

CLAIMS

1. An air module comprising:
 - a controller;
 - an air intake module configured to receive first air from a first air source and to receive second air from a second air source;
 - an evaporative cooling module in fluid communication with the air intake module;
 - a mechanical cooling module in fluid communication with the evaporative cooling module; and
 - wherein the controller is configured to:
 - cause the intake module to mix, based on at least a supply air temperature set point, the first air and the second air to form intake air, and
 - selectively cool the intake air to form supply air by at least one of causing the evaporative cooling module to selectively cool, based on at least the supply air temperature set point, the intake air, and causing the mechanical cooling module to selectively cool the intake air based on at least the supply air temperature set point.
2. The air module of claim 1, wherein the first air source is a source of return air.
3. The air module of claim 1, wherein the second air source is a source of outside air.
4. The air module of claim 1, wherein the controller is further configured to:
 - form the supply air substantially from the first air, if:
 - a temperature of the first air is less than the supply air temperature set point.
5. The air module of claim 1, wherein the controller is further configured to:
 - form the supply air by mixing the first air and the second air, if:
 - a first temperature of the first air is greater than the supply air temperature set point,
 - a second temperature of the second air is less than the supply air temperature set point, and
 - a dew point of the second air is within a dew point range.
6. The air module of claim 1, wherein the controller is further configured to:
 - form mixed air by mixing the first air and the second air, if:
 - a first temperature of the first air is greater than the supply air temperature set point,
 - a second temperature of the second air is less than the first temperature,

a dew point of the second air is less than a lower limit of a dew point range, and

a wet bulb temperature of the second air is less than a wet bulb temperature corresponding to the supply air temperature set point at the lower limit of a dew point range;

form the supply air by evaporatively cooling mixed air with the evaporative cooling module.

7. The air module of claim 1, wherein the controller is further configured to:

form supply air substantially from the second air by evaporatively cooling the second air with the evaporative cooling module, if:

a first temperature of the first air is greater than the supply air temperature set point,

a second temperature of the second air is greater than the supply air temperature set point,

a dew point of the second air is less than an upper limit of a dew point range, and

a wet bulb temperature of the second air is within an evaporative cooling wet bulb temperature range.

8. The air module of claim 1, wherein the controller is further configured to:

form supply air substantially from the first air by mechanically cooling the first air with the mechanical cooling module, if:

a dew point of the second air is greater than an upper limit of a dew point range.

9. The air module of claim 1, wherein the controller is further configured to:

form supply air substantially from the first air by mechanically cooling the first air with the mechanical cooling module, if:

a wet bulb temperature of the second air is greater than an upper limit of an evaporative cooling wet bulb temperature range, and

a dew point of the first air is less than or equal to an upper limit of a dew point range.

10. The air module of claim 1, wherein the controller is further configured to:

form supply air substantially from the first air by mechanically cooling the first air with the mechanical cooling module, if:

a dew point of the first air is greater than an upper limit of a dew point range, and

a dew point of the second air is greater than the upper limit of a dew point range.

11. The air module of claim 1, wherein the controller is further configured to:

form supply air substantially from the second air by mechanically cooling the second air with the mechanical cooling module, if:

a first temperature of the first air is greater than the supply air temperature set point,

a second temperature of the second air is greater than or equal to the supply air temperature set point;

a dew point of the second air is greater than the upper limit of a dew point range,

a wet bulb temperature of the second air is less than an upper limit of an evaporative cooling wet bulb temperature range, and

a humidity ratio of the second air is less than or equal to a threshold humidity ratio.

12. A computer implemented method for controlling an air module comprising:

generating, by a controller, a first instruction to cause an intake module to selectively mix, based upon a supply air temperature set point, first air and second air to form intake air;

generating, by the controller, a second instruction to selectively cool the intake air to form supply air, wherein the second instruction comprises at least one of instructions to cause an evaporative cooling module to selectively cool, based on at least the supply air temperature set point, the intake air, and instructions to cause a mechanical cooling module to selectively cool, based on at least the supply air temperature set point, the intake air.

13. The method of claim 12,

wherein the first instruction comprises instructions to form the intake air substantially from the first air, if:

a temperature of the first air is less than the supply air temperature set point.

14. The method of claim 12,

wherein the first instruction comprises instructions to form the intake air by mixing the first air and the second air, if:

a first temperature of the first air is greater than the supply air temperature set point,

a second temperature of the second air is less than the supply air temperature set point, and

a dew point of the second air is within a dew point range.

15. The method of claim 12,

wherein the first instruction comprises instructions to form intake air by mixing the first air and the second air and the second instruction comprises instructions to cause the evaporative cooling module to selectively cool, based on at least the supply air temperature set point, the intake air, if:

a first temperature of the first air is greater than the supply air temperature set point,

a second temperature of the second air is less than the first temperature,

a dew point of the second air is less than a lower limit of a dew point range, and

a wet bulb temperature of the second air is less than a wet bulb temperature corresponding to the supply air temperature set point at the lower limit of a dew point range.

16. The method of claim 12,

wherein the first instruction comprises instructions to create intake air substantially from second air and the second instruction comprises instructions to cause the evaporative cooling module to selectively cool, based on at least the supply air temperature set point, the intake air, if:

a first temperature of the first air is greater than the supply air temperature set point,

a second temperature of the second air is greater than the supply air temperature set point,

a dew point of the second air is less than an upper limit of a dew point range,

a wet bulb temperature of the second air is within an evaporative cooling wet bulb temperature range.

17. The method of claim 12,

wherein the first instruction comprises instructions to create intake air substantially from first air, wherein the second instruction comprises instructions to cause the mechanical cooling module to selectively cool, based on at least the supply air temperature set point, the intake air, if:

a dew point of the second air is greater than an upper limit of a dew point range.

18. The method of claim 12,

wherein the first instruction comprises instructions to create intake air substantially from first air and the second instruction comprises instructions to cause the mechanical cooling module to selectively cool, based on at least the supply air temperature set point, the intake air, if:

a wet bulb temperature of the second air is greater than an upper limit of an evaporative cooling wet bulb temperature range, and

a dew point of the first air is less than or equal to an upper limit of a dew point range.

19. The method of claim 12,

wherein the first instruction comprises instructions to create intake air substantially from first air and the second instruction comprises instructions to cause the mechanical cooling module to selectively cool, based on at least the supply air temperature set point, the intake air, if:

a dew point of the first air is greater than an upper limit of a dew point range, and

a dew point of the second air is greater than the upper limit of a dew point range.

20. The method of claim 12, further comprising::

wherein the first instruction comprises instructions to create intake air substantially from second air and the second instruction comprises instructions to cause the mechanical cooling module to selectively cool, based on at least the supply air temperature set point, the intake air, if:

a first temperature of the first air is greater than the supply air temperature set point,

a second temperature of the second air is greater than or equal to the supply air temperature set point;

a dew point of the second air is greater than the upper limit of a dew point range,

a wet bulb temperature of the second air is less than an upper limit of an evaporative cooling wet bulb temperature range, and

a humidity ratio of the second air is less than or equal to a threshold humidity ratio.

21. The method of claim 12, further comprising sending the first instruction to the intake module and sending the second instruction to at least one of the evaporative cooling module and the mechanical cooling module.
22. A modular data center comprising:
- an air module comprising:
 - an air module controller;
 - an air intake module configured to receive first air from a first air source and to receive second air from a second air source;
 - an evaporative cooling module in fluid communication with the air intake module;
 - a mechanical cooling module in fluid communication with the evaporative cooling module;
 - wherein the air module controller is configured to cause the intake module to mix the first air and the second air based on at least a supply air temperature set point to form intake air, and wherein the controller is configured to form supply air by at least one of causing the evaporative cooling module to cool the intake air selectively based on at least the supply air temperature set point, and causing the mechanical cooling module to cool the intake air selectively based on at least the supply air temperature set point;
 - one or more data center modules; and
 - a supply air conduit in fluid communication with the air module and a data center module of the one or more data center modules to carry supply air from the air module to the one or more data center modules.
23. The modular data center of claim 22, wherein the data center module further comprises:
- a data center module controller;
 - a data center module intake damper configured to control supply air entering the data center module from the supply air conduit;
 - wherein the data center module controller is configured to actuate the data center module intake damper based on at least one of a temperature and humidity of air in the data center module.
24. The modular data center of claim 22, wherein the air module further comprises a fan array.
25. The modular data center of claim 24, wherein the air module controller is further configured to adjust an air flow of the fan array to maintain a substantially constant air pressure in the supply air conduit.

CLAIMS

1. An air module comprising:
 - a controller;
 - an air intake module configured to receive first air from a first air source and to receive second air from a second air source;
 - an evaporative cooling module in fluid communication with the air intake module;
 - a mechanical cooling module in fluid communication with the evaporative cooling module; and
 - wherein the controller is configured to:
 - based on a first temperature of the first air, a second temperature of the second air, and a dew point of the second air, mix the first air and the second air to form intake air, and
 - selectively cool the intake air to form supply air by at least one of causing the evaporative cooling module to selectively cool, based on at least a supply air temperature set point, the intake air, and causing the mechanical cooling module to selectively cool the intake air based on at least the supply air temperature set point.
2. The air module of claim 1, wherein the first air source is a source of return air.
3. The air module of claim 1, wherein the second air source is a source of outside air.
4. The air module of claim 1, wherein the controller is further configured to:
 - form the supply air by mixing the first air and the second air, if:
 - the first temperature is greater than the supply air temperature set point,
 - the second temperature is less than the supply air temperature set point, and
 - the dew point of the second air is within a dew point range.
5. The air module of claim 1, wherein the controller is further configured to:
 - form mixed air by mixing the first air and the second air, if:

the first temperature is greater than the supply air temperature set point,

the second temperature is less than the first temperature,

the dew point of the second air is less than a lower limit of a dew point range, and

a wet bulb temperature of the second air is less than a wet bulb temperature corresponding to the supply air temperature set point at the lower limit of a dew point range;

form the supply air by evaporatively cooling mixed air with the evaporative cooling module.

6. The air module of claim 1, wherein the controller is further configured to:

form supply air substantially from the second air by evaporatively cooling the second air with the evaporative cooling module, if:

the first temperature is greater than the supply air temperature set point,

the second temperature is greater than the supply air temperature set point,

the dew point of the second air is less than an upper limit of a dew point range, and

a wet bulb temperature of the second air is within an evaporative cooling wet bulb temperature range.

7. An air module comprising:

a controller;

an air intake module configured to receive first air from a first air source and to receive second air from a second air source;

an evaporative cooling module in fluid communication with the air intake module;

a mechanical cooling module in fluid communication with the evaporative cooling module; and

wherein the controller is configured to:

cause the intake module to mix, based on at least a supply air temperature set point, the first air and the second air to form intake air, and

selectively cool the intake air to form supply air by at least one of causing the evaporative cooling module to selectively cool, based on at least the supply air temperature set point, the intake air, and causing the mechanical cooling module to selectively cool the intake air based on at least the supply air temperature set point,

wherein the controller is further configured to:

form supply air substantially from the first air by mechanically cooling the first air with the mechanical cooling module, if:

a wet bulb temperature of the second air is greater than an upper limit of an evaporative cooling wet bulb temperature range, and

a dew point of the first air is less than or equal to an upper limit of a dew point range.

8. The air module of claim 1, wherein the controller is further configured to:

form supply air substantially from the second air by mechanically cooling the second air with the mechanical cooling module, if:

the first temperature is greater than the supply air temperature set point,

the second temperature is greater than or equal to the supply air temperature set point;

the dew point of the second air is greater than the upper limit of a dew point range,

a wet bulb temperature of the second air is less than an upper limit of an evaporative cooling wet bulb temperature range, and

a humidity ratio of the second air is less than or equal to a threshold humidity ratio.

9. A computer implemented method for controlling an air module comprising:

generating, by a controller, a first instruction to cause an intake module to, based upon a supply air temperature set point, a first temperature of the first air, a second temperature of the second air, and a dew point of the second air, selectively mix first air and second air to form intake air;

generating, by the controller, a second instruction to selectively cool the intake air to form supply air, wherein the second instruction comprises at least one of instructions to cause an evaporative cooling module to selectively cool, based on at least the supply air temperature set point, the intake air, and instructions to cause a mechanical cooling module to selectively cool, based on at least the supply air temperature set point, the intake air.

10. The method of claim 9,

wherein the first instruction comprises instructions to form the intake air by mixing the first air and the second air, if:

the first temperature is greater than the supply air temperature set point,

the second temperature is less than the supply air temperature set point, and

the dew point of the second air is within a dew point range.

11. The method of claim 9,

wherein the first instruction comprises instructions to form intake air by mixing the first air and the second air and the second instruction comprises instructions to cause the evaporative cooling module to selectively cool, based on at least the supply air temperature set point, the intake air, if:

the first temperature is greater than the supply air temperature set point,

the second temperature is less than the first temperature,

the dew point of the second air is less than a lower limit of a dew point range, and

a wet bulb temperature of the second air is less than a wet bulb temperature corresponding to the supply air temperature set point at the lower limit of a dew point range.

12. The method of claim 9,

wherein the first instruction comprises instructions to create intake air substantially from second air and the second instruction comprises instructions to cause the

evaporative cooling module to selectively cool, based on at least the supply air temperature set point, the intake air, if:

the first temperature is greater than the supply air temperature set point,

the second temperature is greater than the supply air temperature set point,

the dew point of the second air is less than an upper limit of a dew point range,

a wet bulb temperature of the second air is within an evaporative cooling wet bulb temperature range.

13. The method of claim 9, further comprising:

wherein the first instruction comprises instructions to create intake air substantially from second air and the second instruction comprises instructions to cause the mechanical cooling module to selectively cool, based on at least the supply air temperature set point, the intake air, if:

the first temperature is greater than the supply air temperature set point,

the second temperature is greater than or equal to the supply air temperature set point;

the dew point of the second air is greater than the upper limit of a dew point range,

a wet bulb temperature of the second air is less than an upper limit of an evaporative cooling wet bulb temperature range, and

a humidity ratio of the second air is less than or equal to a threshold humidity ratio.

14. The method of claim 10, further comprising sending the first instruction to the intake module and sending the second instruction to at least one of the evaporative cooling module and the mechanical cooling module.

15. A modular data center comprising:

an air module comprising:

an air module controller;
an air intake module configured to receive first air from a first air source and to receive second air from a second air source;
an evaporative cooling module in fluid communication with the air intake module;
a mechanical cooling module in fluid communication with the evaporative cooling module;
wherein the air module controller is configured to cause the intake module to mix the first air and the second air based on at least a supply air temperature set point, a first temperature of the first air, the second temperature of the second air and a dew point of the second air, to form intake air, and wherein the controller is configured to form supply air by at least one of causing the evaporative cooling module to cool the intake air selectively based on at least the supply air temperature set point, and causing the mechanical cooling module to cool the intake air selectively based on at least the supply air temperature set point;
one or more data center modules; and
a supply air conduit in fluid communication with the air module and a data center module of the one or more data center modules to carry supply air from the air module to the one or more data center modules.

16. The modular data center of claim 15, wherein the data center module further comprises:

a data center module controller;
a data center module intake damper configured to control supply air entering the data center module from the supply air conduit;
wherein the data center module controller is configured to actuate the data center module intake damper based on at least one of a temperature and humidity of air in the data center module.

17. The modular data center of claim 15, wherein the air module further comprises a fan array.

18. The modular data center of claim 17, wherein the air module controller is further configured to adjust an air flow of the fan array to maintain a substantially constant air pressure in the supply air conduit.