CLAIMS

WHAT IS CLAIMED IS:

1. A heat transfer apparatus comprising:

an air inlet and an air outlet;

a process fluid heat exchange circuit for receiving a process fluid, the process fluid heat exchange circuit comprising:

a heat exchanger;

an airflow generator operable to cause air to travel from the air inlet to the air outlet and contact the heat exchanger; and

a mechanical cooler having a condenser and an evaporator;

the heat exchanger to receive process fluid from the condenser of the mechanical cooler and provide cooled process fluid to the evaporator;

the process fluid heat exchange circuit having a plurality of modes including:

a first mode wherein the heat exchanger is operable to transfer heat between the process fluid and the air; and

a second mode wherein the heat exchanger is operable to transfer heat between the process fluid and the air and the evaporator of the mechanical cooler is operable to remove heat from the process fluid; and

a controller operatively connected to the process fluid heat exchange circuit, the controller configured to operate the process fluid heat exchange circuit in one of the plurality of modes based at least in part upon a determination of a thermal duty of the heat transfer apparatus.

2. The heat transfer apparatus of claim 1 wherein the process fluid heat exchange circuit comprises a thermal energy storage; and

wherein the plurality of modes include:

a third mode wherein the heat exchanger is operable to transfer heat between the process fluid and the air and the thermal energy storage is operable to remove heat from the process fluid; and

a fourth mode wherein the heat exchanger is operable to transfer heat between the process fluid and the air, the evaporator of the mechanical cooler is operable to

remove heat from the process fluid, and the thermal energy storage is operable to remove heat from the process fluid;

3. The heat transfer apparatus of claim 2 wherein the controller is configured to determine a charge of the thermal energy storage; and

wherein the controller is configured to operate the process fluid heat exchange circuit in one of the plurality of modes based at least in part upon the determination of the thermal duty of the heat transfer apparatus and the charge of the thermal energy storage.

4. The heat transfer apparatus of claim 1 wherein the controller is configured to receive a request to minimize either water consumption or energy consumption; and

wherein the controller is configured to operate the process fluid heat exchange circuit in one of the plurality of modes based at least in part upon the determination of the thermal duty of the heat transfer apparatus and the request to minimize either water consumption or energy consumption.

5. The heat transfer apparatus of claim 2 wherein the process fluid heat exchange circuit has a fifth mode wherein:

the heat exchanger is operable to transfer heat between the process fluid and the air; and

the mechanical cooler is operable to charge the thermal energy storage.

6. The heat transfer apparatus of claim 5 wherein the process fluid heat exchange circuit in the fifth mode is configured to direct a closed-loop process fluid between the mechanical cooler and the thermal energy storage.

7. The heat transfer apparatus of claim 5 wherein the process fluid heat exchange circuit in the fifth mode includes:

a first process fluid closed loop including the evaporator of the mechanical cooler, the thermal energy storage, and a first closed loop pump to circulate a first process fluid between the evaporator and the thermal energy storage.

8. The heat transfer apparatus of claim 5 wherein the process fluid heat exchange circuit has a sixth mode wherein the heat exchanger and mechanical cooler are operable to charge the thermal energy storage.

9. The heat transfer apparatus of claim 8 wherein the process fluid heat exchange circuit in the sixth mode includes:

a first process fluid closed loop including the evaporator of the mechanical cooler, the thermal energy storage, and a first closed loop pump to circulate a first process fluid between the evaporator and the thermal energy storage; and

a second process fluid closed loop including the condenser of the mechanical cooler, the heat exchanger, and a second closed loop pump to circulate a second process fluid between the condenser and the heat exchanger.

10. The heat transfer apparatus of claim 2 wherein the controller is configured to determine whether the thermal energy storage has an adequate charge; and

wherein the controller is configured to inhibit the process fluid heat exchange circuit from being in the third mode or the fourth mode in response to the thermal energy storage not having the adequate charge.

11. The heat transfer apparatus of claim 1 wherein the heat exchanger has a wet mode and a dry mode; and

wherein the heat exchanger is operable in either the wet mode or the dry mode with the process fluid heat exchange circuit is in the first or second modes.

12. The heat transfer apparatus of claim 2 wherein the process fluid heat exchange circuit is configured to direct the process fluid around the thermal energy storage with the process fluid heat exchange circuit in the first mode and the second mode.

13. The heat transfer apparatus of claim 1 wherein the process fluid heat exchange circuit is configured to direct the process fluid around at least one of the evaporator and the condenser of the mechanical cooler with the process fluid heat exchange circuit in the first mode.

14. The heat transfer apparatus of claim 1 wherein the mechanical cooler is off with the process fluid heat exchange circuit in the first mode.

15. The heat transfer apparatus of claim 1 wherein the mechanical cooler includes a compressor and an expansion valve.

16. The heat transfer apparatus of claim 1 wherein the heat exchanger includes an indirect heat exchanger and an adiabatic precooler.

17. The heat transfer apparatus of claim 1 wherein, with the process fluid heat exchange circuit in the first mode, the mechanical cooler is inoperable to remove heat from the process fluid.

18. The heat transfer apparatus of claim 1 wherein the condenser of the mechanical cooler is configured to be contacted by the airflow after the airflow has contacted the heat exchanger as the airflow travels from the air inlet to the air outlet.

19. The heat transfer apparatus of claim 1 further comprising an outer structure; and

wherein the heat exchanger and mechanical cooler are in the outer structure.

20. The heat transfer apparatus of claim 1 wherein the mechanical cooler comprises a shape memory alloy cooler.

21. The heat transfer apparatus of claim 1 wherein the controller is configured to determine the thermal duty based at least in part upon:

air temperature;

air humidity; and/or

a process fluid set temperature.

22. The heat transfer apparatus of claim 1 wherein the thermal duty comprises one of a plurality of thermal duties including an easier thermal duty and a harder thermal duty; and

wherein the controller is configured to operate the process fluid heat exchange

circuit in the first mode based at least in part upon the thermal duty being the easier thermal duty; and

wherein the controller is configured to operate the process fluid heat exchange circuit in the second mode based at least in part upon the thermal duty being the harder thermal duty.

23. The heat transfer apparatus of claim 1 wherein, with the process fluid heat exchange circuit in the first mode, the evaporator of the mechanical cooler is configured to remove less heat from the process fluid than with the process fluid heat exchange circuit in the second mode.

24. The heat transfer apparatus of claim 1 wherein the mechanical cooler is a chiller.

25. A method of operating a heat transfer apparatus including a process fluid heat exchange circuit comprising:

a heat exchanger; and

a mechanical cooler having a condenser and an evaporator;

the heat exchanger to receive process fluid from the condenser of the mechanical cooler and provide cooled process fluid to the evaporator;

the process fluid heat exchange circuit having a plurality of modes including:

a first mode wherein the heat exchanger is operable to transfer heat between a process fluid and air; and

a second mode wherein the heat exchanger is operable to transfer heat between the process fluid and the air and the evaporator of the mechanical cooler is operable to remove heat from the process fluid;

the method comprising:

determining a thermal duty of the heat transfer apparatus; and

operating the process fluid heat exchange circuit in one of the plurality of modes based at least in part upon the thermal duty of the heat transfer apparatus.

26. The method of claim 25 wherein the heat transfer apparatus comprises a thermal energy storage; and

wherein the plurality of modes includes:

a third mode wherein the heat exchanger is operable to transfer heat between the process fluid and the air and the thermal energy storage is operable to remove heat from the process fluid; and

a fourth mode wherein the heat exchanger is operable to transfer heat between the process fluid and the air, the evaporator of the mechanical cooler is operable to remove heat from the process fluid, and the thermal energy storage is operable to remove heat from the process fluid.

27. The method of claim 25 further comprising receiving a request to minimize either water consumption or energy consumption; and

wherein operating the process fluid heat exchange circuit in one of the plurality of modes includes operating the process fluid heat exchange circuit in one of the plurality of modes based at least in part upon the thermal duty of the heat transfer apparatus and the request to minimize either water consumption or energy consumption.

28. The method of claim 25 wherein the heat exchanger has a wet mode and a dry mode; and

wherein operating the process fluid heat exchange circuit in one of the plurality of modes includes operating the heat exchanger in either the wet mode or the dry mode.

29. The method of claim 25 wherein determining the thermal duty of the heat transfer apparatus includes determining the thermal duty of the heat transfer apparatus to be one of a plurality of thermal duties including an easier thermal duty and a harder thermal duty; and

wherein operating the process fluid heat exchange circuit in one of the plurality of modes includes:

operating the process fluid heat exchange circuit in the first mode in response to the thermal duty of the heat transfer apparatus being the easier thermal duty; and

operating the process fluid heat exchange circuit in the second mode in response to the thermal duty of the heat transfer apparatus being the harder thermal duty.

30. The method of claim 25 wherein, with the process fluid heat exchange circuit in the first mode, the process fluid bypasses at least one of the condenser and the evaporator of the mechanical cooler; and

wherein operating the process fluid heat exchange circuit in one of the plurality of modes comprises operating the process fluid heat exchange circuit in the first mode.