

Claims

1. A vapour compression apparatus comprising:
 - a pumping device which is used to pump a refrigerant;
 - 5 a condenser which is capable of condensing the refrigerant;
 - an evaporator which is capable of evaporating the refrigerant;
 - a heat battery comprising a phase change material (PCM);
 - at least one or a series of temperature and/or pressure sensors capable of monitoring the temperature and/or pressure of the phase change material (PCM) in the
 - 10 heat battery;
 - wherein the heat battery is capable of being connected to the condenser and/or evaporator to release charge (i.e. discharging) energy and/or be charged whereby the heat battery is capable of controlling the temperature of a heat source and/or heat sink temperature in a vapour compression cycle.
- 15 2. A vapour compression apparatus according to claim 1, wherein there is a series of temperature and/or sensors immersed in the phase change material (PCM) which provides a real-time indication of the physical state and physical conditions of the heat battery and provides an indication when the refrigerant flow should be switched.
- 20 3. A vapour compression apparatus according to any of claims 1 or 2, wherein the temperature and/or pressure measurements are conducted constantly and/or continuously or periodically such as every 30 seconds or every minute.
- 25 4. A vapour compression apparatus according to any preceding claim, wherein the at least one or a series of temperature and/or pressure sensors provide real-time temperature and/or pressure measurements which allows the physical state of the phase change material (PCM) to be monitored along with a measurement of the level of charge in the phase change material (PCM).
- 30 5. A vapour compression apparatus according to any preceding claim, wherein the heat battery comprising phase change material (PCM) is located intermediary between the condenser and evaporator.
- 35 6. A vapour compression apparatus according to any preceding claim, wherein the heat battery provides an intermediary stage between the condenser and evaporator which are functioning as either a heat source and/or heat sink.

7. A vapour compression apparatus according to any preceding claim, wherein during a first stage the heat battery pre-cools or pre-heats and during a second stage the heat battery discharges cooling or discharges heating.
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8. A vapour compression apparatus according to any preceding claim, wherein the heat battery functions as an intermediary located heat exchanger.
9. A vapour compression apparatus according to any preceding claim, wherein the apparatus is in a vertical or substantially vertical orientation wherein a liquid containing vessel containing refrigerant is located above or substantially above the compressor and the liquid containing vessel is located vertically or substantially vertically between the evaporator and the condenser.
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10. A vapour compression apparatus according to any preceding claim, wherein the pumping device is a which compressor is used to compress and/or pressurise the refrigerant around a system of pipes around the apparatus.
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11. A vapour compression apparatus according to any preceding claim, wherein when the apparatus is being used for discharge pre-cooling or pre-heating the flow of refrigerant occurs from the top to the bottom of a substantially vertically oriented apparatus.
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12. A vapour compression apparatus according to any preceding claim, wherein when the apparatus is being used for pre-cooling or discharge heating the flow of refrigerant occurs from the bottom to the top in a vertical or substantially vertically oriented apparatus.
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13. A vapour compression apparatus according to any preceding claim, wherein the refrigerant flow in the apparatus is reversible without any loss of functionality.
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14. A vapour compression apparatus according to any preceding claim, wherein the phase change material (PCM) used includes any one of or combination of the following:
a paraffin material, such as decane e.g. forming a PCM with a phase change transition temperature of about 25°C to 35°C or about -30°C, with optionally additives to improve nucleation, crystallisation rates and/or cyclability;
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- a salt-water eutectic, such as sodium chloride and water e.g. forming a PCM with a phase change transition temperature of about 20°C to 25°C or about -22°C, with optionally additives to improve nucleation, crystallisation rates and/or cyclability;
- 5 a salt-water eutectic, such as magnesium sulfate and water e.g. forming a PCM with a phase change transition temperature of about -10°C to 0°C or about -5°C, with optionally additives to improve nucleation, crystallisation rates and/or cyclability;
- 10 a salt-water eutectic, such as sodium sulfate and water e.g. forming a PCM with a phase change transition temperature of about -5°C to +5°C or about -1°C, with optionally additives to improve nucleation, crystallisation rates and/or cyclability;
- an organic ester, such as methyl laurate e.g. forming a PCM with a phase change transition temperature of about 0°C to 10°C or about 5°C, with optionally additives to improve nucleation, crystallisation rates and/or cyclability;
- 15 a clathrate hydrate, such as tetrahydrofuran (THF) and water e.g. forming a PCM with a phase change transition temperature of about 0°C to 10°C or about 5°C, with optionally additives to improve nucleation, crystallisation rates and/or cyclability;
- 20 an ester such as dimethyl succinate e.g. forming a PCM with a phase change transition temperature of about 15°C to 25°C or about 18°C, with optionally additives to improve nucleation, crystallisation rates and/or cyclability;
- a fatty alcohol, such as dodecanol e.g. forming a PCM with a phase change transition temperature of about 15°C to 25°C or about 22°C, with optionally additives to improve nucleation, crystallisation rates and/or cyclability;
- 25 a salt hydrate, such as sodium sulfate decahydrate e.g. forming a PCM with a phase change transition temperature of about 25°C to 35°C or about 32°C, with optionally additives to improve nucleation, crystallisation rates and/or cyclability;
- a salt hydrate, such as sodium acetate trihydrate e.g. forming a PCM with a phase change transition temperature of about 0°C to 10°C about 5°C, with optionally additives to improve nucleation, crystallisation rates and/or cyclability;
- 30 a polyol with a solid-solid phase change, such as trimethyloethane e.g. forming a PCM with a phase change transition temperature of about 70°C to 95°C or about 81°C, with optionally additives to improve nucleation, crystallisation rates and/or cyclability; and
- 35 a polyol, such as erythritol e.g. forming a PCM with a phase change transition temperature of about 100°C to 150°C about 121°C, with optionally additives to improve nucleation, crystallisation rates and/or cyclability.

15. A vapour compression apparatus according to any preceding claim, wherein the phase change material (PCM) is selected from a temperature range neither as low as a user wants to cool to or as high as a user wants to reject heat to.
- 5 16. A vapour compression apparatus according to any preceding claim, wherein the phase change material (PCM) is selected which has a phase change temperature of about 1°C - 20°C or about 10°C - 15°C above the temperature that we require to cool to (e.g. lowest temperature) and/or the phase change temperature that causes a refrigerant to condense with a pressure 1 – 10 BarG or preferably about 1 – 5 BarG above the
10 pressure of the required evaporation pressure.
17. A vapour compression apparatus according to any preceding claim, wherein a phase change material (PCM) is selected which has a phase change temperature of about 1°C - 20°C or about 10°C - 15°C above the temperature (e.g. minimum temperature) of the
15 ambient condition in which the heat pump is sourcing it's heat energy and/or the phase change temperature that causes a refrigerant to evaporate with a pressure of about 1 – 10 BarG or about 1 – 5 BarG above the pressure refrigerant would evaporate at given the design conditions minimum ambient temperature.
- 20 18. A vapour compression apparatus according to any preceding claim, wherein located within the heat battery there is a series of tubes.
19. A vapour compression apparatus according to any preceding claim, wherein the evaporator is a fan coil evaporator.
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20. A vapour compression apparatus according to any preceding claim, wherein the evaporator is located below the condenser.
21. A vapour compression apparatus according to any preceding claim, wherein located
30 above the evaporator there is the condenser which is a fan coil condenser.
22. A vapour compression apparatus according to any preceding claim, wherein the condenser is used in ambient conditions where heat is rejected.
- 35 23. A vapour compression apparatus according to any preceding claim, wherein the condenser is used to heat a space that is designated for heating which provides a flow of refrigerant from top to bottom in the apparatus.

24. A vapour compression apparatus according to any preceding claim, wherein the functionality of the evaporator and condenser is reversible during different cycles.
- 5 25. A vapour compression apparatus according to any preceding claim, wherein the evaporator and condenser are replaceable by other heat exchangers e.g. plate heat exchangers.
- 10 26. A vapour compression apparatus according to any preceding claim, wherein the apparatus comprises a reversing valve to reverse the flow of refrigerant when required and switch between charging and/or discharging.
- 15 27. A vapour compression apparatus according to claim 26, wherein the switching occurs manually or electronically and is dependent on the temperature and/or pressure being measured and when switching is required.
- 20 28. A vapour compression apparatus according to claim 27, wherein when heating is required refrigerant flows from the heat battery and when cooling is required refrigerant flows into the heat battery.
- 25 29. A vapour compression apparatus according to any preceding claim, wherein the apparatus comprises at least one shut-off valve which is connected to the condenser.
- 30 30. A vapour compression apparatus according to any of claims 26 to 29, wherein the apparatus comprises at least one shut-off valve which is connected to the reversing valve and the heat battery.
- 35 31. A vapour compression apparatus according to any preceding claim, wherein connected to the condenser and a liquid containing vessel there is a further valve which functions as a check valve.
32. A vapour compression apparatus according to any preceding claim, wherein the apparatus is oriented vertically or substantially vertically a liquid containing vessel is located above the pumping device (e.g. compressor) and below the condenser.
33. A vapour compression apparatus according to any preceding claim, wherein the apparatus also comprises a dryer such as a filter dryer which is optionally located vertically below the liquid containing vessel.

34. A vapour compression apparatus according to any preceding claim, wherein the apparatus also comprises a window for viewing e.g. a sight glass.
- 5 35. A vapour compression apparatus according to any preceding claim, wherein the apparatus also comprises expansion devices (e.g. expansion valves) which are used for pre-cooling.
- 10 36. A vapour compression apparatus according to any preceding claim, wherein the apparatus also comprises at least one solenoid valve located between the heat battery and the reversing valve which is used to isolate the heat battery when required.
- 15 37. A vapour compression apparatus according to any preceding claim, wherein the apparatus comprises a suction vessel accumulator which is used to direct the refrigerant flow.
38. A vapour compression apparatus according to any preceding claim, wherein the apparatus comprises a crank-case pressure regulator.
- 20 39. A vapour compression apparatus according to any preceding claim, wherein there is a solenoid valve connected to the heat battery and a liquid containing vessel.
40. A vapour compression apparatus according to any preceding claim, wherein there is a solenoid valve which is used for hot gas defrosting.
- 25 41. A vapour compression apparatus according to any preceding claim, wherein the temperature and/or pressure controlled vapour compression apparatus is used to both heat and cool with the cycles being reversible.
- 30 42. A vapour compression apparatus according to any preceding claim, wherein on a discharge cycle the apparatus is required to transfer heat energy between the heat battery (i.e. intermediate heat exchanger) and a temperature-controlled environment.
- 35 43. A vapour compression apparatus according to any preceding claim, wherein the apparatus operates via a refrigerant flow driven by a pressure differential across the compressor.

44. A vapour compression apparatus according to any preceding claim, wherein the apparatus also comprises an integrated capillary tube.
45. A vapour compression apparatus according to any preceding claim, wherein the apparatus also comprises an integrated liquid receiver and a capillary tube.
46. A vapour compression apparatus according to any preceding claim, wherein the apparatus also comprises an integrated microchannel heat exchanger used for condensing refrigerant and charging a heat battery, whereby refrigerant superheated gas enters the microchannel heat exchanger at an inlet port, condenses along cooling channels and exits as a liquid at an exit port.
47. A method for controlling the temperature of a heat source and/or heat sink temperature in a vapour compression cycle using apparatus according to any of the first and second aspects providing:
- a pumping device which is used to pump a refrigerant;
 - a condenser which is capable of condensing the refrigerant;
 - an evaporator which is capable of evaporating the refrigerant;
 - a heat battery comprising a phase change material (PCM);
 - at least one or a series of temperature and/or pressure sensors capable of monitoring the temperature and/or pressure of the phase change material (PCM) in the heat battery;
 - wherein the heat battery is capable of being connected to the condenser and/or evaporator to release charge (i.e. discharging) energy and/or be charged whereby the heat battery is capable of controlling the temperature of a heat source and/or heat sink temperature in a vapour compression cycle.
48. A methodology for selecting phase change materials (PCMs) and/or refrigerants for a vapour compression apparatus comprising:
- Choose lowest Global Warming Potential (GWP) and legally allowed refrigerants and choose a Candidate Refrigerant;
 - Review the refrigerant pressure range of the selected Candidate Refrigerant;
 - Review where the Candidate Refrigerant evaporates and condenses relative to Compartment Target Temperature (CTT) and minimum ambient temperature (Min_Ambient);

- For a list of phase change materials (PCMs) with Transition Temperatures (TT) in the range CTT to Min_Ambient, evaluate for each the refrigerant pressure that arises at the Transition Temperature;
 - Clip the list to remove all candidates that have insufficient pressure differential to drive refrigerant flow between evaporating and condensing on the PCM TT to Min_Ambient refrigeration cycle and/or the CTT to PCM refrigeration cycle;
 - Using refrigerant saturation property tables, calculate the refrigerant thermodynamic state at a plurality of points (e.g. 2 – 10, or preferably 4 points) on the refrigeration cycle for evaporating and condensing on the PCM TT to Min_Ambient refrigeration cycle and/or the CTT to PCM refrigeration cycle:
 - Compressor inlet refrigerant state
 - Compressor outlet refrigerant state
 - Condenser outlet refrigerant state
 - Evaporator inlet refrigerant state
 - Calculate the heat load (kW) across the evaporator and/or condenser and compressor work (kW) for each refrigeration cycle; and
 - Using this information the coefficient of performance (COP) for heating and/or cooling can be determined for each pairing of refrigerant and PCM.
49. A methodology for selecting phase change materials (PCMs) and/or refrigerants for a vapour compression apparatus according to claim 48, wherein using refrigerant saturation property tables the refrigerant thermodynamic state is calculated at 2 - 10 or 4 points on the refrigeration cycle for evaporating and condensing on the PCM TT to Min_Ambient refrigeration cycle and/or the CTT to PCM refrigeration cycle:
- Compressor inlet refrigerant state
 - Compressor outlet refrigerant state
 - Condenser outlet refrigerant state
 - Evaporator inlet refrigerant state