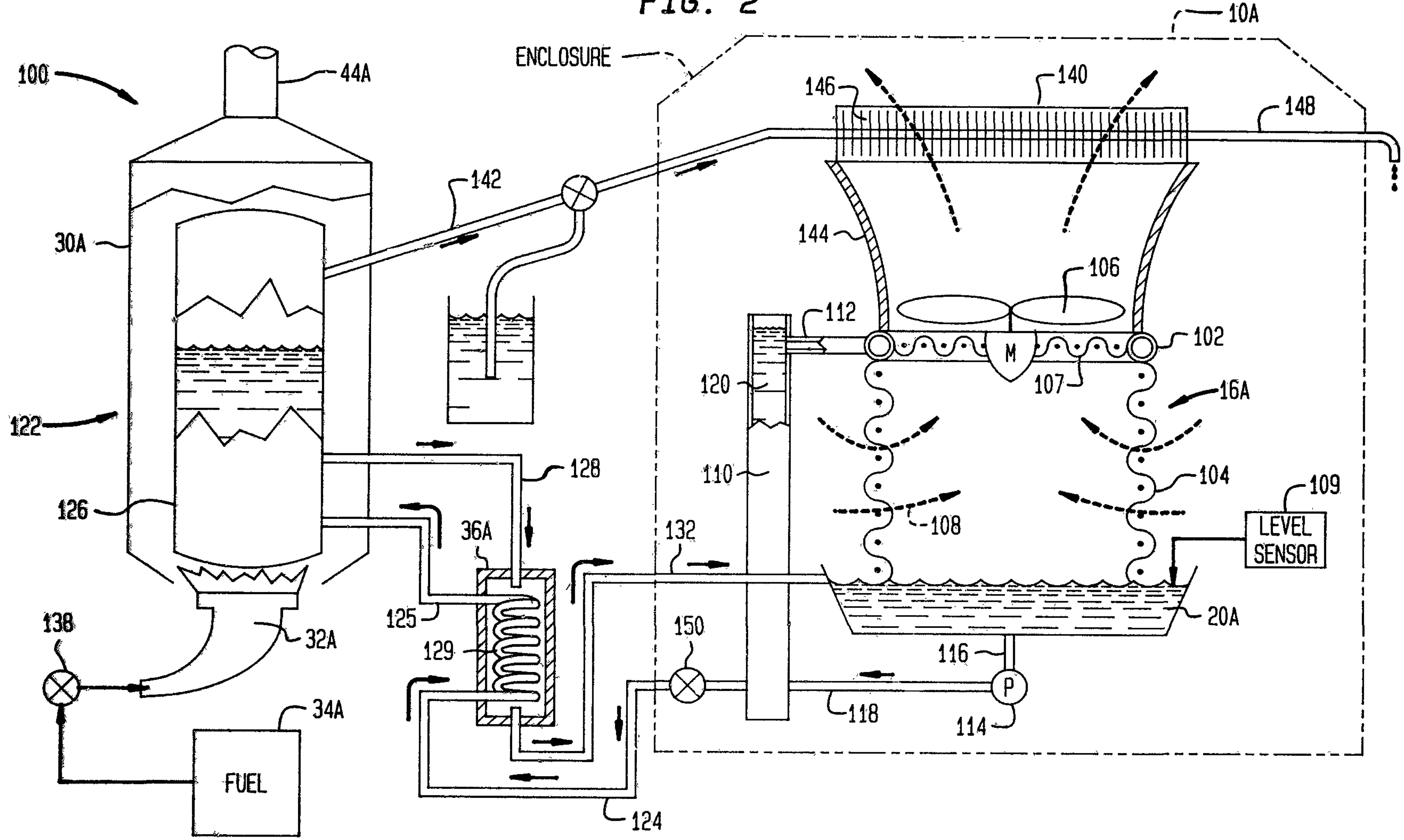

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FIG. 3

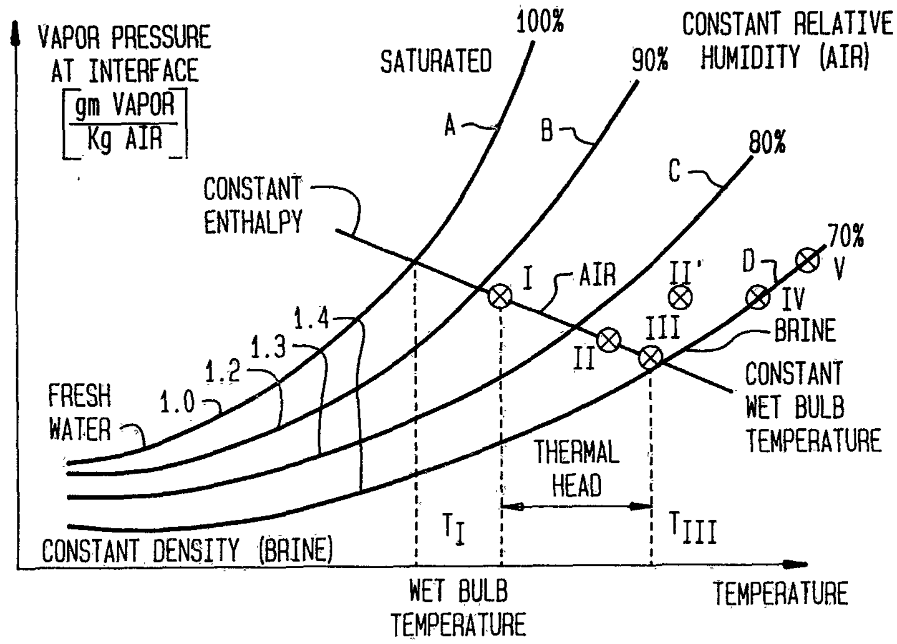
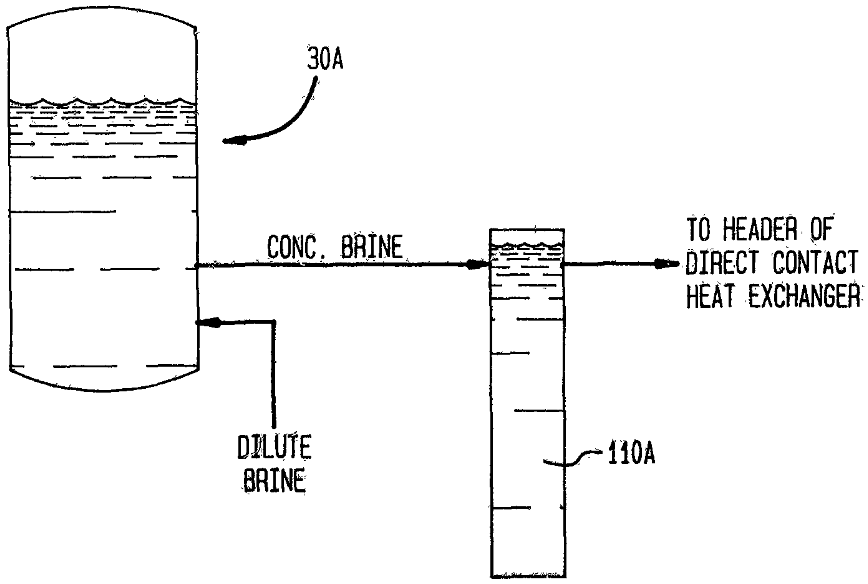

VAPOR PRESSURE AT INTERFACE
gm VAPOR / Kg AIR
SATURATED
100%
90%
CONSTANT RELATIVE HUMIDITY (AIR)
80%
70%
A
B
C
D
CONSTANT ENTHALPY
I
AIR
II
II'
III
IV
V
BRINE
CONSTANT WET BULB TEMPERATURE
1.4
1.3
1.2
1.0
FRESH WATER
THERMAL HEAD
CONSTANT DENSITY (BRINE)
WET BULB TEMPERATURE
TEMPERATURE

FIG. 4


30A
CONC. BRINE
TO HEADER OF DIRECT CONTACT HEAT EXCHANGER
DILUTE BRINE
110A