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(54) **ADSORPTION COOLING SYSTEM AND ADSORPTION COOLING METHOD FOR AN AIRCRAFT**

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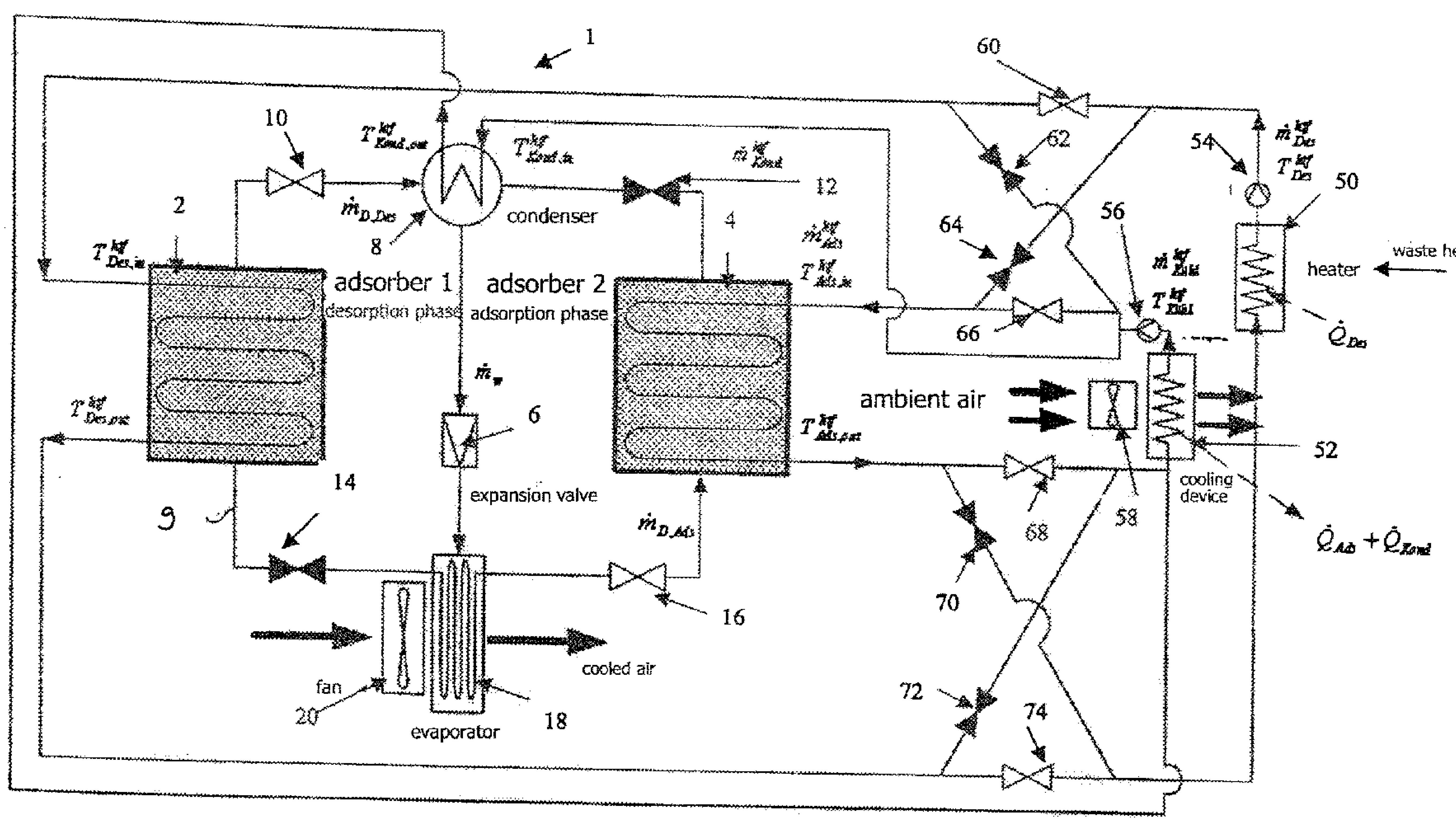
(57) **ABSTRACT**

An adsorption cooling system (**1**) for an aircraft comprises an evaporator (**18**), a first adsorber (**2**), which contains a first adsorption medium for adsorbing an adsorption coolant evaporated in the evaporator (**18**), and a second adsorber (**4**), which contains a second adsorption medium for adsorbing the adsorption coolant evaporated in the evaporator (**18**), the first and the second adsorber (**2**, **4**) being adapted to be operated alternately in an adsorption mode and in a desorption mode, such that one adsorber (**2**, **4**) can adsorb adsorption coolant and the other adsorber (**2**, **4**) can be regenerated. A heat transfer system of the adsorption cooling system (**1**) is adapted to transfer heat energy, by means of a heat transfer fluid, during a transitional operating phase, during which one adsorber (**2**, **4**) is brought from adsorption mode to desorption mode and the other adsorber (**2**, **4**) is brought from desorption mode to adsorption mode, from the adsorber (**2**, **4**) that is brought from desorption mode to adsorption mode to the adsorber (**2**, **4**) that is brought from adsorption mode to desorption mode



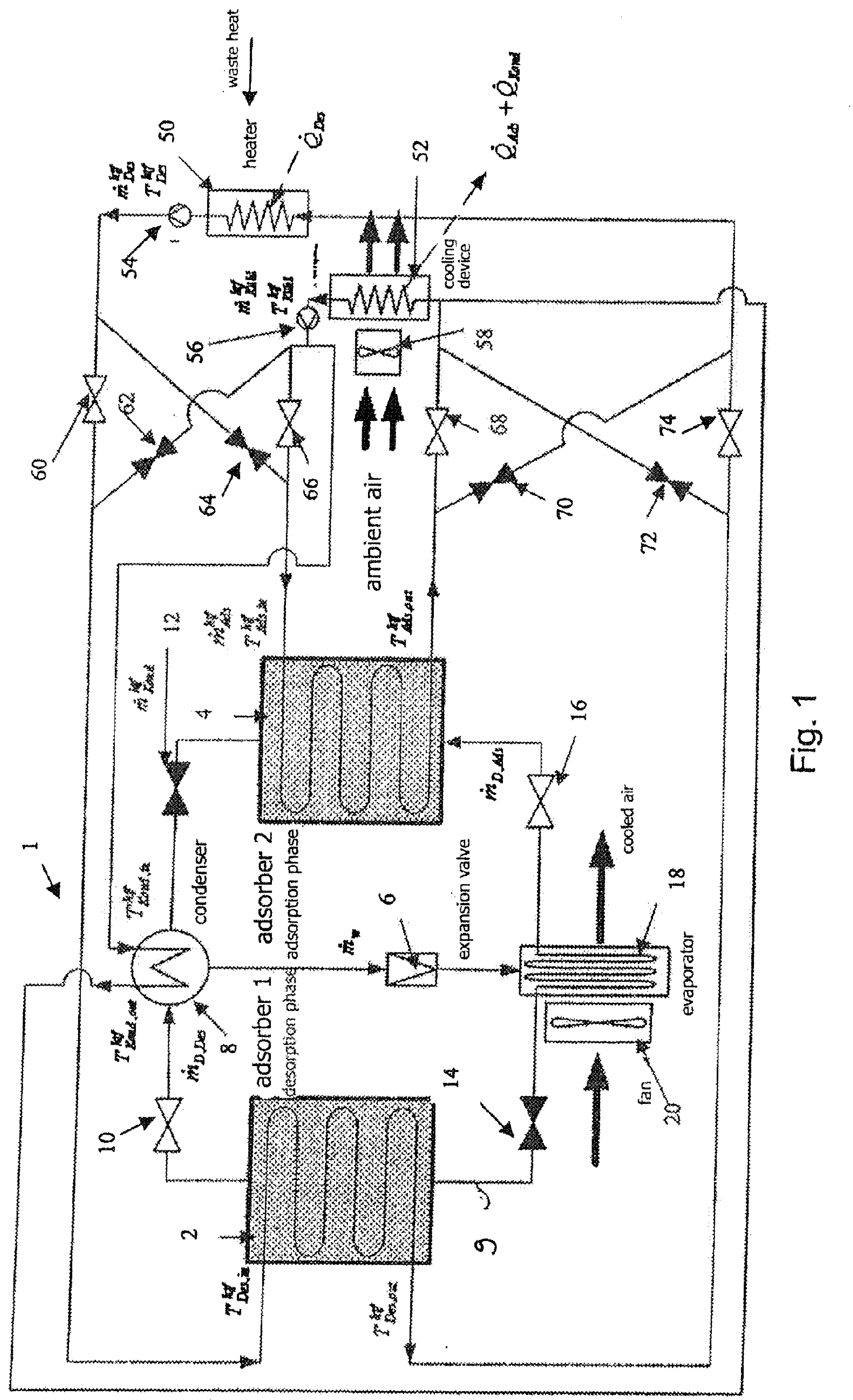

waste heat
heater
cooling device
ambient air
adsorber 1
desorption phase
adsorber 2
adsorption phase
condenser
expansion valve
evaporator
cooled air
fan

Fig. 1

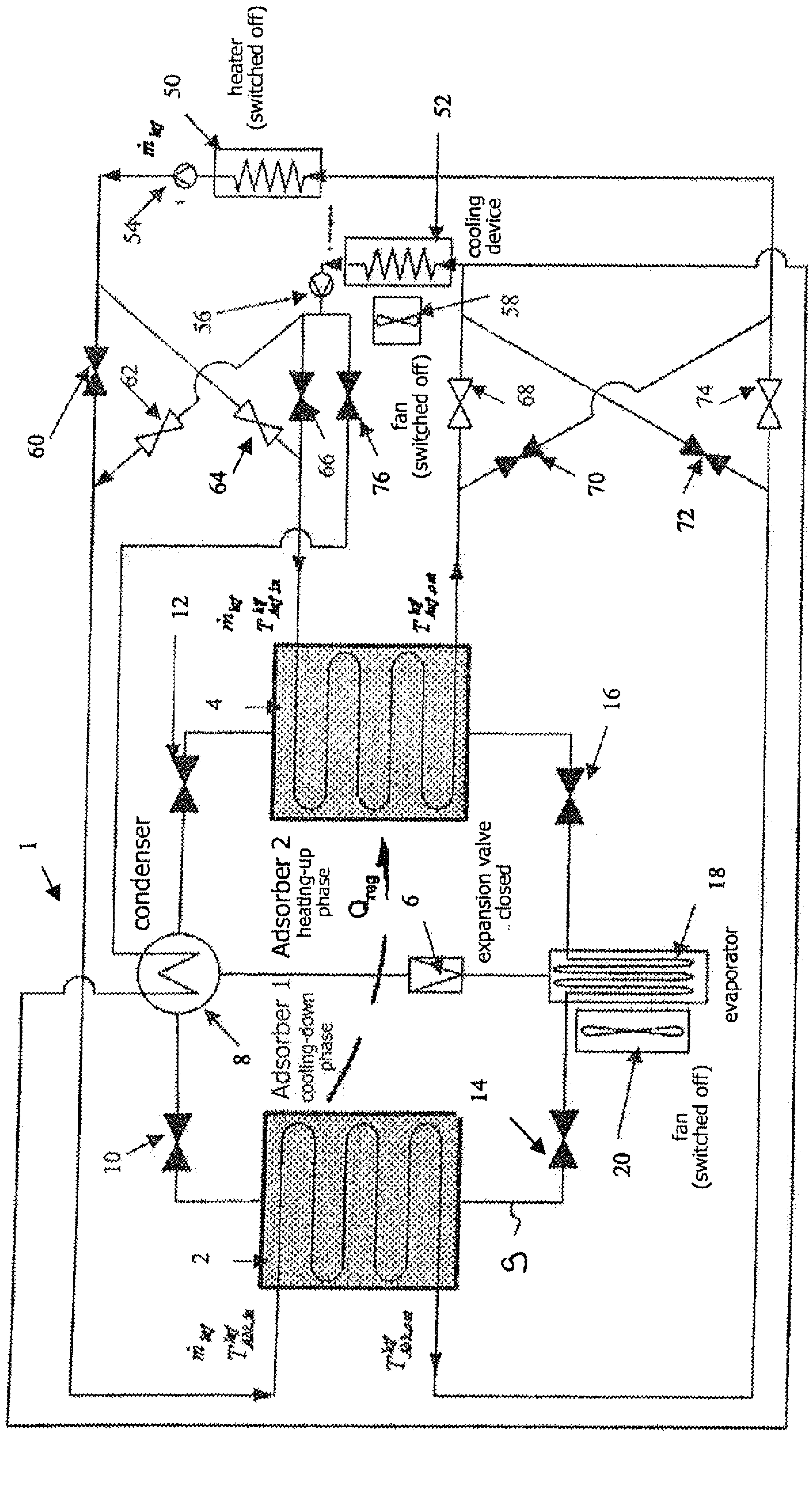
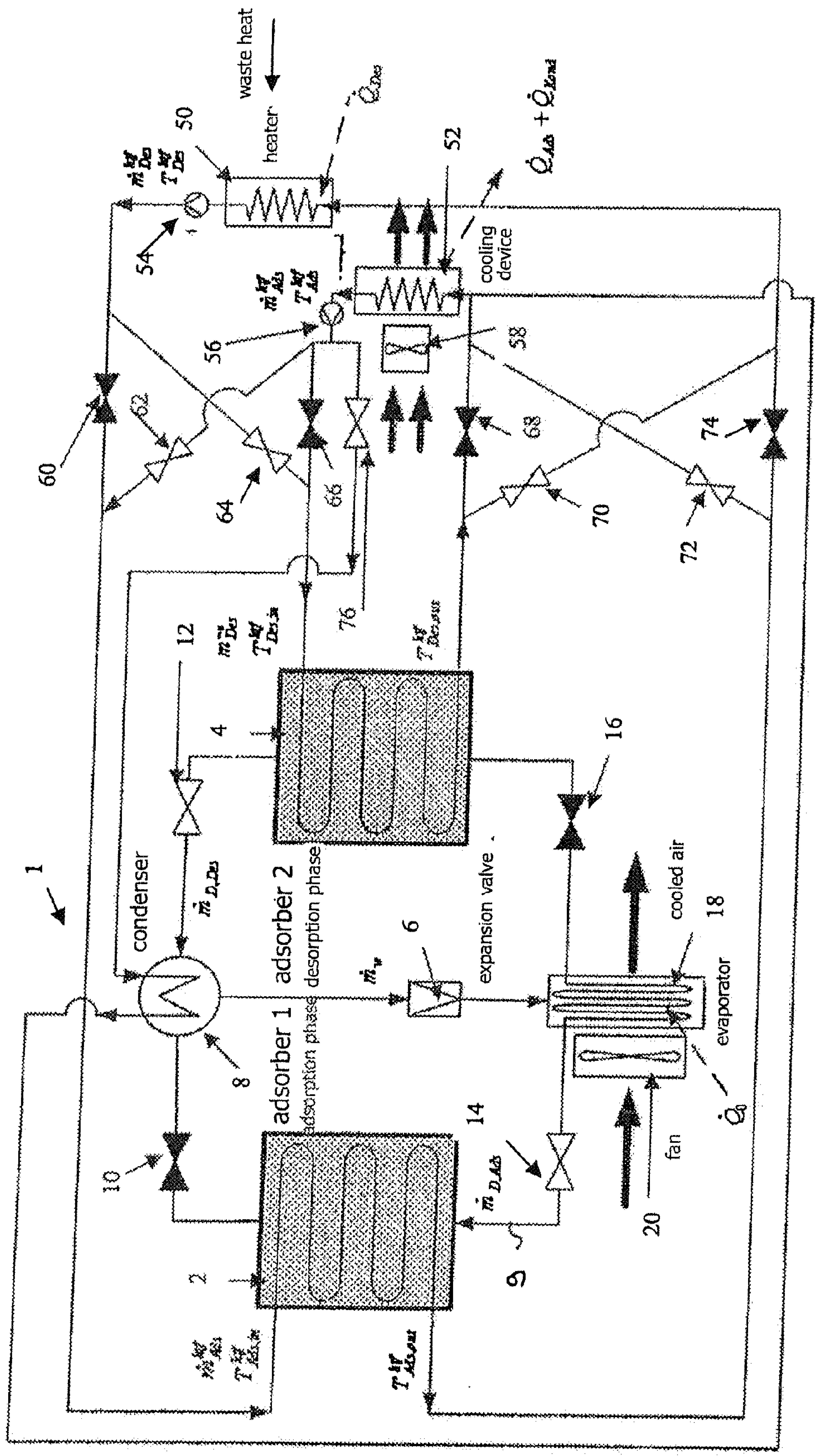

heater
(switched off)
50
52
cooling
device
54
56
58
fan
(switched off)
60
62
64
66
68
70
72
74
76
12
4
condenser
1
Adsorber 2
heating-up
phase
Q_{reg}
6
expansion valve
closed
18
16
evaporator
Adsorber 1
cooling-down
phase
8
10
14
20
fan
(switched off)
2
5

Fig. 2


waste heat
heater
50
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cooling device
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72
74
76
condenser
adsorber 2
desorption phase
adsorber 1
adsorption phase
expansion valve
cooled air
evaporator
fan
1
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Fig. 3

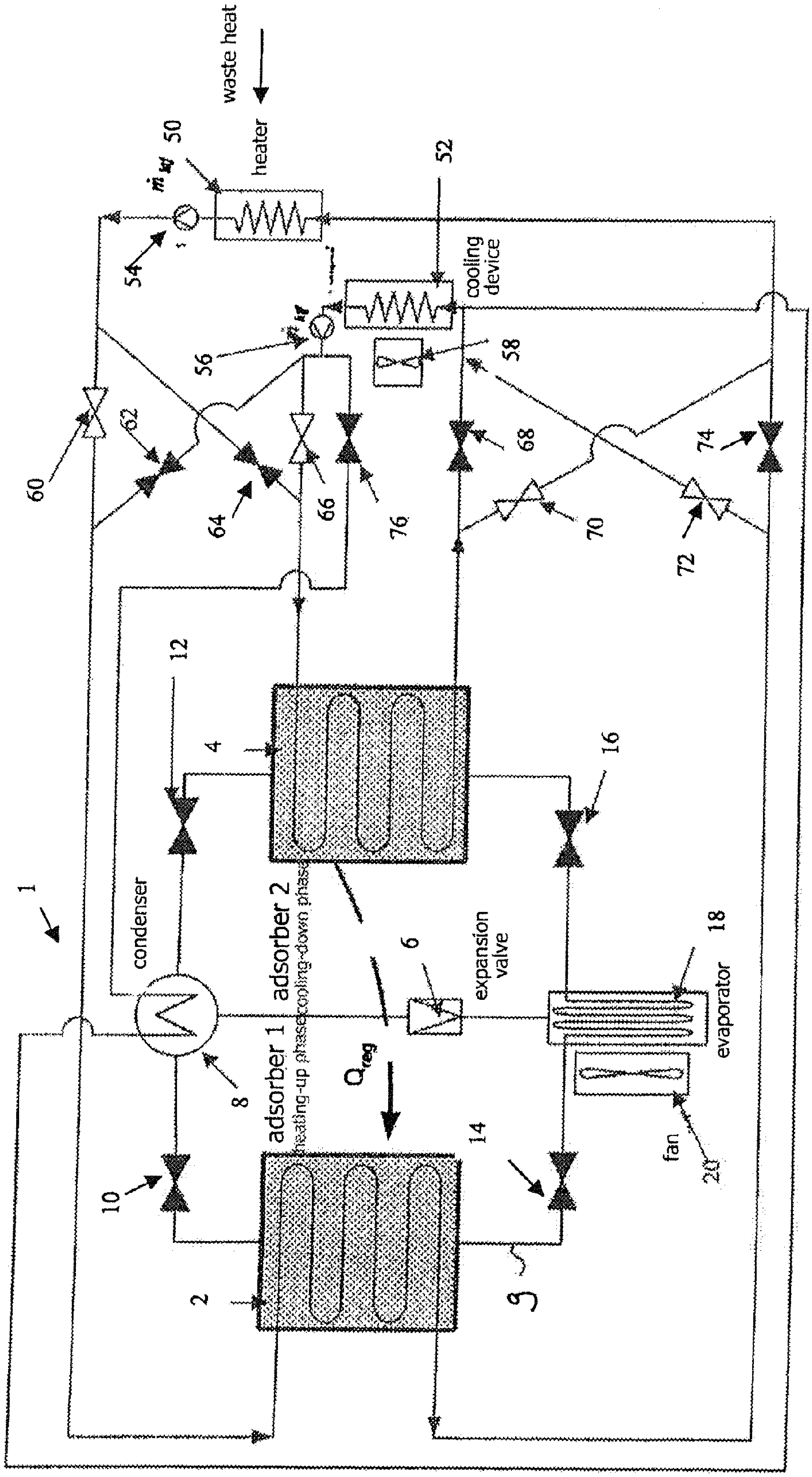
waste heat
heater
50
52
cooling device
54
56
58
60
62
64
66
68
70
72
74
76
12
4
16
1
condenser
adsorber 2
cooling-down phase
expansion valve
6
18
evaporator
adsorber 1
heating-up phase
8
Q_{reg}
14
10
fan
20
2
9

Fig. 4

ADSORPTION COOLING SYSTEM AND ADSORPTION COOLING METHOD FOR AN AIRCRAFT

[0001] The present invention relates to an improved adsorption cooling system and an improved adsorption cooling method for cooling at least one device and/or one region of an aircraft.

[0002] In an aircraft, it is necessary to cool, for example, the cabin, the galleys, the food trolleys in the galleys, electronic devices and the like. Usually, a compression refrigerating machine is used for this purpose, in which a coolant is compressed by means of a compressor, condensed in a condenser, and expanded in an evaporator, with release of refrigerating energy. A compression refrigerating machine has the disadvantage that, in particular, the compressor causes a substantial amount of noise to be produced. Further, a compression refrigerating machine requires a relatively large amount of drive energy, and it is necessary to dissipate a relatively large amount of waste heat. In the case of aircraft of the prior art, the use of a compression refrigerating machine is necessary, in particular, on the ground, where the external temperatures can attain relatively high values. Further, it is frequently necessary to use coolants containing fluorocarbons, the use of which is contentious in respect of protection of the environment.

[0003] In order to overcome the aforementioned problems, it is attempted to use adsorption cooling systems in future aircraft. An exemplary adsorption cooling system is described in DE 10 2006 054 560 A1. The central device of the adsorption cooling system is an adsorber, which contains an adsorption medium. Taken up by the adsorption medium is a gaseous adsorption coolant, which is evaporated in an evaporator providing refrigerating energy. The adsorption medium is preferably a fine-pored material, for example activated carbon, zeolite, silica gel or the like. Water or alcohol may be used as an adsorption coolant. The adsorption coolant may be taken up by the adsorption medium merely in a plurality of molecular layers. Once the adsorption medium is completely wetted with adsorption coolant, such that no further adsorption coolant can be taken up, the adsorber is saturated, and must be regenerated. The adsorption medium is heated for this purpose, such that the adsorption coolant taken up by the adsorption medium becomes desorbed. The desorbed adsorption coolant is condensed, supplied, as a liquid adsorption coolant, to an optional reservoir, and then routed back, via an expansion valve, to the evaporator described at the outset. Thus, when the adsorption cooling system is in adsorption mode, refrigerating energy can be produced, whereas, when the adsorption cooling system is in desorption mode, or regeneration mode, not only can no refrigerating energy be produced, but it is even necessary for regeneration energy to be supplied in the form of heat energy. The adsorption cooling system known from DE 10 2006 054 560 A1 therefore has two adsorbers, which are used, or regenerated, alternately for adsorbing adsorption coolant, such that a quasi-continuous cooling is possible.

[0004] Adsorption cooling systems have the advantage that there is no need for a compressor, enabling the amount of energy required to be reduced and the system reliability to be increased. Further, an adsorption cooling system can be operated with relatively little noise. Finally, an adsorption cooling system does not require any coolant containing fluorocarbons, but can be operated in an environmentally benign manner with water. Known adsorption cooling systems, however, are still deficient in respect of their energy efficiency.

[0005] The invention is based on the object of provided an adsorption cooling system that can be operated in an energy efficient manner and that is suitable for use on board an aircraft. Further, the invention is directed towards the object of specifying a method for operating such an adsorption cooling system.

[0006] This object is achieved by an adsorption cooling system for an aircraft having the features of Claim **1**, and by a method for operating an adsorption cooling system for an aircraft having the features of Claim **7**.

[0007] The adsorption cooling system, according to the invention, for an aircraft comprises an evaporator realized, for example, in the form of a heat exchanger. The evaporator serves to transform a liquid adsorption coolant, for example water, into the gaseous state of matter. The adsorption cooling system further comprises a first adsorber, which contains a first adsorption medium for adsorbing the adsorption coolant evaporated in the evaporator. A second adsorber of the adsorption cooling system according to the invention contains a second adsorption medium for adsorbing the adsorption coolant evaporated in the evaporator. Activated carbon, zeolite or silica gel can be used as an adsorption medium, the same adsorption medium or differing adsorption media being able to be used in the first and in the second adsorber. The first and the second adsorber of the adsorption cooling system according to the invention can be operated alternately in an adsorption mode, in which adsorption coolant is adsorbed at the adsorption medium of the adsorber, and in a desorption mode, in which adsorption coolant taken up by the adsorption medium of the adsorber is desorbed. Consequently, the adsorption cooling system can be operated in a quasi-continuous manner, since one adsorber can adsorb adsorption coolant and the other adsorber can be regenerated.

[0008] The adsorption cooling system according to the invention further comprises a heat transfer system, which is adapted to transfer heat energy, by means of a heat transfer fluid, during a transitional operating phase, during which one adsorber is brought from adsorption mode to desorption mode and the other adsorber is brought from desorption mode to adsorption mode, from the adsorber that is brought from desorption mode to adsorption mode to the adsorber that is brought from adsorption mode to desorption mode. In other words, the heat transfer system of the adsorption cooling system according to the invention is able to transfer the heat energy, which is stored in an adsorber operated in desorption mode because of the supply of regeneration energy into the adsorber, to an adsorber to be brought from adsorption mode to desorption mode, and to use it there as regeneration energy. The adsorption cooling system according to the invention can therefore be operated in a particularly energy efficient manner. Moreover, the transitional operation phase can be shortened and, consequently, an improved quasi-continuous operation of the adsorption cooling system can be realized.

[0009] The heat transfer system can comprise a line network and a plurality of valves, which are disposed in the line network and which can be switched appropriately in order to transfer, by means of the heat transfer fluid, heat energy from the adsorber that is brought from desorption mode to adsorption mode to the adsorber that is brought from adsorption mode to desorption mode.

[0010] The heat transfer system can further comprise a heating device, and be adapted to supply heat energy to an adsorber operated in desorption mode, for the purpose of regenerating the adsorber, or the adsorption medium contained in the adsorber. The heating device can be realized, for example, in the form of a heat exchanger, but can also be any other heating device, for example an electrical heating device. The heating device preferably serves to heat up the heat transfer fluid to an increased temperature. By means of the heat transfer fluid, the heat energy provided by the heating device can then be supplied to the adsorber to be regenerated.

[0011] A further increase in the energy efficiency of the adsorption cooling system according to the invention is possible if the heating device is thermally coupled to an aircraft device that gives off lost heat. The device giving off lost heat can be, for example, an air-conditioning system, a drive device or an energy storage device of the aircraft. For example, engine tap air or the waste heat produced during cooling of the engine tap air in the aircraft air-conditioning system can be used as a heat energy source for the heating device. It is also conceivable to use the waste heat produced by an auxiliary turbine, the so-called auxiliary power unit, as a heat energy source for the heating device. As a result, the overall energy requirement of the aircraft is reduced. Further, the weight of the aircraft is reduced, since the electrical generator can be of smaller dimensions, owing to the fact that there is no need to supply electrical energy to an electrically operated compressor of a compression cooling system or to an electrically operated heating device of an adsorption cooling system.

[0012] The heat transfer system of the adsorption cooling system according to the invention can further comprise a cooling device, and adapted to supply refrigerating energy to an adsorber operated in adsorption mode, for the purpose of cooling the adsorber, or the adsorption medium contained in the adsorber. The cooling of the adsorption medium of an adsorber operated in adsorption mode ensures that the adsorption medium retains its electrostatic attractive force for the gaseous adsorption coolant. Preferably, the cooling device is so designed that it cools the heat transfer fluid down to a desired low temperature, such that the refrigerating energy produced by the cooling device can be supplied, via the heat transfer fluid, to the adsorber operated in adsorption mode. For example, the cooling device can be realized in the form of a heat exchanger, in which ambient air is used as a refrigerating energy source. Preferably, the cooling device has a blower, which guides an ambient air flow over cooling fins of the cooling device that have heat transfer fluid flowing through them.

[0013] The adsorption cooling system according to the invention can further comprise a condenser for condensing adsorption coolant removed from an adsorber operated in desorption mode. The condenser can be connected to the evaporator, in order to supply the evaporator with adsorption coolant in the liquid state of matter for the purpose of renewed evaporation. Further, an expansion valve can be disposed between the condenser and the evaporator.

[0014] Further, the adsorption cooling system according to the invention preferably comprises a first pressure sensor, for measuring the adsorption coolant pressure in the condenser, a second pressure sensor, for measuring the adsorption coolant pressure in an adsorber, and an electronic control unit, which is adapted to acquire signals provided by the pressure sensors. In the case of the adsorption cooling system according to the invention, each adsorber is preferably equipped with a second pressure sensor, for measuring the adsorption coolant pressure in the adsorber. Preferably, the electronic control unit controls the heat transfer system of the adsorption cooling system according to the invention in such a way that, during the transitional operating phase, the supply of heat energy to the adsorber brought from adsorption mode to desorption mode is terminated when the adsorption coolant pressure in the adsorber corresponds to the adsorption coolant pressure in the condenser. Adsorption coolant is thereby prevented from flowing from the condenser into the adsorber when a fluid connection between the condenser and the adsorber is opened at the start of the desorption mode of the adsorber.

[0015] In the case of a method, according to the invention, for operating an adsorption cooling system for an aircraft, comprising an evaporator, a first adsorber, which contains a first adsorption medium for adsorbing an adsorption coolant evaporated in the evaporator, and a second adsorber, which contains a second adsorption medium for adsorbing the adsorption coolant evaporated in the evaporator, the first and the second adsorber being able to be operated alternately in an adsorption mode and in a desorption mode, such that one adsorber can adsorb adsorption coolant and the other adsorber can be regenerated, heat energy is transferred, by means of a heat transfer fluid, during a transitional operating phase, during which one adsorber is brought from adsorption mode to desorption mode and the other adsorber is brought from desorption mode to adsorption mode, from the adsorber that is brought from desorption mode to adsorption mode to the adsorber that is brought from adsorption mode to desorption mode.

[0016] The heat transfer system of the adsorption cooling system preferably comprises a line network and a plurality of valves, which are disposed in the line network and which can be switched appropriately in order to transfer during the transitional operating phase, by means of the heat transfer fluid, heat energy from the adsorber that is brought from desorption mode to adsorption mode to the adsorber that is brought from adsorption mode to desorption mode.

[0017] A heating device of the heat transfer system preferably supplies heat energy to an adsorber operated in desorption mode, for the purpose of regenerating the adsorber, or the adsorption medium contained in the adsorber.

[0018] Preferably, lost heat is supplied to the heating device from an aircraft device that gives off lost heat.

[0019] In the case of a preferred embodiment of the method according to the invention, a cooling device of the heat transfer system supplies refrigerating energy to an adsorber operated in adsorption mode, for the purpose of cooling the adsorber, or the adsorption medium contained in the adsorber.

[0020] Preferably, adsorption coolant removed from an adsorber operated in desorption mode is condensed in a condenser. An electronic control unit can acquire signals from a first pressure sensor, for measuring the adsorption coolant pressure in the condenser, and from a second pressure sensor, for measuring the adsorption coolant pressure in an adsorber, and can control the heat transfer system of the adsorption cooling system according to the invention in such a way that, during the transitional operating phase, the supply of heat energy to the adsorber brought from adsorption mode to desorption mode is terminated when the adsorption coolant pressure in the adsorber corresponds to the adsorption coolant pressure in the condenser.

[0021] The invention is now described in greater detail with reference to the appended figures, wherein:

[0022] FIG. **1** shows an adsorption cooling system in an operating state in which adsorption coolant is desorbed in a first adsorber and adsorption coolant is adsorbed in a second adsorber;

[0023] FIG. **2** shows the adsorption cooling system according to FIG. **1** in an operating state in which the adsorber is switched over between an adsorption mode and a desorption mode;

[0024] FIG. **3** shows the adsorption cooling system according to FIG. **1** in an operating state in which adsorption coolant is adsorbed in the first adsorber and adsorption coolant is desorbed in the second adsorber; and

[0025] FIG. **4** shows the adsorption cooling system according to FIG. **1** in an operating state in which the adsorber is again switched over between an adsorption mode and a desorption mode.

[0026] An aircraft adsorption cooling system **1** shown in the figures has a first adsorber **2** comprising a first adsorption medium, has a second adsorber **4** comprising a second adsorption medium, has a condenser **8**, an expansion valve **6** and an evaporator **18**. The adsorption medium (not shown) in the adsorbers **2**, **4** can be, for example, activated carbon, zeolite, silica gel. The adsorption cooling system **1** further comprises an adsorption coolant circuit **9**, in which an adsorption coolant is circulated and in which a first adsorption control valve **10**, a second adsorption control valve **12**, a third adsorption control valve **14** and a fourth adsorption control valve **16** are disposed. Water and/or alcohol, for example, may be used as an adsorption coolant.

[0027] In the evaporation of the adsorption coolant in the evaporator **18**, refrigerating energy is released in the form of evaporation cold, which can be routed to a place of use, for example by means of an air stream generated by an evaporator blower **20**. The evaporator **18**, realized as a heat exchanger, need not necessarily cool air, but can cool any cooling medium, for example any fluid or any solid. The cooling energy generated by the evaporator **18** can be used to cool a partial region of a cabin, a partial region of a galley, a food trolley in the galley, an electronic device, for example a flight control device, an electronic entertainment system, etc.

[0028] Adsorption coolant evaporated in the evaporator **18** is taken up by the adsorption medium of an adsorber **2**, **4** operated in adsorption mode. The adsorbing of the gaseous adsorption coolant causes the partial pressure of the adsorption coolant in the evaporator **18** to be reduced. This results in further liquid adsorption coolant evaporating in the evaporator **18**. On the other hand, adsorption coolant in the gaseous state of matter is removed from an adsorber **2**, **4** operated in desorption or regeneration mode, and is routed into the condenser **8**. A reservoir (not shown) may be located in the condenser **8** or downstream from the condenser **8**. After being condensed in the condenser **8**, the adsorption coolant is brought back into the evaporator **18**, via the expansion valve **6**, for renewed evaporation.

[0029] In the operating state of the adsorption cooling system **1** shown in FIG. **1**, the second adsorber **4** is operated in adsorption mode, while the first adsorber **2**, or the first adsorption medium in the first adsorber **4**, is regenerated. The first adsorption control valve **10** and the fourth adsorption control valve **16** are open, whereas the second adsorption control valve **12** and the third adsorption control valve **14** are closed.

[0030] Explained more fully in the following is a heat transfer system of the adsorption cooling system **1**, which serves to supply cooling energy or heat energy, as required, to the adsorbers **2**, **4** and the condenser **8**. Disposed in a line network of the heat transfer system, through which there flows a heat transfer fluid, are a heating device **50**, a cooling device **52**, a first supply valve **60**, a second supply valve **62**, a third supply valve **64**, a fourth supply valve **66**, a fifth supply valve **68**, a sixth supply valve **70**, a seventh supply valve **72**, an eighth supply valve **74** and a ninth supply valve **76**. The heat transfer fluid can be conveyed through the line network by natural convection or by a forced convection generated by a first pump **54** and a second pump **56**. The heat transfer fluid can be both gaseous and liquid, a liquid heat transfer fluid being preferred. The heat transfer fluid can be, for example, water, a mixture of water and glycol, or a perfluor polyether, e.g. that offered by Solvay Solexis under the brand name Galden HT 135.

[0031] Waste heat, which is produced as lost heat in another device of the aircraft, is supplied to the heating device **50**. The lost heat can be, for example, lost heat produced by a turbine, an internal combustion engine, an electric motor, an ancillary set or an energy storage device of the aircraft. It is also possible to use the lost heat produced during cooling of engine tap air. In the case of present-day aircraft, this lost heat is dissipated to the environment of the aircraft via ram air heat exchangers. It is also possible, however, for the heating device **50** to be supplied directly with engine tap air, or to be realized in the form of an electrical heating device.

[0032] In the operating state of the adsorption cooling system **1** represented in FIG. **1**, the first supply valve **60**, the fourth supply valve **66**, the fifth supply valve **68** and the eighth supply valve **74** are open, whereas the second supply valve **62**, the third supply valve **64**, the sixth supply valve **70** and the seventh supply valve **72** are closed. The heat transfer fluid heated in the heating device **50** is pumped by the first pump **54**, through the open first supply valve **60**, to the first adsorber **2**. In the first adsorber **2**, the heat transfer fluid provides heat to the first adsorption medium of the first adsorber **2**. As a result, the first adsorption medium of the first adsorber **2** can be regenerated. The heat transfer fluid emerges from the first adsorber **2** and flows, via the open eighth supply valve **74**, to the heating device **50**, where it is again heated.

[0033] Warm heat transfer fluid can continue to be supplied to the first absorber **2** until the adsorption medium contained in the first adsorber **2** is fully regenerated. It is understood that the supply of heat to the first adsorber **2** can also be interrupted before the latter is fully regenerated. This can be necessary, for example, if the second adsorption medium in the second adsorber **4** is fully saturated before the first adsorption medium in the first adsorber **2** is fully regenerated.

[0034] The cooling device **52** serves to cool heat transfer fluid for cooling the second adsorber **4**, in adsorption mode, to a desired low temperature. In the cooling device **52**, heat transfer fluid can be cooled, for example, by an air flow that is taken from the environment and that is directed, by means of a cooling device blower **58**, onto fins of the cooling device, through which the heat transfer fluid flows. The second pump **56** pumps the cooled heat transfer fluid from the cooling device **52**, through the open fourth supply valve **66**, to the second adsorber **4**. In the second adsorber **4**, the heat transfer fluid cools the second adsorption medium of the second adsorber **4**. As a result the adsorption performance of the second adsorber **4** is improved, since the electrostatic attractive force of the adsorption medium for the adsorption coolant is stronger at a lower temperature. The heat transfer fluid flows from the second adsorber **4**, through the open fifth supply valve **68**, back to the cooling device **52**, where it is again cooled.

[0035] Further, the heat transfer fluid is pumped from the cooling device **52**, by means of the second pump **56**, to the condenser **8**, where it is used to remove the waste heat of condensation produced by the condensation of the adsorption coolant in the condenser **8**. After it has flowed through the condenser **8**, the heat transfer fluid, which was heated as it flowed through the condenser **8**, is returned to the cooling device **52** for renewed cooling.

[0036] In the following, the following symbols are used for calculation of the required cooling power and heating power of the adsorption cooling system **1**:

A	[m^2]	area
a_m		dead mass ratio
c_p	[kJ/(kgK)]	specific heat capacity
COP		coefficient of performance/heat ratio
Q	[J]	quantity of heat
$\dot{Q}$	[W]	heat flow
$\dot{\bar{Q}}$	[W]	mean heat flow
h	[kJ/kg]	specific enthalpy
k	[W/(m^2K)]	heat transfer coefficient
m	[kg]	mass
$\dot{m}$	[kg/s]	mass flow
$\dot{V}$	[m^3/s]	volume flow
P	[W]	electric power
p	[Pa]	pressure
r	[kJ/kg]	evaporation enthalpy
t	[s]	time
T	[K]	temperature
q	[kg_w/kg_z]	loading
x		proportionality factor
Δ		difference
ϑ	[° C.]	temperature
λ	[W/(mK)]	thermal conductivity
ρ	[kg/m^3]	density

Indices:

[0037]

0	evaporator, evaporation
1	initial state
2	end state
erf	required
hr	heat recovery
htf	heat transfer fluid
hx	heat exchanger
in	intake
out	output
A	start of adsorption
Abk	cool-down
Auf	heat-up
Ads	adsorption
Ads1	adsorber 1
Ads2	adsorber 2
D	start of desorption
Des	desorption
Kond	condenser, condensation
Kühl	cooling
max	maximal
min	minimal
reg	regeneration
S	saturation

-continued

W	water
Z	zeolite

[0038] The power required for desorbing the first adsorber **2** to be regenerated is:

$$\dot{Q}_{Des} = \dot{m}_{htf} \cdot c_p^{htf} \cdot \left(T_{Des,out}^{htf} - T_{Des,in}^{htf}\right) \tag{1}$$

[0039] The cooling power required for cooling the condenser **8** and the adsorbing adsorber **4** can be calculated as follows:

$$\begin{aligned} \dot{Q}_{Kühl} &= \dot{Q}_{kond} + \dot{Q}_{Ads} \\ &= \dot{m}_{Kond}^{htf} \cdot c_p^{htf} \cdot \left(T_{kond,out}^{htf} - T_{Kond,in}^{htf}\right) + \\ &\quad \dot{m}_{Ads}^{htf} \cdot c_p^{htf} \cdot \left(T_{Ads,out}^{htf} - T_{Ads,in}^{htf}\right) \end{aligned} \tag{2}$$

wherein:

$$\dot{m}_{Ads}^{htf} + \dot{m}_{Kond}^{htf} = \dot{m}_{Kühl}^{htf} \text{ and}$$

$$T_{Ads,in}^{htf} = T_{Kond,in}^{htf};$$

[0040] Once the second adsorption medium of the second adsorber **4** is saturated, it must be regenerated. An adsorption medium is saturated when it can no longer adsorb further adsorption coolant.

[0041] FIG. **2** shows a transitional operating state, in which the first adsorber **2** is prepared for adsorption mode and the second adsorber **4** is prepared for desorption mode. For this, it is necessary for the first adsorber **2**, or the first adsorption medium, to be cooled, and for the second adsorber **4**, or the second adsorption medium, to be heated. During the transitional operating phase, the first, the second, the third and the fourth adsorption control valve **10**, **12**, **14**, **16** are closed, and the blower **20** of the evaporator is switched off, such that the adsorption cooling system **1** does not provide any cooling power during the transitional operating phase.

[0042] In the line network of the heat transfer system, the second supply valve **62**, the third supply valve **64**, the fifth supply valve **68** and the eighth supply valve **74** are open during the transitional operating state. On the other hand, the first supply valve **60**, the fourth supply valve **66**, the sixth supply valve **70**, the seventh supply valve **72** and the ninth supply valve **76** are closed. In addition, the cooling device **52**, the cooling device blower **58** and the heating device **50** can be switched off. The second pump **56** therefore pumps relatively cool heat transfer fluid from the second adsorber **4**, via the fifth supply valve **68**, the cooling device **52** and the second supply valve **62**, to the first adsorber **2**. The heat transfer fluid in the second adsorber **4** has a relatively lower temperature, since the second adsorber **4** has been cooled by the heat transfer fluid during the adsorption mode.

[0043] The heat transfer fluid is heated in the first adsorber **2** through transfer of heat from the first adsorption medium and flows, via the eighth supply valve **74**, the heating device **50**, the first pump **54** and the third supply valve **64**, back to the second adsorber **4**. The heat transfer fluid consequently transports heat energy from the first adsorber **2** to the second adsorber **4** and, conversely, transports refrigerating energy, i.e. negative heat energy, from the second adsorber **4** to the first adsorber **2**. The closed ninth supply valve **76** prevents heat transfer fluid from flowing through the condenser **8** during the transitional operating phase.

[0044] Since heat energy is transported from the first adsorber **2** to the second adsorber **4** and, conversely, refrigerating energy is transported from the second adsorber **4** to the first adsorber **2**, the adsorption cooling system **1** requires less energy during the transitional operating phase. Further, the switch-over of the adsorbers **2**, **4** from adsorption mode to desorption mode and vice versa can be accelerated and, consequently, the duration of the transitional operating phase during which the adsorption cooling system **1** does not provide any cooling power can be shortened.

[0045] During the transitional operating phase, the adsorption cooling system **1** can be regarded as adiabatic, since only a heat exchange is effected within the adsorption cooling system **1**. The quantity of heat transferred from the first adsorber **2** to the second adsorber **4** can be represented as follows:

$$Q_{reg} \underline{\int \dot{m}_{htf} \cdot c_p^{htf} \cdot \left(T_{Abk,out}^{htf} - T_{Abk,in}^{htf}\right) \cdot d\tau} = \underline{\int \dot{m}_{htf} \cdot c_p^{htf} \cdot \left(T_{Auf,out}^{htf} - T_{Auf,in}^{htf}\right) \cdot d\tau} \quad (3)$$

[0046] The first integral describes the quantity of heat removed from the first adsorber **2**, and the second integral describes the quantity of heat taken up by the second adsorber **4**.

[0047] It is understood that the heating device **50** can be switched on to provide additional thermal energy, and the cooling device **52** can be switched on to remove thermal energy, in order that the duration of the transitional operating phase can be shortened yet again.

[0048] Pressure sensors (not shown) are provided, respectively, in the condenser **8** and in the adsorbers **2**, **4** for the purpose of measuring the adsorption coolant pressure. The signals provided by the pressure sensors are acquired by an electronic control unit and are processed. In dependence on the pressure sensor signals, the electronic control unit controls the components of the adsorption cooling system **1** and, in particular, the valves **60**, **62**, **64**, **66**, **68**, **70**, **72**, **74**, **76** of the heat transfer system in such a way that, during the transitional operating phase, the supply of heat to the second adsorber **4** to be switched from adsorption mode to desorption mode is ended once the adsorption coolant pressure prevailing in this second adsorber **4** is equal to that in the condenser **8**. This prevents adsorption coolant from flowing from the condenser **8** into the second adsorber **4** when the fluid connection between the condenser **8** and the second adsorber **4** is opened during the desorption mode of the second adsorber **4**. Consequently, the circulating of the heat transfer fluid between the adsorbers **2**, **4** can be ended in a selective manner once the second absorber **4** has attained an operating state in which regeneration of the second adsorber can commence.

[0049] As an alternative or in addition thereto, the electronic control unit can control the components of the adsorption cooling system **1**, and in particular the valves **60**, **62**, **64**, **66**, **68**, **70**, **72**, **74**, **76**, of the heat transfer system in such a way that, during the transitional operating phase, the supply of heat to the second adsorber **4** to be switched from adsorption mode to desorption mode is ended if the temperature in the second adsorber **4** drops again after attaining a maximal value. For this purpose, the electronic control unit can acquire and process signals from temperature sensors (not shown) disposed in the adsorbers **2**, **4**.

[0050] Represented in FIG. **3** is an operating state of the adsorption cooling system **1** in which the first adsorber **2** adsorbs adsorption coolant and the second adsorber **4** is regenerated. For this purpose, the second adsorption control valve **12** and the third adsorption control valve **14** are opened, whereas the first adsorption control valve **10** and the fourth adsorption control valve **16** are closed. Adsorption coolant thus evaporates in the second adsorber **4**, which adsorption coolant flows, via the open second adsorption control valve **12**, to the condenser **8**, where it condenses. The adsorption coolant then flows to the expansion valve **6** and to the evaporator **18**, where it is evaporated. The gaseous adsorption coolant flows through the open third adsorption control valve **14** into the first adsorber **2**, where it is adsorbed by the first adsorption medium.

[0051] The first adsorber **2**, operated in absorption mode, and the condenser **8** are supplied with cooling energy by the heat transfer system. In contrast thereto, the heat transfer system transfers heat energy to the second adsorber **4**, operated in desorption mode. For this purpose, the second supply valve **62**, the third supply valve **64**, the sixth supply valve **70**, the seventh supply valve **72** and the ninth supply valve **76** are opened. The first supply valve **60**, the fourth supply valve **66**, the fifth supply valve **68** and the eighth supply valve **74** are closed. Consequently, the first pump **54** pumps heat transfer fluid, heated by the heating device **50**, through the open third supply valve **64** to the second adsorber **4**, such that the second adsorption medium becomes heated. The heat transfer fluid then emerges from the second adsorber **4** and flows, via the open sixth supply valve **70**, back to the heating device **50**.

[0052] The second pump **56** pumps heat transfer fluid, cooled by the cooling device **52**, through the ninth supply valve **76** to the condenser **8**. The heat transfer fluid flows from the condenser **8** back to the cooling device **52**. Further, the second pump **56** pumps the heat transfer fluid, cooled by the cooling device **52**, through the second supply valve **62** to the first adsorber **2**, such that the first adsorption medium becomes actively cooled. The adsorption coolant then flows back to the cooling device **52**.

[0053] Once the first adsorber **2** is saturated and/or the second adsorber **4** is regenerated, the adsorbers **2**, **4** can again be switched over. This is performed by means of a second switch-over operation, which corresponds substantially to the first switch-over operation shown in FIG. **2**, heat energy being transferred from the second adsorber **4** to the first adsorber **2** in the case of the second switch-over operation. This second switch-over operation is represented in FIG. **4**.

[0054] During the transitional operating phase illustrated in FIG. **4**, the first, second, third and fourth adsorption control valves **10**, **12**, **14**, **16** are closed. Consequently, the evaporator cannot provide any cooling power during the transitional operating phase. Further, the first supply valve **60**, the fourth supply valve **66**, the sixth supply valve **70** and the seventh supply valve **72** are open. The second supply valve **62**, the third supply valve **64**, the fifth supply valve **68**, the eighth supply valve **74** and the ninth supply valve **76** are closed. The heating device **50** and the cooling device **52** can be switched off. The first pump **54** and the second pump **56** pump warm heat transfer fluid from the second adsorber **4**, via the sixth supply valve **70**, the heating device **50** and the first supply valve **60**, to the first adsorber **2**, as a result of which the first adsorption medium becomes heated. Further, cool heat transfer fluid is routed from the first adsorber **2**, via the seventh supply valve **72**, the cooling device **52** and the fourth supply valve **66**, to the second adsorber **4**, as a result of which heat is removed from the second adsorption medium. The transitional mode is continued until at least the same adsorption coolant pressure prevails in the first adsorber **4** as in the condenser **8**. Otherwise, the transitional mode is effected as previously described with reference to FIG. **2**. After the transitional operating phase has ended, the adsorption cooling system **1** returns to the state described with reference to FIG. **1**. The adsorption cooling system goes through the previously described four operating states according to FIGS. **1** to **4** in a cyclical manner, in the sequence described.

[0055] The control unit of the adsorption cooling system **1** can control the adsorption control valves **10**, **12**, **14**, **16**, the expansion valve **6**, the supply valves **60**, **62**, **64**, **66**, **68**, **70**, **72**, **74**, **76**, the evaporator blower **20**, the heating device **50**, the cooling device **52** and the cooling device blower **58** as previously described with reference to FIGS. **1** to **4**. Further, volume flow sensors can be provided in the adsorption coolant circuit **9**, in order to determine whether an adsorber **2**, **4** is saturated. It is also possible for saturation of an adsorber **2**, **4** to be inferred from an increasing temperature in the evaporator **18**, measured by means of an appropriate temperature sensor. If during regeneration of an adsorber **2**, **4**, it is found that the temperature of the heat transfer fluid is not decreasing (substantially) as it flows through the adsorber **2**, **4**, the adsorber **2**, **4** may be fully regenerated. Consequently, a plurality of temperature sensors can be provided, disposed in the line network of the heat transfer system. The signals of the volume flow sensors and of the temperature sensors are acquired by the control device, and converted into corresponding control signals for controlling the components of the adsorption cooling system **1**.

[0056] Further, the heating device **50** and the cooling device **52** need not be switched off if no heating or cooling is wanted. Instead, corresponding bypass lines and/or bypass valves can be provided, which cause the heat transfer fluid to flow past one of these devices. These can be appropriate, for example, if the heating device **50** is supplied with heat energy from a device that always gives off lost heat.

1-10. (canceled)

11. Adsorption cooling system for an aircraft, comprising:

an evaporator,

a first adsorber, which contains a first adsorption medium for adsorbing an adsorption coolant evaporated in the evaporator,

a second adsorber, which contains a second adsorption medium for adsorbing the adsorption coolant evaporated in the evaporator, the first and the second adsorber being adapted to be operated alternately in an adsorption mode and in a desorption mode, such that one adsorber can adsorb adsorption coolant and the other adsorber can be regenerated,

a heat transfer system, which is adapted to transfer heat energy, by means of a heat transfer fluid, during a transitional operating phase, during which one adsorber is brought from adsorption mode to desorption mode and the other adsorber is brought from desorption mode to adsorption mode, from the adsorber that is brought from desorption mode to adsorption mode to the adsorber that is brought from adsorption mode to desorption mode,

a condenser, for condensing adsorption coolant removed from an adsorber operated in desorption mode, which adsorption coolant, after having been condensed, is supplied to the evaporator,

a first pressure sensor, for measuring the adsorption coolant pressure in the condenser,

a second pressure sensor, for measuring the adsorption coolant in an adsorber, and

an electronic control unit, which is adapted to acquire signals provided by the pressure sensors and to control the heat transfer system of the adsorption cooling system in such a way that, during the transitional operating phase, the supply of heat energy to the adsorber brought from adsorption mode to desorption mode is terminated when the adsorption coolant pressure in the adsorber corresponds to the adsorption coolant pressure in the condenser.

12. Adsorption cooling system according to claim **11**, characterized in that the heat transfer system comprises a line network and a plurality of valves, which are disposed in the line network.

13. Adsorption cooling system according to claim **11**, characterized in that the heat transfer system comprises a heating device, and is adapted to supply heat energy to an adsorber, operated in desorption mode, for the purpose of regenerating the adsorber.

14. Adsorption cooling system according to claim **13**, characterized in that the heating device is thermally coupled to an aircraft device that gives off lost heat.

15. Adsorption cooling system according to claim **11**, characterized in that the heat transfer system further comprises a cooling device, and is adapted to supply refrigerating energy to an adsorber, operated in adsorption mode, for the purpose of cooling the adsorber.

16. Method for operating an adsorption cooling system for an aircraft, the adsorption cooling system comprising:

an evaporator,

a first adsorber, which contains a first adsorption medium for adsorbing an adsorption coolant evaporated in the evaporator, and

a second adsorber, which contains a second adsorption medium for adsorbing the adsorption coolant evaporated in the evaporator, the first and the second adsorber being adapted to be operated alternately in an adsorption mode and in a desorption mode, such that one adsorber can adsorb adsorption coolant and the other adsorber can be regenerated,

wherein, in the method for operating an adsorption cooling system,

heat energy is transferred, by means of a heat transfer fluid, during a transitional operating phase, during which one adsorber is brought from adsorption mode to desorption mode and the other adsorber is brought from desorption mode to adsorption mode, from the adsorber that is brought from desorption mode to adsorption mode to the adsorber that is brought from adsorption mode to desorption mode,

adsorption coolant, removed from an adsorber operated in desorption mode, is condensed in a condenser and supplied to the evaporator, and

an electronic control unit acquires signals from a first pressure sensor, for measuring the adsorption coolant pressure in the condenser, and from a second pressure sensor, for measuring the adsorption coolant pressure in an adsorber, and controls the heat transfer system of the adsorption cooling system in such a way that, during the transitional operating phase, the supply of heat energy to the adsorber brought from adsorption mode to desorption mode is terminated when the adsorption coolant pressure in the adsorber corresponds to the adsorption coolant pressure in the condenser.

17. Method according to claim **16**,

characterized in that the heat transfer system comprises a line network and a plurality of valves, which are disposed in the line network and which are appropriately controlled in order to transfer heat energy during the transitional operating phase, by means of the heat transfer fluid, from the adsorber that is brought from desorption mode to adsorption mode to the adsorber that is brought from adsorption mode to desorption mode.

18. Method according to claim **16**,

characterized in that a heating device of the heat transfer system supplies heat energy to an adsorber, operated in desorption mode, for the purpose of regenerating the adsorber.

19. Method according to claim **18**,

characterized in that lost heat is supplied to the heating device from an aircraft device that gives off lost heat.

20. Method according to claim **16**,

characterized in that a cooling device of the heat transfer system supplies refrigerating energy to an adsorber, operated in adsorption mode, for the purpose of cooling the adsorber.

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