various design and operational constraints, such as best practices for refrigerant velocity, (so called “oil management”) for the pumped refrigerant systems that ensure oil does not get trapped in the various piping lengths of the system and returns reliably to the compressor where it is needed. These oil management constraints become problematic when operating in the pumped (near passive mode) because the flow paths and flow rates for the pumped mode may not coincide with the rules required for the DX mode. Refrigerant volume for proper operation within the system may also be quite different during the pumped mode and the DX mode due to differing available superheat and sub-cool levels, and coil flooding levels, for example.

[0007] Cooling systems with further reductions in energy use are thus desired, as are cooling systems that do not require oil management in a passive or near passive mode.

Summary

[0008] In one aspect, the present disclosure relates to an airstream cooling assembly that is operable in passive and active modes. The airstream cooling assembly includes an evaporator, a passive condenser, and a heat exchanger. The evaporator has an outer surface and contains a primary cooling medium. The evaporator is configured to have a first airstream directed over the outer surface thereof and, when the first airstream is directed over the outer surface, to change the phase of the primary cooling medium from liquid to gas. The passive condenser has an outer surface and is fluidly coupled to the evaporator. The heat exchanger is also fluidly coupled to the evaporator. In the passive mode, the passive condenser is configured to receive the primary cooling medium in the gas phase from the evaporator, receive a second airstream directed over its outer surface to change the phase of the primary cooling medium from gas to liquid, and supply the primary cooling medium in

the liquid phase to the evaporator without a pump configured to circulate the primary cooling medium in the flow path of the primary cooling medium between the passive condenser and the evaporator. In the active mode, the heat exchanger is configured to

receive the primary cooling medium in the gas phase from the evaporator, transfer heat from the primary cooling medium unit to change the primary cooling medium from a gas to a liquid, and supply the primary cooling medium in the liquid phase to the evaporator without a pump configured to circulate the primary cooling medium in the flow path of the primary cooling medium between the heat exchanger and the evaporator.

[0008a] In another aspect, the present disclosure relates to a cooling system comprising a plurality of airstream cooling assemblies of the above aspect.

[0009] In another aspect, the present disclosure relates to an airstream cooling assembly that includes an evaporator, a heat exchanger, and a passive condenser. The evaporator has an outer surface and contains a primary cooling medium. The evaporator is configured to have a first airstream directed over the outer surface thereof and, when the first airstream is directed over the outer surface, to change the phase of the primary cooling medium from liquid to gas. The heat exchanger is fluidly coupled to the evaporator and configured to accept a secondary cooling medium. When the heat exchanger is accepting the secondary cooling medium, the heat exchanger is configured to receive the primary cooling medium in the gas phase from the evaporator, transfer heat from the primary cooling medium, and change the phase of the primary cooling medium from gas to liquid. The passive condenser has an outer surface and is fluidly coupled to the evaporator. The passive condenser is configured to have a second airstream directed over the outer surface thereof. When the heat exchanger is not accepting the secondary cooling medium, the passive condenser is configured to receive the primary cooling medium in the gas phase from the evaporator, transfer heat from the primary cooling medium, and change the phase of the primary cooling medium from gas to liquid. The evaporator is configured to receive the

primary cooling medium in the liquid phase from either the heat exchanger or the passive condenser without a pump configured to circulate the primary cooling medium in the flow path of the primary cooling medium between the heat exchanger and the evaporator and between the passive condenser and the evaporator.

[0010] In a further aspect, the present disclosure relates to an airstream cooling assembly includes an evaporator, a passive condenser, and a heat exchanger. The evaporator has an In a further aspect, the present disclosure relates to an airstream cooling assembly includes an evaporator, a passive condenser, and a heat exchanger. The evaporator has an outer surface and contains a primary cooling medium. The evaporator is configured to have an airstream directed over the outer surface thereof and, when the airstream is directed over the

outer surface, to change the phase of the primary cooling medium from liquid to gas. The passive condenser has an outer surface and is coupled to the evaporator. The passive condenser is configured to have ambient air directed over the outer surface thereof, transfer heat from the primary cooling medium, and change the phase of the primary cooling medium from gas to liquid. The heat exchanger is coupled to the evaporator and configured to selectively accept heat by mechanical cooling, transfer heat from the primary cooling medium, and change the phase of the primary cooling medium from gas to liquid. The evaporator is configured to receive the primary cooling medium in the liquid phase from either the passive condenser or the heat exchanger without a pump configured to circulate the primary cooling medium in the flow path of the primary cooling medium between the heat exchanger and the evaporator and between the passive condenser and the evaporator. The evaporator is configured to receive the primary cooling medium in the liquid phase from the heat exchanger when the heat exchanger is accepting heat by mechanical cooling.

[0011] In still another aspect, the present disclosure relates to method of cooling an airstream. The method includes directing an airstream over an outer surface of an evaporator to change a primary cooling medium contained therein from a liquid phase to a gas phase, and selectively utilizing one of a heat exchanger and a passive condenser to change the primary cooling medium from the gas phase to the liquid phase. Each of the heat exchanger and the passive condenser is coupled to the evaporator to receive the primary coolant in the gas phase from the evaporator and supply the primary cooling medium in the

liquid phase to the evaporator. The method further comprises circulating the primary cooling medium between the evaporator and at least one of the heat exchanger and the passive condenser by natural circulation.

[0012] In an example, the present disclosure relates to an airstream cooling assembly including an evaporator, a first condenser, and a second condenser. The evaporator has an outer surface and contains a primary cooling medium. The evaporator is configured to have a first airstream directed over the outer surface thereof and, when the first airstream is directed over the outer surface, to change the phase of the primary cooling medium from liquid to gas. The first condenser has an outer surface and is coupled to the evaporator. The first condenser

is configured to have a second airstream directed over the outer surface thereof, and when the second airstream is directed over the outer surface of the first condenser, to receive the primary cooling medium from the evaporator, transfer heat from the primary cooling medium, and change the phase of the primary cooling medium from gas to liquid. The second condenser is coupled to the evaporator and configured to accept a secondary cooling medium. When accepting the secondary cooling medium, the second condenser is configured to receive the primary cooling medium from the evaporator, transfer heat from the primary cooling medium, and change the phase of the primary cooling medium from gas to liquid. The evaporator is configured to receive the primary cooling medium in the liquid phase from at least one of the first condenser and the second condenser.

[0013] In a further example, the present disclosure relates to a modified heat pipe including a heat pipe and a second microchannel coil. The heat pipe contains a refrigerant therein and has an evaporator section and a condensing section. The condensing section is located in a condensing airstream. The heat pipe is a first microchannel coil. The second microchannel coil is fluidly coupled to the heat pipe to receive the cooling medium in the vapor phase from a vapor end of the heat pipe. The second microchannel coil is positioned in the condensing airstream prior to the condensing section of the heat pipe. The second microchannel coil is configured to facilitate condensation of the refrigerant and create a modified thermosiphon by allowing gravity return and recirculate the condensed refrigerant to the evaporator section of the heat pipe.

[0014] These and other aspects, objects, features, and advantages of the invention will become apparent from the following detailed description of illustrative embodiments thereof, which is to be read in connection with the accompanying drawings.

What is claimed is:

1. An airstream cooling assembly operable in passive and active modes, the airstream cooling assembly comprising:

an evaporator having an outer surface and containing a primary cooling medium, the evaporator being configured to have a first airstream directed over the outer surface thereof and, when the first airstream is directed over the outer surface, to change the phase of the primary cooling medium from liquid to gas;

a passive condenser having an outer surface and being fluidly coupled to the evaporator; and

a heat exchanger fluidly coupled to the evaporator,

wherein, in the passive mode, the passive condenser is configured to:

receive the primary cooling medium in the gas phase from the evaporator,

receive a second airstream directed over its outer surface to change the phase of the primary cooling medium from gas to liquid, and

supply the primary cooling medium in the liquid phase to the evaporator without a pump configured to circulate the primary cooling medium in the flow path of the primary cooling medium between the passive condenser and the evaporator, and

wherein, in the active mode, the heat exchanger is configured to:

receive the primary cooling medium in the gas phase from the evaporator,

transfer heat from the primary cooling medium to change the primary cooling medium from a gas to a liquid, and

supply the primary cooling medium in the liquid phase to the evaporator without a pump configured to circulate the primary cooling medium in the flow path of the primary cooling medium between the heat exchanger and the evaporator.

2. The airstream cooling assembly of claim 1, wherein at least one of the evaporator and the passive condenser is a tube coil.

3. The airstream cooling assembly of claim 1, wherein at least one of the evaporator and passive condenser is a microchannel coil.

4. The airstream cooling assembly of claim 1, wherein the evaporator is a microchannel coil having a liquid side and a vapor side and including a header on the vapor side having a plurality of vapor connections.

5. The airstream cooling assembly of claim 1, wherein the passive condenser has a liquid side and a vapor side and the passive condenser is a microchannel coil including a header on the vapor side having a plurality of vapor connections.

6. The airstream cooling assembly of claim 1, wherein the heat exchanger is a plate heat exchanger and utilizes a secondary cooling medium.

7. The airstream cooling assembly of claim 1, wherein the heat exchanger is a coaxial heat exchanger and utilizes a secondary cooling medium.

8. The airstream cooling assembly of claim 1, wherein the heat exchanger is cooled by a direct expansion cooling system.

9. The airstream cooling assembly of claim 1, wherein the heat exchanger is cooled by chilled water.

10. The airstream cooling assembly of claim 1, wherein the passive condenser and the heat exchanger are arranged in parallel relative to the flow of the primary cooling medium.

11. The airstream cooling assembly of claim 1, wherein the passive condenser and the heat exchanger are arranged in series relative to the primary cooling medium.

12. The airstream cooling assembly of claim 1, further comprising a controller configured to selectively control the mode of the airstream cooling assembly.

13. The airstream cooling assembly of claim 12, wherein the controller is configured to switch to the active mode by supplying a secondary cooling medium to cool the heat exchanger, and

wherein the controller is configured to switch to the passive mode by turning off the supply of the secondary cooling medium.

14. The airstream cooling assembly of claim 12, further comprising:

an airstream temperature sensor communicatively coupled to the controller and configured to measure the temperature of the first airstream at a position downstream of the evaporator,

wherein the controller is further configured to:

receive a signal representative of the temperature of the first airstream from the airstream temperature sensor; and

switch to the active mode when the temperature of the first airstream is above a set point.

15. The airstream cooling assembly of claim 12, further comprising:

an airstream temperature sensor communicatively coupled to the controller and configured to measure the temperature of the first airstream at a position downstream of the evaporator,

wherein the controller is further configured to:

receive a signal representative of the temperature of the first airstream from the airstream temperature sensor; and

switch to the passive mode when the temperature of the first airstream is below a set point.

16. A cooling system comprising a plurality of airstream cooling assemblies of claim 1.

17. The cooling system of claim 16, wherein the evaporator of a first one and a second one of the plurality of cooling assemblies are arranged in series relative to the first airstream.

18. The cooling system of claim 16, wherein the evaporator of a first one and a second one of the plurality of cooling assemblies are arranged in parallel relative to the first airstream.

19. The cooling system of claim 16, wherein the passive condensers of a first one and a second one of the plurality of cooling assemblies are arranged in series relative to the second airstream.

20. The cooling system of claim 16, wherein the passive condensers of a first one and a second one of the plurality of cooling assemblies are arranged in parallel relative to the second airstream.

21. An airstream cooling assembly comprising:

an evaporator having an outer surface and containing a primary cooling medium, the evaporator being configured to have a first airstream directed over the outer surface thereof and, when the first airstream is directed over the outer surface, to change the phase of the primary cooling medium from liquid to gas;

a heat exchanger fluidly coupled to the evaporator and configured to accept a secondary cooling medium, wherein, when accepting the secondary cooling medium, the heat exchanger is configured to receive the primary cooling medium in the gas phase from the evaporator, transfer heat from the primary cooling medium, and change the phase of the primary cooling medium from gas to liquid; and

a passive condenser having an outer surface and being fluidly coupled to the evaporator, the passive condenser being configured to have a second airstream directed over the outer surface thereof, wherein, when the heat exchanger is not accepting the secondary cooling medium, the passive condenser is configured to receive the primary cooling medium in the gas phase from the evaporator, transfer heat from the primary cooling medium, and change the phase of the primary cooling medium from gas to liquid,

wherein the evaporator is configured to receive the primary cooling medium in the liquid phase from either the heat exchanger or the passive condenser without a pump configured to circulate the primary cooling medium in the flow path of the primary cooling

medium between the heat exchanger and the evaporator and between the passive condenser and the evaporator.

22. An airstream cooling assembly comprising:

an evaporator having an outer surface and containing a primary cooling medium, the evaporator being configured to have an airstream directed over the outer surface thereof and, when the airstream is directed over the outer surface, to change the phase of the primary cooling medium from liquid to gas;

a passive condenser having an outer surface and being coupled to the evaporator, the passive condenser being configured to have ambient air directed over the outer surface thereof, transfer heat from the primary cooling medium, and change the phase of the primary cooling medium from gas to liquid; and

a heat exchanger coupled to the evaporator and configured to selectively accept heat by mechanical cooling, transfer heat from the primary cooling medium, and change the phase of the primary cooling medium from gas to liquid,

wherein the evaporator is configured to receive the primary cooling medium in the liquid phase from either the passive condenser or the heat exchanger without a pump configured to circulate the primary cooling medium in the flow path of the primary cooling medium between the heat exchanger and the evaporator and between the passive condenser and the evaporator, the evaporator being configured to receive the primary cooling medium in the liquid phase from the heat exchanger when the heat exchanger is accepting heat by mechanical cooling.

23. A method of cooling an airstream, the method comprising:

directing an airstream over an outer surface of an evaporator to change a primary cooling medium contained therein from a liquid phase to a gas phase;

selectively utilizing one of a heat exchanger and a passive condenser to change the primary cooling medium from the gas phase to the liquid phase, each of the heat exchanger and the passive condenser being coupled to the evaporator to receive the primary coolant in the gas phase from the evaporator and supply the primary cooling medium in the liquid phase to the evaporator; and

circulating the primary cooling medium between the evaporator and at least one of the heat exchanger and the passive condenser by natural circulation.

24. The method of claim 23, wherein cooling the heat exchanger comprises using a secondary cooling medium to change the phase of the primary cooling medium from gas to liquid.

25. The method of claim 23, wherein cooling the passive condenser comprises directing an airstream over the passive condenser, the airstream directed over the passive condenser being from a different source than the airstream directed over the evaporator.