



- (51) **International Patent Classification:** Not classified
- (21) **International Application Number:**
PCT/IN2010/000812
- (22) **International Filing Date:**
15 December 2010 (15.12.2010)
- (25) **Filing Language:** English
- (26) **Publication Language:** English
- (30) **Priority Data:**
2763/MUM/2009 15 December 2009 (15.12.2009) IN
- (72) **Inventor; and**
- (71) **Applicant : DHALIWAL, Sukhdarshan, Singh**
[IN/IN]; 401, Damania Heights, KK Marg, Nani Daman,
Daman Ut (IN).
- (74) **Agent: MALIK, Shivendra, Singh;** Krishna & Saurastri
Associates, 74/F, Venus, Worli Sea Face, Mumbai 400
018, Maharashtra (IN).
- (81) **Designated States** (*unless otherwise indicated, for every
kind of national protection available*): AE, AG, AL, AM,
AO, AT, AU, AZ, BA, BB, BG, BH, BR, BW, BY, BZ,
CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO,

DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT,
HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP,
KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD,
ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI,
NO, NZ, OM, PE, PG, PH, PL, PT, RO, RS, RU, SC, SD,
SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR,
TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

- (84) **Designated States** (*unless otherwise indicated, for every
kind of regional protection available*): ARIPO (BW, GH,
GM, KE, LR, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG,
ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ,
TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK,
EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU,
LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK,
SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ,
GW, ML, MR, NE, SN, TD, TG).

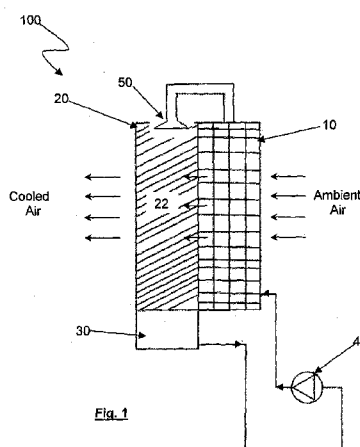
Declarations under Rule 4.17:

— *of inventorship (Rule 4.17(iv))*

Published:

— *without international search report and to be republished
upon receipt of that report (Rule 48.2(g))*

(54) **Title:** A PRE-COOLING SYSTEM AND METHOD FOR PRE-COOLING AIR



(57) **Abstract:** The present invention provides a simple pre-cooling system and method for pre-cooling air. The pre-cooling system comprising a first stage sensible cooling means for exchanging sensible heat indirectly between water and air to cool air and raising the temperature of the water and a second stage adiabatic cooling means for cooling the air adiabatically by direct contact of water with sub-cooled air from the first stage sensible cooling means. In the method for pre-cooling air, atmospheric air and water indirectly contacted for exchanging sensible heat to cool air and heat water, and directly contacting water and cooled air for adiabatic cooling of cooled air and water wherein air and water are cooled to wet bulb temperature lower than ambient wet bulb by evaporation of less quantity of water.

A PRE-COOLING SYSTEM AND METHOD FOR PRE-COOLING AIR.

FIELD OF THE INVENTION:

The present invention relates to a sub-cooling and/or pre-cooling system and method for pre-cooling air.

BACKGROUND AND PRIOR ART:

The presently available pre-cooler generally comprises evaporator pads or spray nozzles, a fan or blower for drawing air through the evaporator pads, and a water distribution system having piping and pump connected to spray nozzles for spraying water or a distribution means to distribute water over the evaporator pads and a water reservoir or sump or tank. Pump supplies water from the tank into distribution means located along the top edges of evaporator pads.

From distribution means, water drips through the evaporator pads. Water level in tank is maintained by a water supply line and a float controlled valve. The fan draws outside or ambient air through the air inlet side of pre-cooler and delivers air through its outlet side to condenser of an air conditioning system, refrigeration or heat pump or any other system to be cooled. As the air passes through pre-cooler, it exchanges heat with the dripping water resulting in evaporation of water and delivers a humid air considerably cooler than outside air. This pre-cooled air can be used for cooling the condenser in refrigeration, air conditioning system and heat pump systems and where cooled air is required to reject the heat.

US Patent No. 7765827 discloses a multi stage cooling apparatus for bringing down the temperature of air. The system incorporates a direct evaporative cooling subsystem and an indirect evaporative cooling subsystem having one of a horizontal and

a vertical set of heat exchanger channels. The system is devised with the heat exchanger channels extending from one stage into the other. The multi-stage hybrid evaporative cooling system further includes a refrigeration system for lowering the temperature of the indirect evaporative cooling subsystem air without affecting its pressure flow.

US Patent No. 4380810 discloses a process and apparatus in which a supply of low humidity air is introduced into an evaporative cooler where such air is indirectly cooled without an increase in moisture content by a first re-circulating water evaporative unit in a first and second stage unit and then is further indirectly and directly cooled by a second re-circulating water evaporative unit in a third and fourth stage unit. In the third and fourth stages, the air which is cooled indirectly is used to cool the re-circulating water in the direct cooling phase of the evaporative unit of such fourth stage.

However, traditional methods and devices are based on direct evaporative cooling system limited to ambient wet bulb temperature and above said US Patents disclose complex system. Further, these systems have drawbacks like high cost of accomplishing the sub-cooling and/or pre-cooling, and/or the ineffectiveness or inadequate effectiveness of the sub-cooling and/or pre-cooling besides disproportionate use of electrical energy and water for pre cooling application.

SUMMARY OF THE INVENTION:

An object of the present invention is to provide a simple pre-cooling system and method to obviate the shortcoming associated with existing systems.

A still further object of the invention is to provide such a means in a form which facilitates its installation over an existing cooler or condenser and which requires a minimum of additional mounting space and inexpensive changes.

Accordingly, the present invention in one aspect provides a pre-cooling system comprising a first stage sensible cooling means for exchanging sensible heat indirectly between water and air to cool air and raising the temperature of the water and a second stage adiabatic cooling means for cooling the air adiabatically by direct contact of water with sub-cooled air from the first stage sensible cooling means. The air and water are cooled to a wet bulb temperature lower than ambient wet bulb temperature.

In an optional embodiment of the system, the present invention provides a middle cooling means to cool warmed water of first stage before passing to the second stage adiabatic cooling means.

In a further optional embodiment, the present invention provides the middle cooling means integrally adapted between the first stage i.e. sensible cooling means and second stage i.e. adiabatic cooling means along with a diversion means to divert a part of cooled air leaving the first stage sensible cooling means cross to the flow of warmed water.

In another aspect, the present invention provides a method for pre-cooling air comprising steps of indirectly contacting atmospheric air and water to exchange sensible heat to cool air and heat water, and directly contacting for adiabatic cooling of cooled air and water wherein air and water are cooled to wet bulb temperature lower than ambient wet bulb by evaporation of less quantity of water.

In an optional embodiment of the method for pre-cooling air, the present invention provides a step of cooling warmed water by indirectly or directly before directly contacting with the cooled air.

DESCRIPTION OF THE DRAWINGS

The features, aspects and other advantages of the present invention will become better understood when the following detailed description is read with reference to the

accompanying drawings in like characters represent like parts throughout the drawings, wherein:

Figure 1 shows one embodiment of a Pre-cooler system according to the present invention;

Figure 2 shows another embodiment of a Pre-cooler system according to the present invention;

Figure 3 shows a pre-cooler system showing preferred arrangement of a middle cooling means;

Figure 4 shows a psychometric chart illustrating the various stage of air in an illustrative example using a pre-cooling system of Figure 1.

DETAILED DESCRIPTION OF THE INVENTION

In general, the present invention provides a pre-cooling system. The first stage is a sensible cooling means for cooling air indirectly by exchanging sensible heat with water to cool the air and raise the temperature of water and second stage is an adiabatic cooling means for direct contact of warmed water with cooled air of the first stage. Optionally, a middle cooling means can be adapted to cool warmed water of first stage before passing to the second stage adiabatic cooling means. According to the present invention, the middle cooling means can be a heat exchanger to cool the warmed water indirectly or a cooling tower to cool warmed water adiabatically. Moreover, the middle cooling means can be integrally adapted between the first stage sensible cooling means and second stage adiabatic cooling means along with a diversion means to divert a part of cooled air leaving the first stage sensible cooling means cross to the flow of warmed water.

According to the present invention, the sensible cooling means includes a heat exchanger configured for sensibly sub-cooling the air by providing indirect contact with water.

According to the present invention, the adiabatic direct cooling means comprises a surface evaporation media for direct contact between sub-cool air and warmed water for adiabatic cooling of air, a distributing means for distributing water over the surface evaporation media; and a water reservoir below the surface evaporation media for collecting cooled water. Cooled water from the water reservoir is pumped through the heat exchanger by a pump. A make-up water tank is adapted for providing water to water reservoir at predetermined level.

According to the present invention, the system may comprise a means for drawing or passing air from the heat exchanger and the surface evaporation media. Alternatively, the means for passing/drawing air can be a means of system to which the pre-cooler system is adapted and can be a fan or blower. The system to which pre-cooler system is adapted, can be an air handling unit, Air-conditioning or refrigeration condenser or any other sensible heat rejection equipment such as dry cooling tower, Gas Turbine Inlet Air Cooling (GTIAC) system, Compressor Air Pre Cooler (CAPC) system, Treated Fresh Air Unit (TFA), Dedicated Outdoor Air system (DOAS), Air Side Economizer (ASE) system, Computer Room Air conditioner (CRAC) system or any other system requiring heat rejection.

According to the present invention, the system may comprise a controller configured for controlling pre-cooling operations.

The present invention also provides a method for pre-cooling air which comprises two steps. Initially, indirectly contacting the air flow and water flow to exchange sensible

heat to cool air and heat water, and then directly contacting said flows for adiabatic cooling of cooled air and hot water.

Hereinafter, the preferred embodiments of the present invention will be described in detail with reference to the accompanying drawings. Reference now should be made to the drawings, in which the same reference numerals are used throughout the different drawings to designate the same or similar components. As it is well understood by those skilled in the art, the components associated with the system can take any design form with acceptable change in dimensions that fall within the scope of the present invention for incorporating similar features as associated and illustrated by referencing to the present invention.

Figures 1, 2 and 3 show exemplary preferred embodiments of the pre-cooling system according to the present invention.

Figures 1, 2 and 3 show the precooling system (100, 200, 300) comprises two stages namely a means for sensibly sub-cooling air as a first stage and an adiabatic cooling means (20) as second stage.

According to the present invention the means for sensibly sub-cooling air includes a heat exchanger referred as 10 in the Figure 1, 2 and 3.

As shown in Figure 1, the adiabatic cooling means (20) includes a surface evaporation media/evaporative pads (22) for cooling the air adiabatically by directly contacting air and water, a water reservoir (30) adapted below the surface evaporation media (22) and a water pump (40) connected to the water reservoir (30) for pumping water and a distributing means (50) adapted above the surface evaporation media (22) and connected to the outlet of the heat exchanger (10) for distributing water over the surface evaporation media (22).

According to the present invention, the evaporation media (22) can be evaporator pads, single phase atomizing nozzles, Two phase atomizing nozzles or ultrasonic atomizing devices and in combination thereof. The evaporation media are preferably evaporative pads made of cellulose/polymer having very high surface to volume area ratio.

According to the present invention, the heat exchanger (10) is preferably tube type heat exchanger. The tube may have multiple partitions (not shown) to create multiple independent passages along with or without (not shown) fins to increase the heat transfer area. The tubes are connected to supply and discharge header. According to the present invention, the tubes are made of polymer or metal and are flat or round. Further, these tubes are coated with proprietary nano-coating (not shown) to improve thermal conductivity and for breaking the boundary layer on the air side.

According to the present invention, the surface evaporation media/evaporative pads (22) can be made of cellulose pads having very high surface to volume area ratio.

According to further embodiment of the present invention, a controller (not shown) is provided to the pre-cooling system for controlling predetermined set points such as controlling the pumping based on ambient temperature, protecting the pump from overload, controlling level of water in the water reservoir etc. Further, the controller can be configured with the system to which pre-cooling system of the present invention is adapted such as configuring the controller with the refrigeration system for cooling refrigerant wherein the controller can be configured to the refrigeration compressor by controlling the pump during low temperature periods i.e. winter season by sensing the refrigerant return temperature. Further, the controller can be configured for regulating the fan speed of condenser fan or supply air fan to save energy.

Figure 2 shows the precooling system (200) comprises three stages namely a means for sensibly sub-cooling air as a first stage, an adiabatic cooling means (20) as second stage and a middle cooling means to cool warmed water of first stage before sending to the second stage. The middle cooling means can be a heat exchanger to cool the warmed water indirectly or a cooling tower to cool warmed water adiabatically.

To cool air in the first stage according to the method of the present invention the pre-cooling system operates when the ambient temperature is higher than the set temperature. As shown in Figures 1 and 2 the outside/atmospheric air to be cooled is passed/ drawn through the heat exchanger (10) and the water is pumped by a water pump (40) from the reservoir tank (30) flows through tubes of the heat exchanger (10) where sensible heat transfer takes place between air and water. The heat transfer reduces temperature of air and simultaneously raises the temperature of water flowing in the tubes.

In second stage, as shown in Figure 1 the warmed water leaving the heat exchanger (10) is then sprayed from top of the surface evaporation media (22) by a distributor means (50) and the subcooled air is drawn or passed through surface evaporation media (22). The surface evaporation media (22) by contacting the warmed water with air thereby adiabatically cool both air and water. As the air coming from the heat exchanger pads is sensibly pre-cooled hence the wet bulb of the air is lower than the ambient wet bulb temperature. This ensures that the water and air can be cooled to this new wet bulb temperature, which is always lower than ambient wet bulb therefore less water evaporates in the adiabatic cooling ensuring cooling of the air. The water dripping through the surface evaporation media (22) is collected in the water tank/sump (30) for re-circulating. The cooled air coming through the surface evaporative media is allowed to pass through a heat rejection heat exchanger of the

system to which the pre-cooler adapted. Air leaving the system (100) is cooled to wet bulb temperature lower than ambient wet bulb by evaporation of less quantity of water.

As shown in Figure 2, the warmed water from the heat exchanger (10) is cooled by a middle cooling means (60) before spraying over the evaporation media (22).

Referring Figure 3 shows a preferred arrangement of the middle cooling means (60) of a pre-cooling system (300) according to the present invention. As shown in Figure 3, a part of cooled air from the first stage sensible cooling means (10) is diverted by a diversion means (65) for cooling warmed water in the middle cooling means. The diverted cooled-air flows upward cross to the warmed water and cooled air flows which results in adiabatic cooling of warmed water. The system (300) comprises a separate water reservoir (30B) below the middle cooling means to collect cooled water which is then sprayed in the adiabatic cooling means (20) of second stage. This cooled water can be re-circulated to the First stage i.e. heat exchanger (10) The water dripping through the adiabatic cooling means (20) is chilled water and collected in a separate water reservoir (30A) as shown in Figure 3. This chilled water can be used for chiller or may pump through the heat exchanger (10) of first stage to cool the ambient air. The air leaving the precooling system (300) is closer to ambient dew point temperature.

According to the present invention, the pre-cooling system of the present invention can be configured with a system to which cooling is required such as an air handling unit, Air-conditioning or refrigeration condenser or any other sensible heat rejection equipment such as dry cooling tower, Gas Turbine Inlet Air Cooling (GTIAC) system, Compressor Air Pre Cooler (CAPC) system, Treated Fresh Air Unit (TFA), Dedicated Outdoor Air system (DOAS), Air Side Economizer (ASE) system, Computer Room Air conditioner (CRAC) system or any other system requiring heat rejection and the controller of the pre-cooling system can be configured with the said system.

According to the present invention, all the components of the present invention can be manufactured from the polymer to avoid corrosion.

Referring to Figures 1 and 4, an illustrative treatment of air may be described as follows. Supply air is available, for example, during the summer in one part of India with a dry bulb temperature of 34 DEG C. and wet bulb temperature of 22 DEG C. This is illustrated at point 1 on chart Figure 4. In the first stage of cooling the supply air passes through the sensible heat exchanger (10) where its dry bulb temperature is reduced to 24.5 DEG C., and wet bulb to 16 DEG C., without any increase in its dew point of 10 DEG C. Its relative humidity, however, increases from 23% at point 1 to 40% at point 2.

Then cooled air passed through the evaporation media 22 of the adiabatic cooling means 20. The air leaving the adiabatic cooling means 20 has wet bulb of 16 DEG C. and dry bulb temperature of 17 DEG C. and has a relative humidity at discharge of 90% (point 3 on the chart).

It will be seen, therefore, that the entering air having dry bulb temperature of 34 DEG C. is cooled to the relatively extremely low temperature of 17 DEG C. which is suitable for both residential, industrial and commercial use.

The system of the present invention is easy to install and requires about 50% or less water compared to state of the art pre coolers. Further, when the system of the present invention used in combination with air conditioning system or refrigeration circuit, it reduces power consumption and also provides integrated control to protect the refrigeration system.

While the present invention has been described with reference to one or more exemplary embodiments, it will be understood by those skilled in the art that various changes can be made in respect of pre-cooling such as a water reservoir is shown as

integrated part of the second stage adiabatic cooling means which can be an independent means, without departing from the scope of the present invention. In addition, many modifications can be made to adapt a particular geometry or dimension to the teachings of the description without departing from the scope thereof. Therefore, it is intended that the present invention not be limited to the particular embodiment(s) disclosed as the best mode contemplated, but that the invention will include all embodiments falling within the scope of the appended claims.

CLAIMS

1. A pre-cooling system for air, comprising:

a first stage sensible cooling means for exchanging sensible heat indirectly between water and air to cool air and raising the temperature of the water;

and

a second stage adiabatic cooling means for cooling the air adiabatically by direct contact of water with sub-cooled air from the first stage sensible cooling means.

wherein air is cooled to a wet bulb temperature lower than ambient wet bulb temperature.
2. The pre-cooling system as claimed in claim 1 optionally comprises a middle cooling means to cool warmed water of first stage before passing to the second stage adiabatic cooling means.
3. The pre-cooling system as claimed in claim 2, wherein the middle cooling means can be a heat exchanger to cool warmed water indirectly or a cooling tower to cool the warmed water adiabatically.
4. The precooling system as claimed in claim 2 or 3 wherein a part cooled air from the first stage sensible cooling means can be utilized for cooling warmed water in the middle cooling means.
5. The precooling system as claimed in claim 4, wherein the middle cooling means can be integrally adapted between the first stage sensible cooling means and second stage adiabatic cooling means along with a diversion means to divert a part of cooled air leaving the first stage sensible cooling means cross to the flow of warmed water to pre-cool the air closer to ambient dew point temperature.

6. The pre-cooling system as claimed in claim 1, wherein the first stage sensible indirect cooling means includes a heat exchanger configured for sensibly sub-cooling the air.
7. The pre-cooling system as claimed in claim 1, wherein the second stage adiabatic direct cooling means includes:
 - a surface evaporation media for direct contact between sub-cool air and warmed water for adiabatic cooling of air;
 - a distributing means for distributing water over the surface evaporation media; and
 - a water reservoir below the surface evaporation media for collecting cooled water.
8. The pre-cooling system as claimed in one of the claims 1, wherein water from the water reservoir is pumped through the heat exchanger by a pump.
9. The pre-cooling system as claimed in one of the claims 1 to 8 optionally comprises a means for drawing or passing air from the heat exchanger and the surface evaporation media.
10. The pre-cooling system as claimed in one of the claims 1 to 8 further comprises a controller configured for controlling pre-cooling operations.
11. The pre-cooling system according to claim 1 further comprising a make-up water tank adapted for providing water to the heat exchanger by action of the integral pump.
12. The pre-cooling system according to claim 6, wherein the heat exchanger is preferably a tube type heat exchanger.

13. The pre-cooling system according to claim 10, wherein heat exchanger comprises one or multiple partitions to create multiple independent passages along with or without fins for increasing heat transfer area.
14. The pre-cooling system according to claim 10, wherein the tubes are made of polymer or metal and are flat or round and can have coated with proprietary nano-coating to improve thermal conductivity and for breaking the boundary layer on the air side
15. The pre-cooling system according to claim 7, wherein the surface evaporation media can be evaporator pads, single phase atomizing nozzles, two phase atomizing nozzles or ultrasonic atomizing devices and in combination thereof.
16. The pre-cooling system according to claim 15, wherein the evaporation media are preferably evaporative pads made of cellulose/polymer having very high surface to volume area ratio.
17. The pre-cooling system according to claim 9, wherein the means for passing/drawing air can be a means of system to which the precooler system is adapted and can be a fan or blower.
18. The pre-cooling system as claimed in claim 17 wherein the system to which precooler system is adapted can be an air handling unit, Air-conditioning or refrigeration condenser or any other sensible heat rejection equipment such as dry cooling tower, Gas Turbine Inlet Air Cooling(GTIAC) system, Compressor Air Pre Cooler (CAPC) system, Treated Fresh Air Unit (TFA),Dedicated Outdoor Air system(DOAS), Air Side Economizer(ASE) system, Computer Room Air conditioner(CRAC) system or any other system requiring heat rejection.
19. A method for pre-cooling air comprising steps of:

indirectly contacting atmospheric air and water to exchange sensible heat to cool air and heat water; and

directly contacting water and cooled air for adiabatic cooling of cooled air and water.

wherein air and water are cooled to wet bulb temperature lower than ambient wet bulb.

20. The method for pre-cooling air as claimed in claim 19 further comprising controlling the pre-cooling operation based on the predetermined set points including starting of pump if the ambient temperature is above the set point; controlling water level in the water reservoir, regulating fan speed etc.

21. The method for pre-cooling air as claimed in claim 19 or 20, further comprising a step of cooling warmed water by indirectly or directly before directly contacting with the cooled air.

22. The method for pre-cooling air as claimed in claim 21, wherein step of cooling warmed water comprises step of diverting a part of cooled air to cool warmed water.

23. A system and method for pre-cooling air as herein described with reference to the foregoing description and the accompanying drawings.

1 / 4

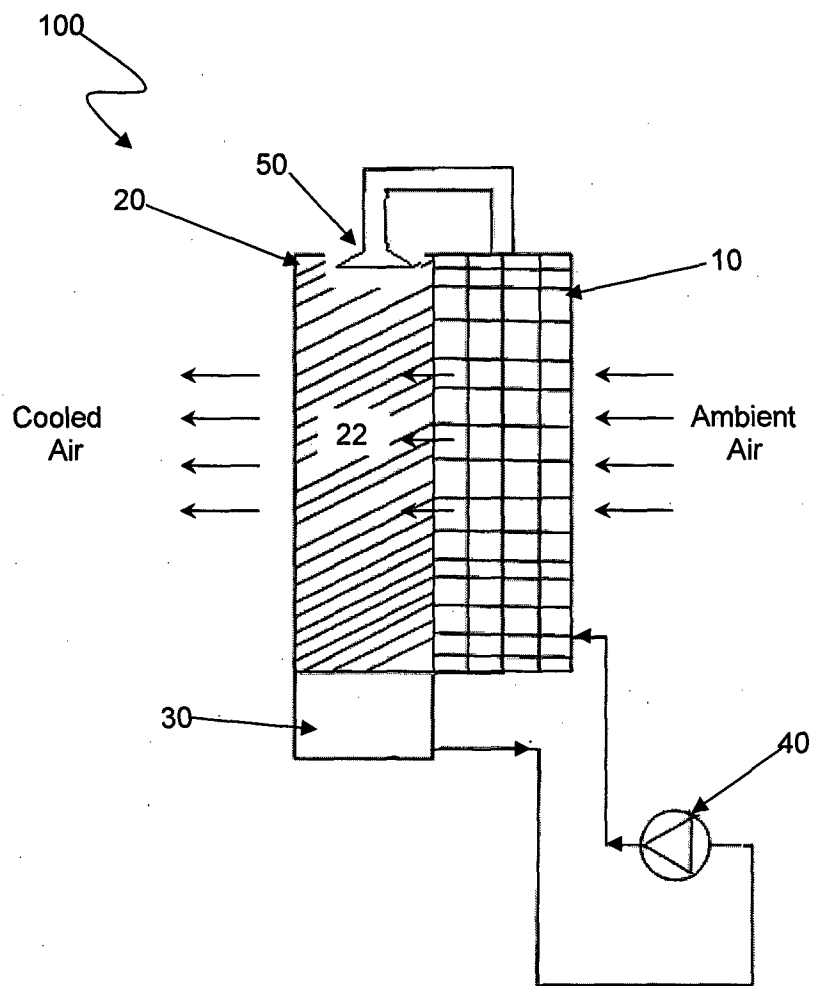


Fig. 1

2 / 4

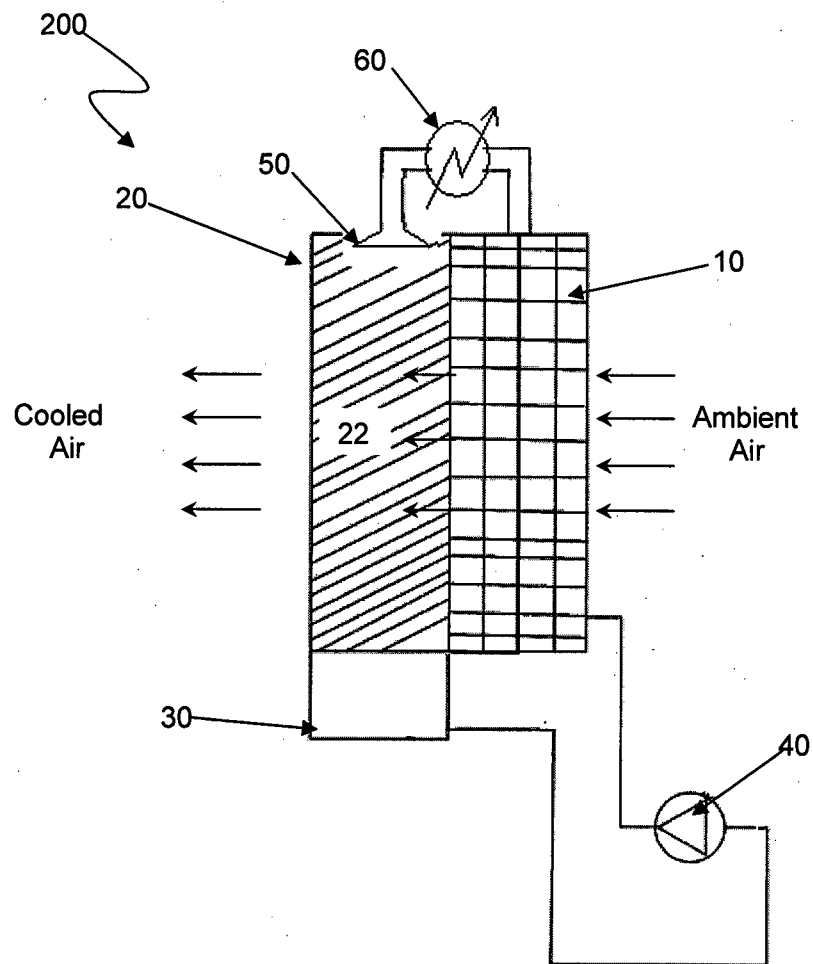


Figure 2

3 / 4

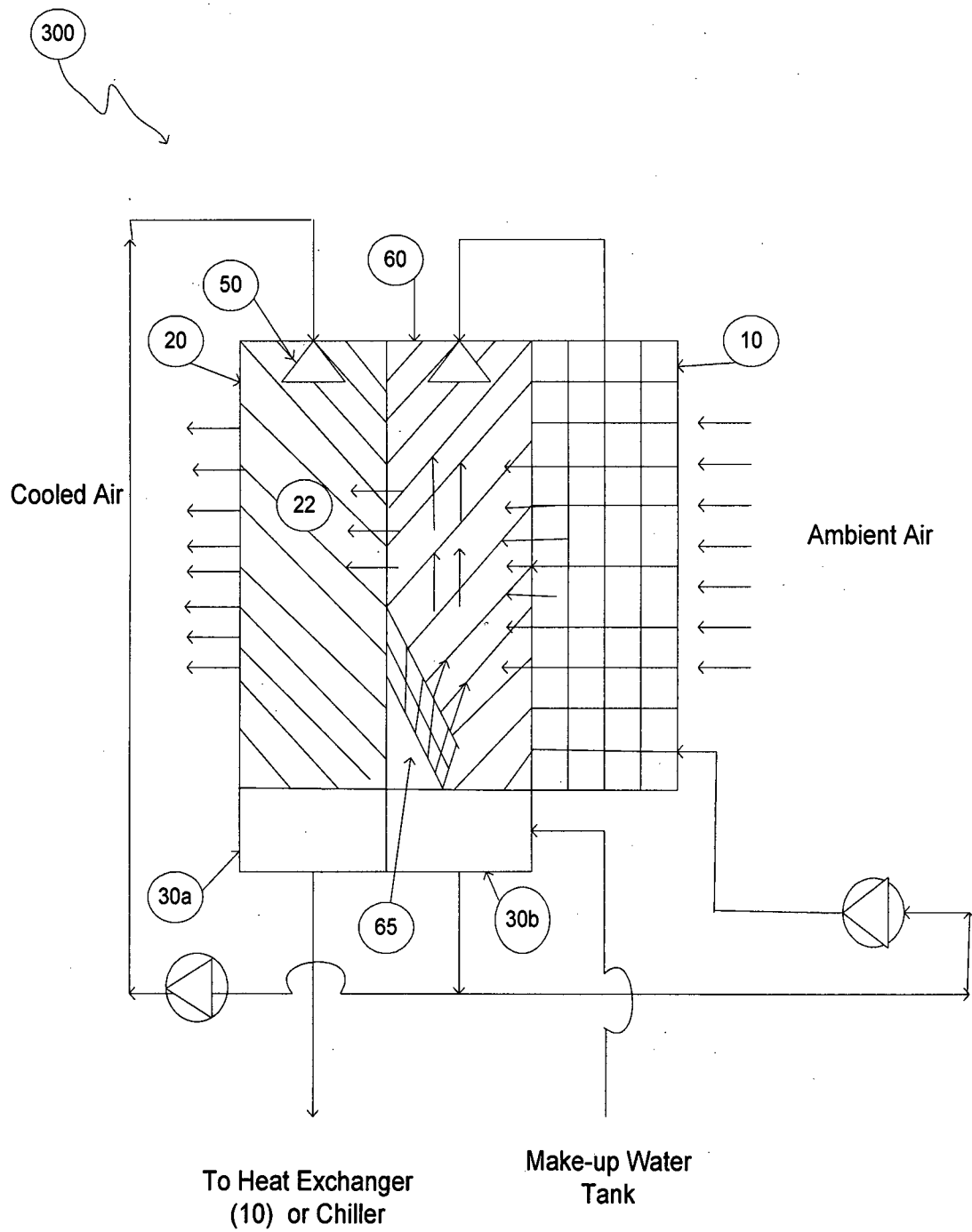


Figure 3

4 / 4

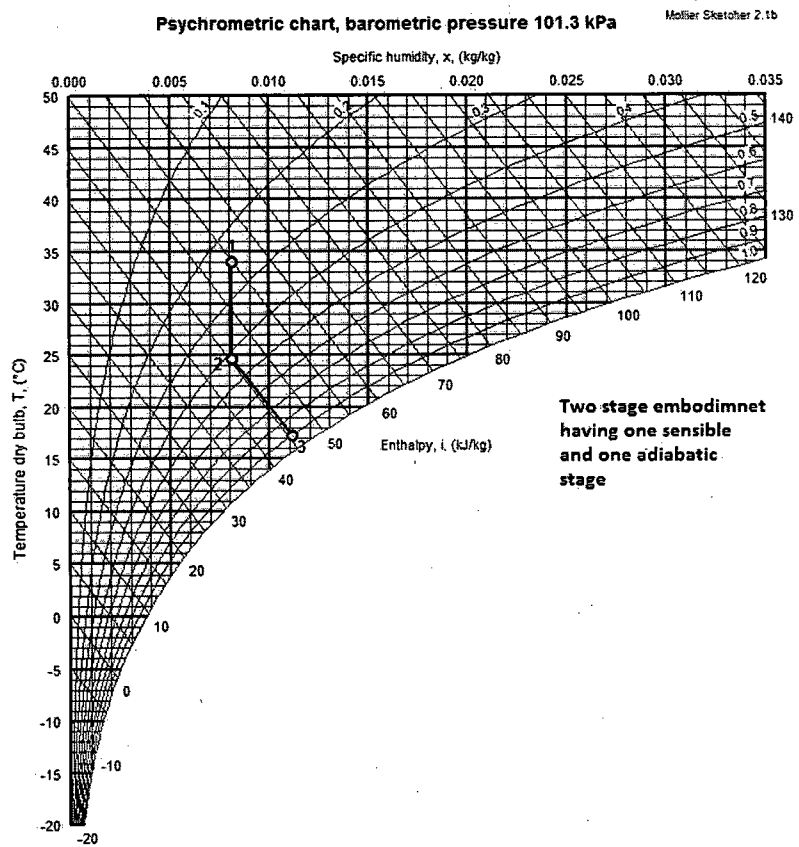


Figure 4