SUMMARY OF THE DISCLOSURE

[0006] The present disclosure relates to systems and methods of controlling the temperature and humidity of a defined space. More specifically, the present disclosure is directed to systems and methods employing a two-phase process for pre-cooling air prior to dehumidification. In an embodiment of the present disclosure, external air is passed through a dry channel of a heat exchanger for pre-cooling prior to undergoing dehumidification. Any additional energy requirements for the heat exchanger are reduced or eliminated by simultaneously passing conditioned air through a wet channel of the heat exchanger prior to venting the conditioned air to the environment. Liquid in the wet channel evaporates into the exhausted, conditioned air, cooling the channel. The wet channel is thermally coupled to the dry channel, thereby cooling the dry channel and initially cooling and dehumidifying the external air before it enters the dehumidifier for additional dehumidification.

[0006a] An aspect of the present disclosure provides an air conditioning system for conditioning air in a space, comprising: a conditioned space; a dehumidifier; and a heat exchanger. The heat exchanger comprises: a first channel having a first inlet configured to intake exhaust air from the conditioned space and a first outlet configured to expel the exhaust air from the first channel to an outdoor environment; a second channel having a second inlet configured to intake outdoor ambient air from the outdoor environment and a second outlet configured to deliver the outdoor ambient air to the dehumidifier; wherein a wall of the first channel and an adjacent wall of the second channel form a shared, thermally coupled wall comprised of a single impenetrable plate. A first surface of the thermally coupled wall in the first channel is coated in a liquid such that the passage of the exhaust air through the first channel evaporates at a least a portion of the liquid coated on the first surface of the thermally coupled wall thereby reducing the temperature of the first surface of the thermally coupled wall. The evaporation of the liquid transfers heat between the first surface of the thermally

coupled wall and a second surface of the thermally coupled wall disposed within the second channel such that reducing the temperature of the first surface of the thermally coupled wall reduces the temperature of the second surface of the thermally coupled wall and cools the outdoor ambient air traversing the second channel to create pre-cooled air. The dehumidifier dehumidifies the pre-cooled air received from the second channel to a desired condition and delivers conditioned air to the conditioned space, and the conditioned air circulates within the conditioned space and exits the conditioned space as the exhaust air.

[0006b] Another aspect of the present disclosure provides a method of conditioning a space by circulating air through a heat exchanger, dehumidifier, and a conditioned space, the method comprising the steps of: drawing ambient air through a first dry channel of the heat exchanger to precondition the ambient air; passing the preconditioned ambient air through the dehumidifier to produce conditioned air and delivering the conditioned air to the conditioned space; passing the conditioned air through the conditioned space and directing the conditioned air out of the conditioned space as exhaust air; moving the exhaust air from the conditioned space through a wet channel of the heat excahnger, the wet channel and first dry channel having a shared, thermally coupled wall, the exhaust air evaporating a liquid from a surface of the thermally coupled wall within the wet channel and reducing temperature of the first dry channel. The liquid coats the surface of the thermally coupled wall in the wet channel; wherein the evaporation of liquid from the thermally coupled wall removes heat from the thermally coupled wall to reduce the temperature of the first dry channel. The reduction in temperature of the first dry channel pre-

cools and partially dehumidifies the ambient air as it passes through the first dry channel prior to delivering the preconditioned ambient air to the dehumidifier.

[0006c] Another aspect of the present disclosure provides a heat exchanger as a system for conditioning air, the heat exchanger comprising: a wet channel to draw exhaust air from a conditioned room through an inlet and discharge the exhaust air through an outlet located on an opposite end of the wet channel; a first dry channel sharing a thermally coupled wall with the wet channel; and an operative connection between the dehumidifier and the conditioned room directing the ambient air through the dehumidifier to create dehumidified air which is delivered to the conditioned room and exits the conditioned room as the exhaust air. The first dry channel is disposed to draw ambient air through an inlet and discharge the ambient air through an outlet located on an opposite end of the first dry channel and toward a dehumidifier. A surface of the thermally coupled wall within the wet channel is coated in a liquid; and when the temperature of the exhaust air is less than the ambient air, passage of the exhaust air through the wet channel evaporates liquid from the thermally coupled wall to cool the wet channel, and the first dry channel transfers heat to the wet channel to modulate the ambient air to a desired condition as the ambient air passes through the first dry channel.

[0006d] Another aspect of the present disclosure provides an air conditioning system for conditioning air in a space, comprising: a heat exchanger comprising: a first channel; a second channel; wherein a wall of the first channel and an adjacent wall of the second channel form a shared, thermally coupled wall; a dehumidifier operatively connected to the second channel; a conditioned space operatively connected to the first channel; a first inlet proximate a first end of the first channel, the first inlet configured to draw conditioned air from the conditioned space; a first outlet proximate a second end of the first channel, the first outlet configured to

expel the conditioned air to an environment; a second inlet proximate a first end of the second channel, the second inlet configured to intake ambient air from the environment; a second outlet proximate a second end of the second channel, the second outlet configured to deliver the ambient air to the dehumidifier, wherein the dehumidifier dehumidifiers the ambient air into conditioned air prior to delivering the conditioned air to the conditioned space; and a coat of liquid is disposed along walls within the first channel such that the conditioned air evaporates the liquid as the conditioned air passes through the first channel and reduces the temperature of the shared thermally coupled wall and wherein the second channel transfers heat through the thermally coupled wall to the first channel, reducing temperature of the second channel and pre-cooling the ambient air as it passes through the second channel.

BRIEF DESCRIPTION OF THE DRAWINGS

[0007] The following detailed description, given by way of example, but not intended to limit the disclosure solely to the specific embodiments described, may best be understood in conjunction with the accompanying drawings.

[0008] FIG. 1 shows a diagram of the air conditioning system comprising a heat exchanger, dehumidifier, conditioned room, and the airflow into and out of the system.

[0009] FIG. 2 displays a first embodiment of the system of FIG. 1 comprising a heat exchanger with a plurality of channels.

[0010] FIG. 3 displays a second embodiment of the system of FIG. 1 comprising a heat exchanger with a plurality of channels.

embodiment, a further air conditioning system is employed to further cool the pre-cooled air before it is introduced into the conditioned space.

[0021] As shown, air from the conditioned room 106 is expelled from the conditioned room 106 as exhaust 120. The exhaust 120 is passed through the heat exchanger 102 before being released into another environment. In embodiments, fresh external air is continuously brought into the conditioned space while a corresponding volume of exhaust 120 is expelled, such that the pressure in the conditioned room 106 is maintained substantially unchanged while constantly ventilating the conditioned space.

[0022] FIG. 2 shows an embodiment of a system 200 comprising a heat exchanger 202 comprising at least one dry channel 208 and at least one wet channel 210. Hereafter, use of the singular version of "dry channel" and "wet channel" comprise both the plural or singular use of these terms.

[0023] In the embodiment shown in FIG. 2, external air is pulled into and passes through the dry channel 208 before being provided to the dehumidifier 104. Similarly, the exhaust 120 is passed through the wet channel 210 before being expelled into the environment 222. The walls of the dry channel 214a, 214b and the walls of the wet channel 214c, 214d are thermally coupled, such that a change in temperature of any one wall 214 results in a corresponding change of temperature of the other walls 214. In the embodiment shown, the surfaces of the walls of the wet and dry working channels may be connected to form a shared wall made from a thermally conductive material 217. Each channel 208, 210 forms an enclosed space passing from a respective air inlet 213a, 213b to an air outlet 215a, 215b. Air flows from each inlet, through the respective channel, to the outlet. The walls 214c, 214d of the wet channel are coated in a liquid. In the embodiment shown, the walls 214c, 214d are coated in water. As exhaust 120 passes through the wet channel 210, water from

the walls 214c, 214d evaporates, thereby reducing the temperature of the walls 214c, 214d. As the exhaust has already been conditioned, it will generally have a low moisture content and thus effectuate significant evaporation. As the walls of the wet channel 210 cool, heat is transferred from the dry channel 208 to the wet channel 210. External air 124 passing through the dry channel 208 is thereby cooled through contact with the dry channel walls 214a, 214b, and results in condensation and removal of moisture from the air.

[0024] In the embodiment shown in FIG. 2, a fluid connection between the dry channel 208 and the wet channel 210 continuously replenishes the supply of liquid in the wet channel 210 with moisture derived from the air passing through the dry channel 208. In an alternative embodiment, the fluid connection is entirely passive, such that no external energy is needed to transport moisture from the dry channel 208 to the wet channel 210.

[0025] The dry channel 208 and wet channel 210 may be arranged in multiple configurations. As will be clear to one of skill in the art, combinations of these embodiments and other passive transport techniques may be used to effectuate the transfer of moisture from the dry channel 208 to the wet channel 210 while preventing backflow of moisture from the wet channel 210 to the dry channel 208. In an embodiment, the dry channel 208 is located above the wet channel 210 such that gravity effectuates the transfer of moisture from the dry channel 208 to the wet channel 210. In an alternative embodiment, the fluid connection is structured such that capillary action effectuates the transfer of moisture from the dry channel 208 to the wet channel 210. Regardless of the arrangement of the dry channel 208 and wet channel 210, the walls 214a, 214b of the dry channel 208 may be coated with a hydrophobic substance, such that water collecting thereon is driven through the fluid connection to the wet channel 210.

214 of the channels 208, 210 and the air passing through the channels 208, 210. Greater contact area will increase the amount of evaporation and/or condensation, thereby enabling both the degree of pre-cooling and the amount of dehumidification to be adjusted based on the desired capacity of the system.

[0030] In the preferred embodiment, the liquid 216 used in the wet working channel 210 is water. In alternative embodiments, any liquid may be used to facilitate heat transfer between the channels.

[0031] In the preferred embodiment of FIG. 2, exhaust air 120 exits the conditioned room 106 and is delivered to the wet working channel 210. As the exhaust air passes through the wet working channel 210, the exhaust air 120 absorbs the liquid 216 on the channel walls 214c, 214d. The absorption of liquid 216 removes heat from the wet channel walls 214c, 214d and cools the shared wall 217. In turn, the shared wall 217 cools the dry working channel 208 as well as the outdoor air 124 passes through the dry working channel 208. As the outdoor air 124 cools, its moisture content is reduced. The partially cooled and dehumidified outdoor air 226 is then delivered to a dehumidifier 104 where it is further dehumidified. After passing through the dehumidifier, the outdoor air 228 is delivered to the conditioned room 106 where it compensates the cooling and moisture loads in the conditioned room, before reaching the parameters for exhaust and exiting the conditioned room. The exhaust air 120 is then delivered to the working channels 208, 210 and the cycle begins again.

[0032] The placement of the two-phase heat exchanger 202 before the dehumidifier 104 dramatically reduces the required capacity of the dehumidifier 104 because the bulk of the cooling and dehumidification process can occur during the pre-cooling process before the air reaches the dehumidifier 104. In embodiments, the degree of pre-cooling provided by the heat exchanger 202 entirely eliminates the need for subsequent dehumidification 104.

[0033] In an embodiment of the heat exchanger 202, the plates and walls 214 are comprised of a non-woven fabric, such as a Polyethylene Terephthalate (PET) non-woven fabric. In other embodiments, the plates and walls 214 are comprised of materials suitable for heat exchange which include but are not limited to metals and metal alloys, such as aluminum, copper, carbon steel, stainless steel, nickel alloys, and titanium. In another embodiment, the plates and walls 214 are comprised of ceramic material.

[0034] In an additional embodiment, the heat exchanger 202 may further comprise plates and walls 214 which provide an extended surface so as to increase the contact area between the air and water. In order to reduce a thickness of the liquid on the surface of the walls, the walls 214 may be coated with a hydrophilic surface.

[0035] FIG. 3 shows a second embodiment of the air conditioning system 300, wherein the heat exchanger 302 comprises a second dry working channel 318 for additional pre-cooling of the exhaust air 120. As will be clear to one of skill in the art, any number of wet and/or dry channels may be used based on the desired capacity of the system.

[0036] In the embodiment of FIG. 3, the exhaust air 120 is delivered to the additional dry working channel 318 before moving on to the wet working channel 210. In this embodiment, the heat exchanger 302 comprises an alternating series of thermally coupled wet working and dry working channels 208, 210, 318. Similar to the embodiment of FIG. 2, the walls 314 between the channels 208, 210, 318 are thermally coupled, such that a change in temperature on one surface of a wall 314 results in a corresponding change of temperature on an opposing surface of the same wall 314.

[0037] In an embodiment of FIG. 3, the air conditioning system 300 comprises the same elements and steps as the described embodiment of FIG. 2.

[0038] FIG. 4 shows a system 400 generally equivalent to the embodiment of FIG. 1 discussed above except as otherwise noted. In system 400, an exhaust fan 440 is placed along the path of movement of the exhaust air 120. The exhaust fan 440 functions to expel the exhaust 120 from

CLAIMS

1. An air conditioning system for conditioning air in a space, comprising:

a conditioned space;

a dehumidifier; and

a heat exchanger comprising:

a first channel having a first inlet configured to intake exhaust air from the conditioned space and a first outlet configured to expel the exhaust air from the first channel to an outdoor environment;

a second channel having a second inlet configured to intake outdoor ambient air from the outdoor environment and a second outlet configured to deliver the outdoor ambient air to the dehumidifier;

wherein a wall of the first channel and an adjacent wall of the second channel form a shared, thermally coupled wall comprised of a single impenetrable plate;

wherein a first surface of the thermally coupled wall in the first channel is coated in a liquid such that the passage of the exhaust air through the first channel evaporates at a least a portion of the liquid coated on the first surface of the thermally coupled wall thereby reducing the temperature of the first surface of the thermally coupled wall;

wherein the evaporation of the liquid transfers heat between the first surface of the thermally coupled wall and a second surface of the thermally coupled wall disposed within the second channel such that reducing the temperature of the first surface of the thermally coupled wall reduces the temperature of the second surface of the thermally coupled wall and cools the outdoor ambient air traversing the second channel to create pre-cooled air;

wherein the dehumidifier dehumidifies the pre-cooled air received from the second channel to a desired condition and delivers conditioned air to the conditioned space; and

wherein the conditioned air circulates within the conditioned space and exits the conditioned space as the exhaust air.

2. The air conditioning system of claim 1, wherein:

the first inlet is proximate a first end of the heat exchanger;

the first outlet is proximate a second end of the heat exchanger;

a second inlet is proximate the second end of the heat exchanger;

a second outlet is proximate the first end of the heat exchanger; and

the outdoor ambient air drawn through the second inlet of the second channel comprises a mixture of outdoor air and the exhaust air expelled from the first outlet of the first channel.

3. The air conditioning system of claim 1, wherein the dehumidifier is selected from a group consisting of a membrane dehumidifier, desiccant dehumidifier, or mechanical compression dehumidifier.

4. The air conditioning system of claim 1, wherein the heat exchanger includes a third channel, wherein the third channel pre-cools the exhaust air before the exhaust air enters through the first channel.

5. The air conditioning system of claim 1, wherein the liquid is comprised of water.

6. The air conditioning system of claim 5, wherein the system further comprises a connection to an external water supply to replenish the water coated on the first surface of the thermally coupled wall.

7. The air conditioning system of claim 1, wherein the walls of the first channel and second channel are comprised of a plastic, metal, metal alloy, ceramic material, or combination thereof.

8. The air conditioning system of claim 1, wherein the air conditioning system further comprises:

an exhaust fan drawing the exhaust air from the conditioned room and into the first channel, and

a supply fan drawing the outdoor ambient air into the second channel.

9. A method of conditioning a space by circulating air through a heat exchanger, dehumidifier, and a conditioned space, the method comprising the steps of:

drawing ambient air through a first dry channel of the heat exchanger to precondition the ambient air;

passing the preconditioned ambient air through the dehumidifier to produce conditioned air and delivering the conditioned air to the conditioned space;

passing the conditioned air through the conditioned space and directing the conditioned air out of the conditioned space as exhaust air;

moving the exhaust air from the conditioned space through a wet channel of the heat exchanger, the wet channel and first dry channel having a shared, thermally coupled wall, the exhaust air evaporating a liquid from a surface of the thermally coupled wall within the wet channel and reducing temperature of the first dry channel;

wherein the liquid coats the surface of the thermally coupled wall in the wet channel;

wherein the evaporation of liquid from the thermally coupled wall removes heat from the thermally coupled wall to reduce the temperature of the first dry channel; and

wherein the reduction in temperature of the first dry channel pre-cools and partially dehumidifies the ambient air as it passes through the first dry channel prior to delivering the preconditioned ambient air to the dehumidifier.

10. The method of conditioning a space in claim 9, wherein the ambient air drawn through the first dry channel comprises a mixture of outdoor air from an outdoor environment and the exhaust air expelled from the wet channel.

11. The method of conditioning a space in claim 10, wherein the dehumidifier is selected from a group consisting of a membrane dehumidifier, desiccant dehumidifier, or mechanical compression dehumidifier.

12. The method of conditioning a space in claim 10, wherein the thermally coupled wall is comprised of a single impenetrable plate.

13. The method of conditioning a space in claim 12, further comprising a pre-cooling step wherein a second dry channel pre-cools the exhaust air before the exhaust air enters the wet channel.

14. The method of conditioning a space in claim 13, further comprising the step of replenishing supply of the liquid to the wet channel, wherein the wet channel includes a connection to an external supply of the liquid to replenish supply of the liquid in the wet channel.

15. A heat exchanger as a system for conditioning air, the heat exchanger comprising:

a wet channel to draw exhaust air from a conditioned room through an inlet and discharge the exhaust air through an outlet located on an opposite end of the wet channel;

a first dry channel sharing a thermally coupled wall with the wet channel, the first dry channel disposed to draw ambient air through an inlet and discharge the ambient air through an outlet located on an opposite end of the first dry channel and toward a dehumidifier; and

wherein a surface of the thermally coupled wall within the wet channel is coated in a liquid; and

wherein when the temperature of the exhaust air is less than the ambient air, passage of the exhaust air through the wet channel evaporates liquid from the thermally coupled wall to cool the wet channel, and the first dry channel transfers heat to the wet channel to modulate the ambient air to a desired condition as the ambient air passes through the first dry channel; and

an operative connection between the dehumidifier and the conditioned room directing the ambient air through the dehumidifier to create dehumidified air which is delivered to the conditioned room and exits the conditioned room as the exhaust air.

16. The heat exchanger system of claim 15, the heat exchanger further comprising a second dry channel to pre cool the exhaust air before the exhaust air enters through the wet channel.

17. An air conditioning system for conditioning air in a space, comprising:

a heat exchanger comprising:

a first channel;

a second channel;

wherein a wall of the first channel and an adjacent wall of the second channel form a shared, thermally coupled wall;

a dehumidifier operatively connected to the second channel;

a conditioned space operatively connected to the first channel;

a first inlet proximate a first end of the first channel, the first inlet configured to draw conditioned air from the conditioned space;

a first outlet proximate a second end of the first channel, the first outlet configured to expel the conditioned air to an environment;

a second inlet proximate a first end of the second channel, the second inlet configured to intake ambient air from the environment;

a second outlet proximate a second end of the second channel, the second outlet configured to deliver the ambient air to the dehumidifier, wherein the dehumidifier dehumidifiers the ambient air into conditioned air prior to delivering the conditioned air to the conditioned space; and

a coat of liquid is disposed along walls within the first channel such that the conditioned air evaporates the liquid as the conditioned air passes through the first channel and reduces the temperature of the shared thermally coupled wall and wherein the second channel transfers heat through the thermally coupled wall to the first channel, reducing temperature of the second channel and pre-cooling the ambient air as it passes through the second channel.

18. The air conditioning system of claim 17, wherein the air conditioning system further comprises:

an exhaust fan to draw the conditioned air from the conditioned room and into the first channel, and

a supply fan to draw the ambient air into the second channel.

19. The air conditioning system of claim 18, wherein the heat exchanger includes a third channel, wherein the third channel pre-cools the conditioned air after it exits the conditioned room and before the conditioned air enters the first channel.