SYSTEMS AND METHODS FOR MANAGING CONDITIONS IN ENCLOSED SPACE

SUMMARY

[0001] An aspect of the disclosure provides a system for controlling conditions in an enclosed space, the system comprising:

a first plenum configured to direct a first air stream from a first inlet to a first outlet;

a second plenum configured to direct a second air stream from a second inlet to a second outlet, the second inlet receiving heated air from the space and the second outlet supplying cooled air to the space;

a first liquid-to-air membrane energy exchanger (LAMEE1) arranged inside the first plenum, LAMEE1 configured to use a liquid desiccant to lower an enthalpy of the first air stream;

a second LAMEE (LAMEE2) arranged inside the first plenum downstream of LAMEE1, LAMEE2 configured to use the first air stream to evaporatively cool water flowing through LAMEE2;

a first liquid-to-air heat exchanger (LAHX1) arranged inside the second plenum, LAHX1 configured to directly and sensibly cool the second air stream using a first cooling fluid; and

a second LAHX (LAHX2) in fluid communication with LAMEE1, LAHX2 being configured to receive the liquid desiccant from LAMEE1 and cool the liquid desiccant using outdoor air, independently of LAMEE2 and the water flowing through LAMEE2.

[0001a] Another aspect of the disclosure provides a system for controlling conditions in an enclosed space, the system comprising:

a scavenger plenum configured to direct scavenger air from a scavenger inlet to a scavenger outlet;

a process plenum configured to direct process air from a process inlet to a process outlet, the process inlet receiving heated air from the space and the process outlet supplying cooled air to the space;

a first liquid-to-air membrane energy exchanger (LAMEE1) arranged inside the scavenger plenum, LAMEE1 configured to use a first fluid flowing through LAMEE1 to reduce a humidity of the scavenger air, a first concentration of water in the scavenger air at an air inlet of LAMEE1 being higher than a

second concentration of water in the scavenger air at an air outlet of LAMEE1;

an evaporative cooler arranged inside the scavenger plenum downstream of LAMEE1, the evaporative cooler configured to use the scavenger air to evaporatively cool a second fluid flowing there through, a temperature of the second fluid at a fluid outlet of the evaporative cooler being lower than a temperature of the second fluid at a fluid inlet of the evaporative cooler;

a first liquid-to-air heat exchanger (LAHX1) arranged inside the process plenum, LAHX1 configured to directly and sensibly cool the process air being directed through the process plenum using a third fluid flowing through LAHX1; and

a second LAHX (LAHX2), LAHX2 in fluid communication with LAMEE1 and configured to receive and cool the first fluid using outdoor air, independently of the evaporative cooler and the second fluid flowing through the evaporative cooler.

[0001b] Another aspect of the disclosure provides a method for controlling conditions in an enclosed space, the method comprising:

directing a first air stream through a first liquid-to-air membrane energy exchanger (LAMEE1) arranged inside a first plenum, LAMEE1 configured to use a liquid desiccant to lower an enthalpy of the first air stream;

directing the first air stream through a second LAMEE (LAMEE2) arranged inside the first plenum downstream of LAMEE1, LAMEE2 configured to use the first air stream to evaporatively cool water flowing through LAMEE2;

directing a first cooling fluid through a first liquid-to-air heat exchanger (LAHX1) arranged inside a second plenum, the second plenum configured to direct a second air stream from a second inlet to a second outlet, the second inlet receiving heated air from the space and the second outlet supplying cooled air to the space, LAHX1 configured to directly and sensibly cool the second air stream using the first cooling fluid; and

directing the liquid desiccant through a second LAHX (LAHX2) in fluid communication with LAMEE1, LAHX2 being configured to cool the liquid desiccant using outdoor air, independently of LAMEE2 and the water flowing through LAMEE2.

[0001c] Another aspect of the disclosure provides a system for controlling conditions in an enclosed space, the system comprising:

a first plenum configured to direct a first air stream from a first inlet to a first outlet;

a second plenum configured to direct a second air stream from a second inlet to a second outlet, the second inlet receiving heated air from the space and the second outlet supplying cooled air to the space;

a first liquid-to-air membrane energy exchanger (LAMEE1) arranged inside the first plenum, LAMEE1 configured to use a liquid desiccant to lower an enthalpy of the first air stream;

an evaporative cooler arranged inside the first plenum downstream of LAMEE1, the evaporative cooler configured to use the first air stream to evaporatively cool water flowing therethrough;

a first liquid-to-air heat exchanger (LAHX1) arranged inside the second plenum, LAHX1 configured to directly and sensibly cool the second air stream using a first cooling fluid; and

a second LAHX (LAHX2) in fluid communication with LAMEE1, LAHX2 being configured to receive the liquid desiccant from LAMEE1 and cool the liquid desiccant using outdoor air, independently of the evaporative cooler and the water flowing through the evaporative cooler.

DESCRIPTION OF DRAWINGS

[0001d] In the drawings, which are not necessarily drawn to scale, like numerals may describe similar components in different views. Like numerals having different letter suffixes may represent different instances of similar components, sub-components of a larger logical or physical system, or the like. The drawings illustrate generally, by way of example, but not by way of limitation, various examples described in the present disclosure.

[0002] FIG. 1 schematically depicts an example conditioning system in accordance with this disclosure.

[0003] FIG. 2 depicts another example conditioning system in accordance with this disclosure.

[0004] FIG. 3 is a psychometric process diagram for a theoretical system substantially similar to example system of FIG. 2.

[0005] FIG. 4 depicts another example conditioning system.

[0006] FIG. 5 is a psychometric process diagram for a theoretical system substantially similar to example system of FIG. 4.

[0007] FIG. 6 is a psychometric process diagram for a theoretical system with the same components and arrangements thereof as the system modeled to produce the process diagram of FIG. 5, except the pre-cooler and the recovery coil have lower capacities/conditioning effectiveness, and a different outdoor air condition is evaluated.

[0008] FIG. 7 depicts an example liquid desiccant regeneration system connected to a conditioning system in accordance with this disclosure.

[0009] FIG. 8 depicts an example liquid-to-air heat exchanger configured to cool a liquid desiccant employed in a desiccant dryer liquid-to-air membrane energy exchanger.

[0010] FIGS. 9 and 10 depict two other example conditioning systems.

[0011] FIG. 11 depicts another example conditioning system.

[0012] FIG. 12 depicts another example conditioning system.

[0013] FIG. 13 depicts another example conditioning system.

[0014] FIG. 14 is a flowchart depicting a method of operating a conditioning system in accordance with this disclosure.

[0015] FIG. 15 depicts another example conditioning system.

CLAIMS

What is claimed is:

1. A system for controlling conditions in an enclosed space, the system comprising:

a first plenum configured to direct a first air stream from a first inlet to a first outlet;

a second plenum configured to direct a second air stream from a second inlet to a second outlet, the second inlet receiving heated air from the space and the second outlet supplying cooled air to the space;

a first liquid-to-air membrane energy exchanger (LAMEE1) arranged inside the first plenum, LAMEE1 configured to use a liquid desiccant to lower an enthalpy of the first air stream;

a second LAMEE (LAMEE2) arranged inside the first plenum downstream of LAMEE1, LAMEE2 configured to use the first air stream to evaporatively cool water flowing through LAMEE2;

a first liquid-to-air heat exchanger (LAHX1) arranged inside the second plenum, LAHX1 configured to directly and sensibly cool the second air stream using a first cooling fluid; and

a second LAHX (LAHX2) in fluid communication with LAMEE1, LAHX2 being configured to receive the liquid desiccant from LAMEE1 and cool the liquid desiccant using outdoor air, <u>independently of LAMEE2 and the water flowing through LAMEE2</u>.

2. The system of claim 1, wherein LAMEE1 is configured to lower the enthalpy of the first air stream by removing water therefrom.

3. The system of claim 1, wherein LAMEE1 is configured to lower the enthalpy of the first air stream by removing water therefrom and wherein at least a portion of the water flowing through LAMEE2 comprises the water removed from the first air stream by LAMEE1.

4. The system of claim 1, further comprising a pre-cooler coil arranged inside the scavenger plenum upstream of LAMEE2, the pre-cooler coil configured to condition the scavenger air prior to the scavenger air entering LAMEE2.

5. The system of claim 4, wherein the pre-cooler coil is configured to receive at least a portion of the water cooled by LAMEE2 to condition the scavenger air.

6. The system of claim 4, further comprising a fluid storage tank to store the water received from a fluid outlet of LAMEE2.

7. The system of claim 6, further comprising a mechanical cooling system configured to cool the water in the storage tank using a first cooling fluid.

8. The system of claim 6, further comprising a liquid-to-liquid heat exchanger (LLHX) configured to cool the water in the storage tank using a first cooling fluid.

9. The system of claim 8, further comprising a third LAHX (LAHX3), LAHX3 arranged inside of the first plenum downstream of LAMEE2 and configured to cool at least one of the water and the first cooling fluid using the scavenger air.

10. The system of claim 9, further comprising:

a first fluid circuit configured to transport the water from a fluid outlet of LAMEE2, through the LLHX and return the water to a fluid inlet of LAMEE2; and

a second fluid circuit fluidically isolated from the first fluid circuit, the second fluid circuit configured to transport the first cooling fluid from an outlet of LAHX3 through the LLHX to an inlet of LAHX1, and return the first cooling fluid from the fluid outlet of LAHX1 to a fluid inlet of LAHX3.

11. The system of claim 1, further comprising a direct exchange (DX) coil arranged inside the process plenum downstream of LAHX1, the DX coil being configured to cool the process air using a second cooling fluid flowing there through.

12. The system of claim 1, wherein LAMEE1 is configured to lower the enthalpy of the first air stream by removing water and heat therefrom, a temperature of the liquid desiccant at a fluid inlet of LAMEE1 being lower than a temperature of the liquid desiccant at a fluid outlet of LAMEE1.

13. A system for controlling conditions in an enclosed space, the system comprising:

a scavenger plenum configured to direct scavenger air from a scavenger inlet to a scavenger outlet;

a process plenum configured to direct process air from a process inlet to a process outlet, the process inlet receiving heated air from the space and the process outlet supplying cooled air to the space;

a first liquid-to-air membrane energy exchanger (LAMEE1) arranged inside the scavenger plenum, LAMEE1 configured to use a first fluid flowing through LAMEE1 to reduce a humidity of the scavenger air, a first concentration of water in the scavenger air at an air inlet of LAMEE1 being higher than a second concentration of water in the scavenger air at an air outlet of LAMEE1;

an evaporative cooler arranged inside the scavenger plenum downstream of LAMEE1, the evaporative cooler configured to use the scavenger air to evaporatively cool a second fluid flowing there through, a temperature of the second fluid at a fluid outlet of the evaporative cooler being lower than a temperature of the second fluid at a fluid inlet of the evaporative cooler;

a first liquid-to-air heat exchanger (LAHX1) arranged inside the process plenum, LAHX1 configured to directly and sensibly cool the process air being directed through the process plenum using a third fluid flowing through LAHX1; and

a second LAHX (LAHX2), LAHX2 in fluid communication with LAMEE1 and configured to receive and cool the first fluid using outdoor air, independently of the evaporative cooler and the second fluid flowing through the evaporative cooler.

14. The system of claim 13, wherein LAMEE1 is configured to lower the enthalpy of the first air stream by removing water therefrom.

15. The system of claim 13, wherein the second fluid comprises water, and wherein LAMEE1 is configured to lower the enthalpy of the first air stream by removing water therefrom, and wherein at least a portion of the water flowing through the evaporative cooler comprises the water removed from the first air stream by LAMEE1.

16. The system of claim 13, further comprising a pre-cooler coil arranged inside the scavenger plenum upstream of LAMEE2, the pre-cooler coil configured to condition the scavenger air prior to the scavenger air entering LAMEE2.

17. The system of claim 16, wherein the pre-cooler coil is configured to receive at least a portion of the second fluid cooled by the evaporative cooler to condition the scavenger air.

18. The system of claim 16, further comprising a fluid storage tank to store the second fluid received from a fluid outlet of the evaporative cooler.

19. The system of claim 18, further comprising a mechanical cooling system configured to cool the second fluid in the storage tank using a first cooling fluid.

20. The system of claim 18, further comprising a liquid-to-liquid heat exchanger (LLHX) configured to cool the second fluid in the storage tank using a first cooling fluid.

21. The system of claim 20, further comprising a third LAHX (LAHX3), LAHX3 arranged inside of the first plenum downstream of the evaporative cooler and configured to cool at least one of the second fluid and the first cooling fluid using the scavenger air.

22. The system of claim 21, further comprising:

a first fluid circuit configured to transport the water from a fluid outlet of the evaporative cooler, through the LLHX and return the water to a fluid inlet of the evaporative cooler; and

a second fluid circuit fluidically isolated from the first fluid circuit, the second fluid circuit configured to transport the first cooling fluid from an outlet of LAHX3 through the LLHX to an inlet of LAHX1, and return the first cooling fluid from the fluid outlet of LAHX1 to a fluid inlet of LAHX3.

23. The system of claim 13, further comprising a direct exchange (DX) coil arranged inside the process plenum downstream of LAHX1, the DX coil being configured to cool the process air using a second cooling fluid flowing there through.

24. The system of claim 13, wherein LAMEE1 is configured to lower the enthalpy of the first air stream by removing water and heat therefrom, a temperature of the liquid desiccant at a fluid inlet of LAMEE1 being lower than a temperature of the liquid desiccant at a fluid outlet of LAMEE1.

25. A method for controlling conditions in an enclosed space, the method comprising:

directing a first air stream through a first liquid-to-air membrane energy exchanger (LAMEE1) arranged inside a first plenum, LAMEE1 configured to use a liquid desiccant to lower an enthalpy of the first air stream;

directing the first air stream through a second LAMEE (LAMEE2) arranged inside the first plenum downstream of LAMEE1, LAMEE2 configured to use the first air stream to evaporatively cool water flowing through LAMEE2;

directing a first cooling fluid through a first liquid-to-air heat exchanger (LAHX1) arranged inside a second plenum, the second plenum configured to direct a second air stream from a second inlet to a second outlet, the second inlet receiving heated air from the space and the second outlet supplying cooled air to the space, LAHX1 configured to directly and sensibly cool the second air stream using the first cooling fluid; and

directing the liquid desiccant through a second LAHX (LAHX2) in fluid communication with LAMEE1, LAHX2 being configured to cool the liquid desiccant using outdoor air, independently of LAMEE2 and the water flowing through LAMEE2.

26. A system for controlling conditions in an enclosed space, the system comprising:

a first plenum configured to direct a first air stream from a first inlet to a first outlet;

a second plenum configured to direct a second air stream from a second inlet to a second outlet, the second inlet receiving heated air from the space and the second outlet supplying cooled air to the space;

a first liquid-to-air membrane energy exchanger (LAMEE1) arranged inside the first plenum, LAMEE1 configured to use a liquid desiccant to lower an enthalpy of the first air stream;

an evaporative cooler arranged inside the first plenum downstream of LAMEE1, the evaporative cooler configured to use the first air stream to evaporatively cool water flowing therethrough;

a first liquid-to-air heat exchanger (LAHX1) arranged inside the second plenum, LAHX1 configured to directly and sensibly cool the second air stream using a first cooling fluid; and

a second LAHX (LAHX2) in fluid communication with LAMEE1, LAHX2 being configured to receive the liquid desiccant from LAMEE1 and cool the liquid desiccant using outdoor air, independently of the evaporative cooler and the water flowing through the evaporative cooler.

27. The system of claim 26, wherein the evaporative cooler comprises a second LAMEE.

28. The system of claim 26, wherein LAMEE1 is configured to lower the enthalpy of the first air stream by removing water therefrom.

29. The system of claim 26, wherein LAMEE1 is configured to lower the enthalpy of the first air stream by removing water therefrom and wherein at least a portion of the water flowing through LAMEE2 comprises the water removed from the first air stream by LAMEE1.

30. The system of claim 26, wherein LAMEE1 is configured to lower the enthalpy of the first air stream by removing water and heat therefrom, a temperature of the liquid desiccant at a fluid inlet of LAMEE1 being lower than a temperature of the liquid desiccant at a fluid outlet of LAMEE1.