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[Continued on next page]

(54) Title: DEFROSTING THE EVAPORATOR OF A HEAT-DRIVEN HEAT PUMP OR REFRIGERATION SYSTEM

(57) Abstract: A method of defrosting an evaporator of a heat-driven heat pump is described, where the evaporator is for extracting heat from an ambient heat source outside an entity to be heated when the heat pump is driven using heat from a driving heat source. At least some of the heat from the driving heat source is used to defrost an exterior surface of the evaporator.

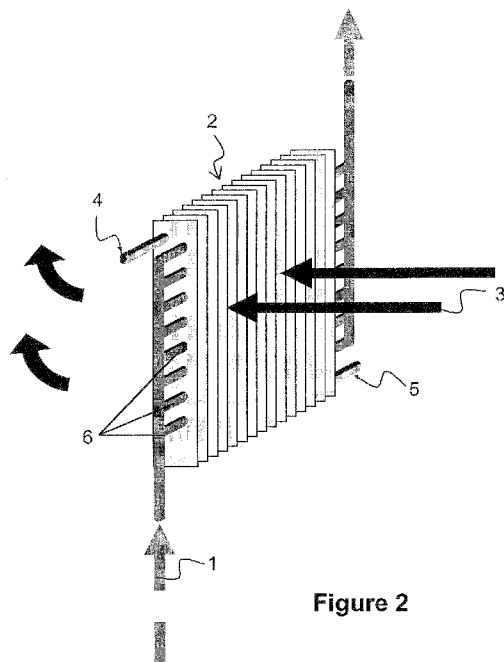


Figure 2



— *as to applicant's entitlement to apply for and be granted
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DEFROSTING THE EVAPORATOR OF A HEAT-DRIVEN HEAT PUMP OR REFRIGERATION SYSTEM

The present invention relates to a method for defrosting the evaporator of a heat-driven
5 heat pump or refrigeration system.

Heat pumps and cooling systems are used to remove heat from or to introduce heat to a region (e.g. a building) which causes the temperature of the region to be lowered or raised. Such systems are generally based on the thermodynamics of condensation
10 and evaporation of a refrigerant gas. On condensation of a gas to a liquid, heat is rejected to the environment and on evaporation of a liquid, heat is absorbed. The evaporation/condensation cycle is driven by compression. If a selected environment is brought into thermal contact with the gas/liquid only during the evaporation phase, for example, then that environment experiences an overall cooling effect.

15 Heat pumps used to provide heat for space-heating and provision of hot water in a building usually use air as a heat source, utilising an evaporator typically installed outside the building. However, when the evaporator temperature is less than 0°C, and the air passing over the evaporator is even slightly humid, ice forms on the evaporator
20 and reduces its performance.

In conventional vapour compression heat pumps the necessary compression is driven by mechanical work that is normally provided by an electrical motor. In such heat pumps, various means are employed to de-ice the evaporator, such as reversing the
25 cycle, hot gas bypass from the compressor or even electrical heating. All these methods increase energy consumption but are necessary to avoid a major build up of ice that could seriously degrade performance or lead to failure.

Heat-driven heat pumps provide an alternative to mechanically driven devices. One
30 example of such a device is a sorption device which is driven by the adsorption or absorption of the refrigerant gas (or sorbate), such as ammonia, by a solid or liquid sorbent. The sorbent therefore acts as a chemical compressor. Examples of sorption devices are described in US 5845507 and EP 1535002.

In comparison with conventional heat pumps, those based on a sorption cycle have the benefit that the energy needed to drive the system can be in the form of heat. A sorption heat pump may be gas or oil fired or even solar powered. The use of primary heat energy as a driver, as opposed to a secondary source such as electricity, means
5 that sorption devices inherently offer the potential to be more energy efficient and they may be operated independently of, or with significantly reduced reliance upon, the infrastructure of an electricity grid.

However, such devices will still suffer from the problem described above that ice may
10 build up on an evaporator located outside a building. There is therefore still a need to de-ice the evaporator of a heat-driven heat pump.

In accordance with one aspect of the present invention there is provided a method of defrosting an evaporator of a heat-driven heat pump, where the evaporator is for
15 extracting heat from a heat source remote from an entity to be heated when the heat pump is driven using heat from a driving heat source. At least some of the heat from the driving heat source is used to defrost an exterior surface of the evaporator. Further aspects and optional features are set out in the accompanying claims.

20 In other words, heat-driven heat pumps (e.g. those based on absorption or adsorption cycles) have an additional source of heat available for defrosting the evaporator. Whether these machines are driven by combustion of a fuel such as gas, waste heat from, for example, a fuel cell or an engine, or heat gathered in solar collectors, there will always be heat available from that source after it has already been utilised to power
25 the heat pump. For example, a gas-fired sorption heat pump, having extracted as much heat as possible from the combustion products, might still have flue gas temperatures of 60°C which can be used to defrost an evaporator.

There are two main approaches to using this heat for de-icing the evaporator. Firstly it
30 can be applied to the whole evaporator either when in operation or when the system is briefly shut down. Secondly the evaporator can be split into two or more sections with separate air streams over each. For an evaporator comprising two sections (A and B), when defrost is required one evaporator (A) can be disabled so that the flue gas or other source of defrost heat can be used to defrost it whilst the other (B) is more

heavily loaded (at some penalty to performance). At a later stage the other section (B) can be shut down for defrost whilst section A is more heavily loaded.

Referring to the figures, for the example of the gas-fired sorption heat pump, there are many ways in which heat can be transferred from the flue gas to the evaporator or evaporator sections requiring defrost with advantages and disadvantages as follows:

1. Figure 1 shows an evaporator or section 2 through which a refrigerant liquid is passed. The refrigerant liquid enters the through pipe 4 and exits through pipe 5. Ambient air 3 is blown through the evaporator (when not being defrosted) in order for the heat transfer to occur, as shown by the solid arrows. Flue gas 1 from the combustion of gas is blown over the outside of the evaporator or section 2 when defrosting as shown by the dashed arrows, either during normal heat-pump operation or when it is briefly shut down. This approach is probably the simplest and cheapest to implement; however, it is difficult to ensure the flue gas reaches all the parts requiring heat.
2. Figure 2 shows an evaporator or section 2 through which a refrigerant liquid is passed. As in figure 1, the refrigerant liquid enters the through pipe 4 and exits through pipe 5 and ambient air 3 is blown through the evaporator (when not being defrosted) in order for the heat transfer to occur, as shown by the solid arrows. During defrosting, flue gas 1 is blown through tubes 6 within the fin block of the evaporator or section 2, either during normal heat-pump operation or when it is briefly shut down. This approach has the advantage of heating the metal surfaces directly and thereby causing the ice to melt first at the metal-ice interface, which may encourage ice to fall away cleanly and require less heating. However it may introduce a high pressure drop in the overall flue-gas path and furthermore there is the possibility of water of combustion in the flue gases condensing and later freezing in the tubes.
3. Figure 3 shows two evaporators or sections 2 through which a refrigerant liquid is passed, entering via tubes 4 and exiting via tube 5. The flue gas 1 is blown continuously over a heat exchanger 8, heating up a heat transfer fluid. Indirect heating of the evaporator or sections 2 is then provided via a circulating loop of

5 piping 7 containing heat transfer fluid that will not freeze under ambient conditions, for example it will not boil under flue gas temperature or freeze at evaporator temperature. This approach provides heat where needed and heats the metal surfaces directly. However it requires tubes 6 in the evaporator blocks together with a heat exchanger 8, circulating pump 9 and piping 7 and valves 10 to divert flow of the heat transfer fluid from the flue gas heat exchanger 8 to the required evaporator section 2 and to isolate the de-icing loops within the piping 5 when necessary. The circulating pump 9 may only be operated when defrosting of one or more of the evaporators or sections 2 is required.

15 4. Figure 4 shows indirect heating of the evaporators or sections 2 via a thermosyphon or wicked heat pipe. This approach is similar to that described in 3 above and shown in Figure 3, but it does not require a circulating pump. However, it does require piping 7 and valves 10 and 11 to divert heat to the required evaporator section 2 and to isolate the de-icing loops within the piping 7 when necessary. The valves 10 and 11, which may be solenoid valves, can close off either evaporator section 2 so that the heat transfer fluid from the heat exchanger 6 condenses in the evaporator section being defrosted and not in the one that is still extracting heat from the outside air.

25 Figures 2, 3 and 4 only show one row of refrigerant tubes and therefore only one row of heat transfer fluid tube, however there may be many rows of refrigerant tubes in an evaporator, and therefore correspondingly there may need to be multiple rows of heat transfer fluid tube

30 When other forms of heat are used to power the heat pump, such as those mentioned above, similar methods of transferring the available heat to the evaporator for de-icing can be used.

While described above in terms of heat pumps used for space heating and hot water, these systems can be used for any application of heat-driven heat pumps where heat is extracted from air, whether for heating or cooling purposes. For example, the invention has been described as a heater with reference to a remote heat source and an "entity

to be heated” (*i.e.* a heat sink). If the heat pump is used for refrigeration (including air conditioning), then the remote heat source will correspond to the entity to be cooled (*e.g.* cold store, interior of a building), and the “entity to be heated” will be external to the entity to be cooled.

CLAIMS:

1. A method of defrosting an evaporator of a heat-driven heat pump, the evaporator for extracting heat from a remote heat source remote from an entity to be heated when the heat pump is driven using heat from a driving heat source, the method comprising using at least some of the heat from the driving heat source to defrost an exterior surface of the evaporator.
5
2. The method of claim 1, wherein the remote heat source includes ambient air.
10
3. The method of claim 1 or 2, wherein the entity to be heated includes water.
4. The method of claim 1, 2 or 3, wherein the entity to be heated includes at least some of the internal space of a building.
15
5. The method of any preceding claim, wherein some or all of the heat from the driving heat source is derived from solar heat.
6. The method of any preceding claim, wherein the heat from the driving heat source is derived from combustion of fuel.
20
7. The method of claim 6, wherein the combustion of fuel produces combustion products including hot flue gas, and wherein the hot flue gas is used to defrost the evaporator.
25
8. The method of claim 7, wherein the hot flue gas is directed towards the surface of the evaporator to defrost the evaporator.
9. The method of claim 7, wherein the hot flue gas is passed through passages within the evaporator to defrost the evaporator.
30
10. The method of any of claims 1 to 7, wherein the at least some of the heat from the driving heat source is used to heat a heat transfer fluid, and the heat transfer fluid is passed through passages within the evaporator to defrost the evaporator.

11. The method of claim 10, wherein the heat transfer fluid is heated in a heat exchanger.
- 5 12. The method of claim 10 or 11, wherein the heat transfer fluid is pumped through the evaporator.
13. The method of claim 10 or 11, wherein the heat transfer fluid is a secondary refrigerant which boils when heated by the at least some of the heat from the driving
10 heat source and condenses in the evaporator.
14. The method of any preceding claim, wherein the evaporator is configured so as not to extract heat from the ambient heat source while being defrosted.
- 15 15. The method of any preceding claim, wherein the heat pump comprises two or more evaporators so that at least one evaporator is usable to extract heat from the ambient heat source while at least one other evaporator is defrosted.
16. The method of any preceding claim, wherein the heat pump is a sorption heat
20 pump.
17. The method of any preceding claim, designed to be used for cooling, wherein the remote heat source comprises the entity to be cooled.
- 25 18. Apparatus arranged to carry out the method of any preceding claim.
19. A heat pump comprising the apparatus of claim 18.

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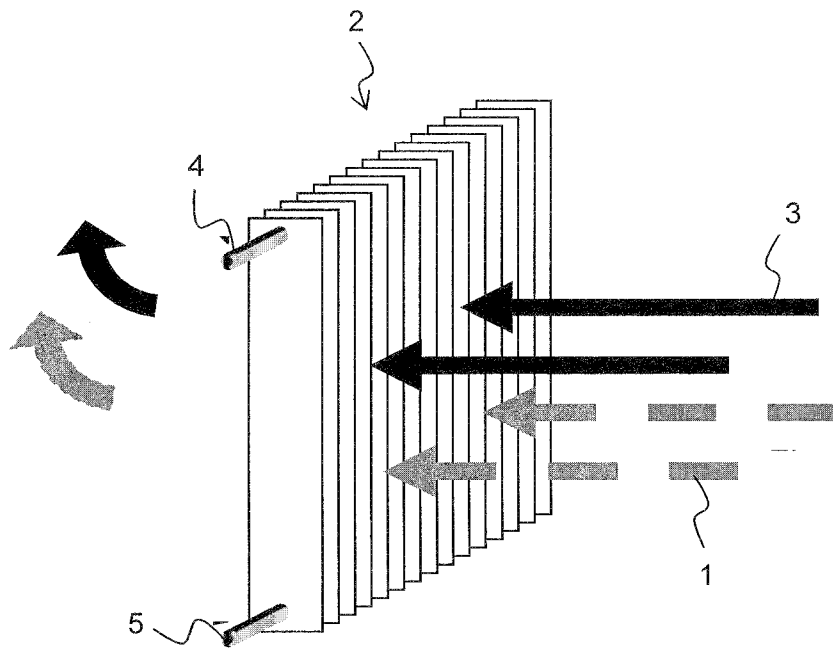


Figure 1

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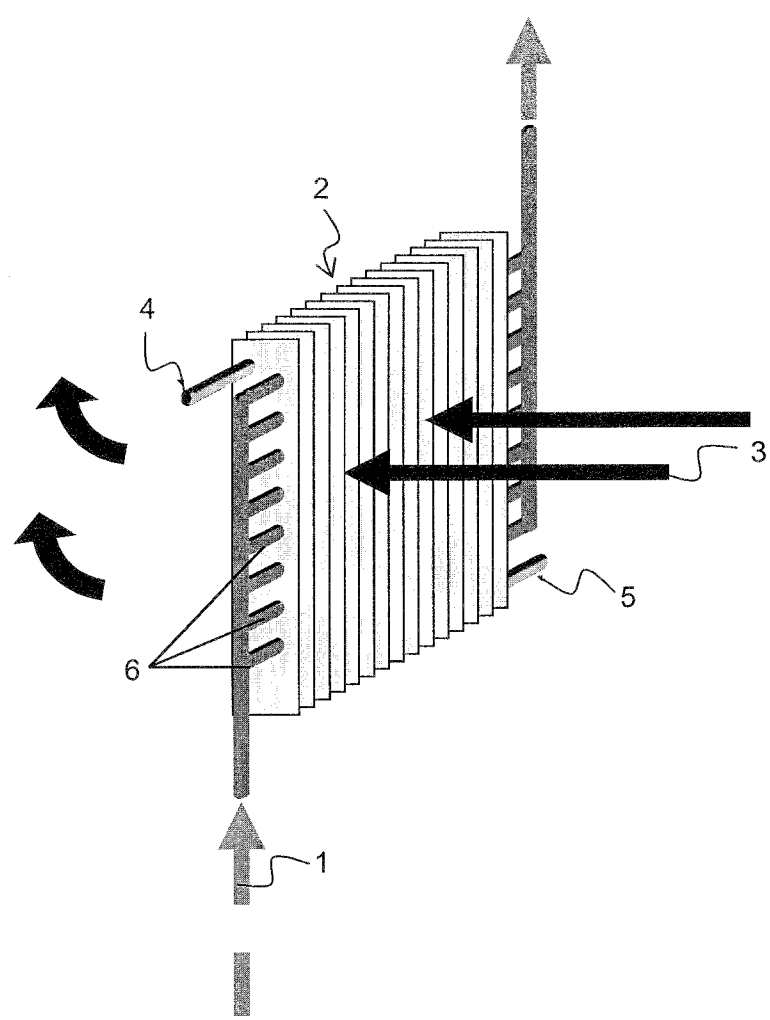


Figure 2

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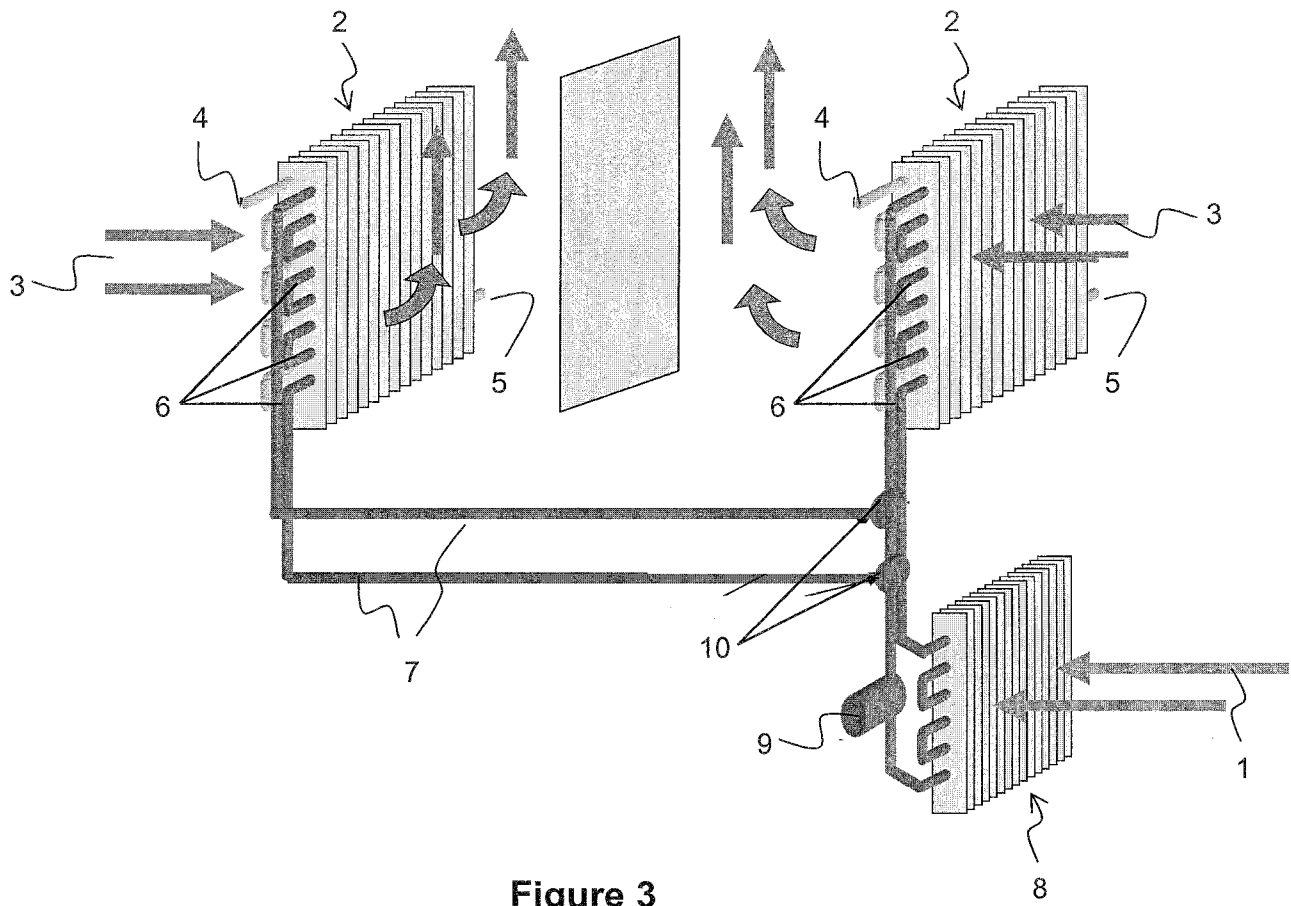


Figure 3

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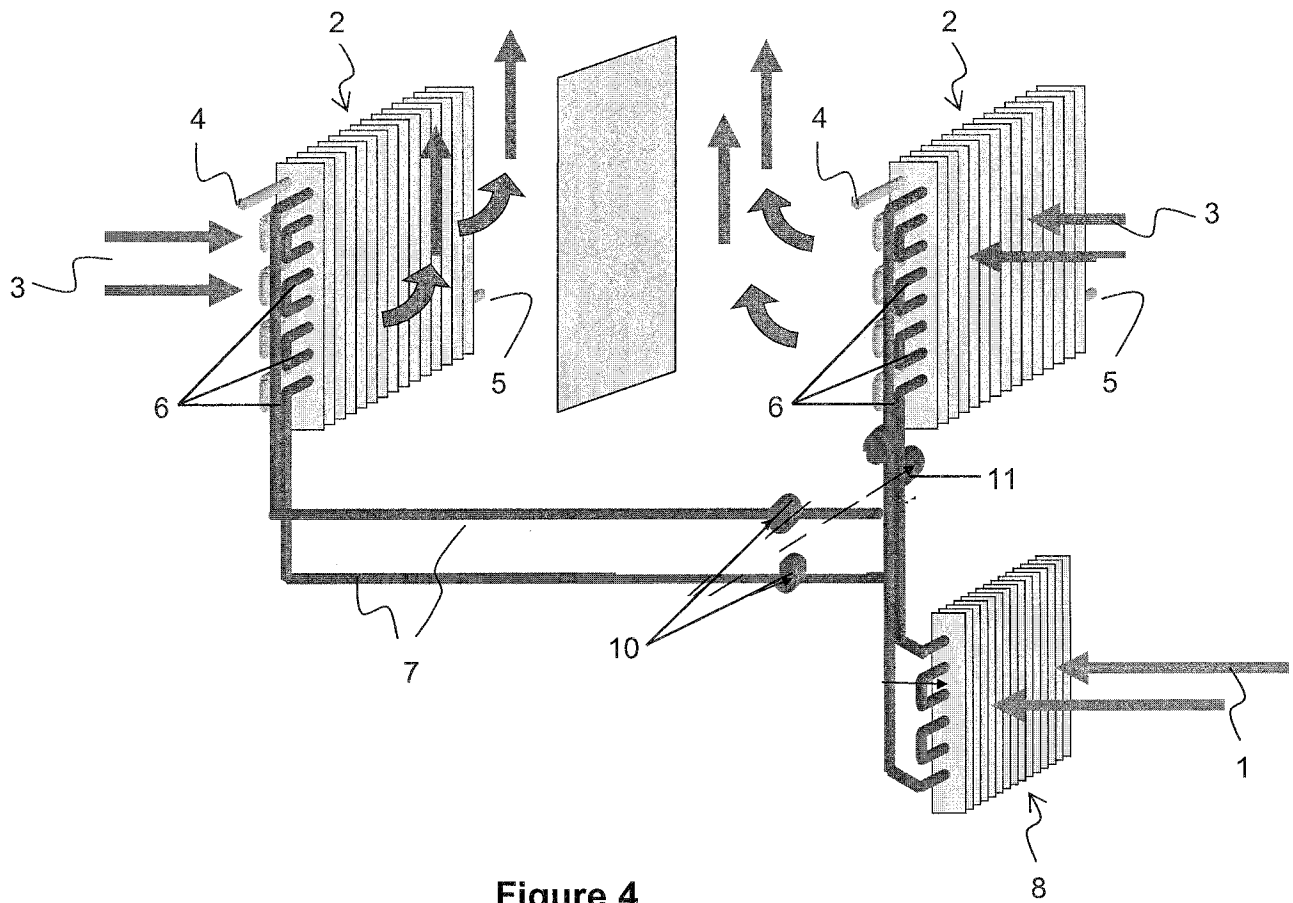


Figure 4