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United States Patent	12384223
Kind Code	B2
Date of Patent	August 12, 2025
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Refrigerant circuit for a vehicle, and method for controlling such a circuit

Abstract

A thermal regulation circuit for a vehicle includes a first heat exchanger, a second heat exchanger, and a third heat exchanger. The first and the second heat exchangers are situated in series such that an ambient air flow passes through the first heat exchanger prior to passing through the second heat exchanger. The ambient air flow also passes through the third heat exchanger. The thermal regulation circuit is configured to allow a refrigerant fluid to circulate through the first heat exchanger and then the third heat exchanger. The thermal regulation circuit is configured to allow a heat-transfer fluid to circulate through the second heat exchanger.

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Appl. No.:	17/641222
Filed (or PCT Filed):	September 07, 2020
PCT No.:	PCT/FR2020/051542
PCT Pub. No.:	WO2021/048490
PCT Pub. Date:	March 18, 2021

Prior Publication Data

Document Identifier	Publication Date
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Foreign Application Priority Data

FR

1909878

Sep. 09, 2019

Publication Classification**Int. Cl.:** **B60H1/00** (20060101); **B60H1/32** (20060101)**U.S. Cl.:**

CPC **B60H1/00921** (20130101); **B60H1/00385** (20130101); **B60H1/3211** (20130101); **B60H1/3227** (20130101); **B60H1/323** (20130101); B60H2001/00307 (20130101); B60H2001/00949 (20130101); B60H2001/3291 (20130101); Y02T10/70 (20130101)

Field of Classification Search

CPC: B60H (1/00921); B60H (1/00385); B60H (1/3211); B60H (1/3227); B60H (1/323); B60H (2001/00307); B60H (2001/00949); B60H (2001/3291); Y02T (10/70)

References Cited**U.S. PATENT DOCUMENTS**

Patent No.	Issued Date	Patentee Name	U.S. Cl.	CPC
5408843	12/1994	Lukas	62/506	F02B 29/0443
5899086	12/1998	Noda	62/238.7	B60H 1/323
6230505	12/2000	Noda	165/203	F25B 41/24
7310961	12/2006	Hoshi	62/244	B60H 1/00764
9592717	12/2016	Katoh	N/A	B60H 1/3213
10611212	12/2019	Kuroda	N/A	B60H 1/10
10717337	12/2019	Kim	N/A	B60L 58/24
10773586	12/2019	Lucke	N/A	H01M 10/6568
10787061	12/2019	Durrani	N/A	B60H 1/00921
10836233	12/2019	Allgaeuer	N/A	B60H 1/00392
10889157	12/2020	Kim	N/A	B60H 1/00921
10953727	12/2020	Hötzel	N/A	B60H 1/3211
10987997	12/2020	Hötzel	N/A	B60H 1/32281

11021037	12/2020	Hwang	N/A	B60H 1/323
11110778	12/2020	Semel	N/A	F25D 21/06
11167620	12/2020	Tan	N/A	B60H 1/00328
11214126	12/2021	Hötzel	N/A	B60H 1/321
11446978	12/2021	Bara	N/A	B60H 1/32284
11548349	12/2022	Li	N/A	B60H 1/3208
11679642	12/2022	Yahia	62/79	B60H 1/32284
11780287	12/2022	Li	62/190	B60H 1/00035
11794555	12/2022	Shimizu	N/A	B60H 1/22
11912105	12/2023	Shey	N/A	B60H 1/32284
11919368	12/2023	Shey	N/A	B60H 1/00921
11987095	12/2023	Kim	N/A	H01M 10/613
11987098	12/2023	Shey	N/A	F25B 41/24
11999216	12/2023	Harper	N/A	B60H 1/00278
2012/0304674	12/2011	Schwarzkopf	62/238.1	B60H 1/00385
2015/0052928	12/2014	Uchida et al.	N/A	N/A
2015/0217622	12/2014	Enomoto et al.	N/A	N/A
2019/0135071	12/2018	Hwang et al.	N/A	N/A
2019/0168569	12/2018	Lee	N/A	B60L 58/26
2019/0366800	12/2018	Durrani	N/A	B60H 1/00921
2022/0212517	12/2021	Yu	N/A	B60H 1/00392
2022/0212518	12/2021	Tan	N/A	B60L 58/26
2022/0332169	12/2021	Nicolas	N/A	B60H 1/143
2023/0019811	12/2022	Yahia	N/A	F25B 5/02
2023/0142706	12/2022	Vaddiraju	62/259.2	B60H 1/3227
2023/0147794	12/2022	Vaddiraju	165/104.14	B60H 1/00899
2023/0311611	12/2022	Kim	165/202	B60H 1/00921
2023/0356564	12/2022	Dong	N/A	B60H 1/00907
2023/0364963	12/2022	Kim	N/A	B60H 1/00392

2024/0042829	12/2023	Nicolas	N/A	B60H 1/00921
2024/0092138	12/2023	Yang	N/A	H01M 10/66
2024/0149641	12/2023	Shey	N/A	B60H 1/00342

FOREIGN PATENT DOCUMENTS

Patent No.	Application Date	Country	CPC
104114961	12/2013	CN	N/A
106029409	12/2015	CN	N/A
113748032	12/2020	CN	B60H 1/00278
102015016241	12/2016	DE	N/A
102017125170	12/2018	DE	N/A
102017220376	12/2018	DE	N/A
102015122721	12/2018	DE	B60H 1/00028
102020100428	12/2019	DE	B60H 1/00007
102018219859	12/2019	DE	N/A
2263894	12/2009	EP	B60H 1/00492
3260319	12/2016	EP	N/A
3480040	12/2018	EP	N/A
4112341	12/2022	EP	B60H 1/00899
3104495	12/2020	FR	B60H 1/00278
20190137682	12/2018	KR	N/A
2013/136148	12/2012	WO	N/A
2014/040854	12/2013	WO	N/A
2015010909	12/2014	WO	N/A
WO-2021156348	12/2020	WO	B60H 1/00278
WO-2022179917	12/2021	WO	N/A
WO-2022194806	12/2021	WO	B60H 1/00278
WO-2023239637	12/2022	WO	F01P 3/12

OTHER PUBLICATIONS

Office Action issued in counterpart Chinese application No. 202080062845.7, dated Jan. 10, 2024 (10 pages). cited by applicant

International Search Report and Written Opinion in corresponding International Application No. PCT/FR2020/051542, mailed Dec. 16, 2020 (12 pages). cited by applicant

Office Action issued in counterpart Chinese Patent Application No. 202080062845.7 mailed Mar. 20, 2025 (15 pages). cited by applicant

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Background/Summary

(1) The field of the present invention is that of refrigerant circuits for vehicles, in particular for motor vehicles. The invention also relates to a method for controlling such a circuit.

(2) Motor vehicles are currently equipped with a refrigerant circuit used to heat or cool various zones or various components of the vehicle. It is particularly known practice for this refrigerant circuit to be used to thermally treat an air flow sent into the interior of the vehicle.

(3) In another application of this circuit, it is known practice to cool an electrical storage device used to supply energy to the components of an electric powertrain of the vehicle, particularly an electric motor, capable of causing said vehicle to move, and an associated electric converter, intended to convert the DC electrical current delivered by the electrical storage device into AC current for powering the electric motor. The refrigerant circuit thus provides the energy capable of cooling the electrical storage device when it is used during driving phases. The refrigerant circuit is thus designed to cool this electrical storage device for temperatures that remain moderate.

(4) It is also known practice for the electrical storage device of the vehicle to be charged by connecting it for several hours to the domestic grid. This long charging technique allows the temperature of the electrical storage device to be kept below a certain threshold, which allows any system for cooling the electrical storage device to be dispensed with.

(5) A rapid charging technique may also be employed. It involves charging the electrical storage device at a high voltage and amperage, so as to charge the electrical storage device over a short time of a few minutes. This rapid charging causes heating of the electrical storage device, which needs to be cooled. This heating governs the rating of the components because this is one of the situations that are the most severe in terms of the cooling power that has to be supplied. For example it involves having to be able to dissipate more than 17 kW even when the ambient air temperature might be high, for example 40° C.

(6) Another factor in the rating of the device for conditions that are among the most severe in terms of the cooling power that has to be supplied is operation with a dissipated power equal, or close, to the maximum available power. This corresponds to conditions in which the ambient air temperature is high, namely 45° C., and the speed of the air flow available for cooling is 3 m/s. The temperature of a liquid coolant used for cooling the components of the electric powertrain of the vehicle is then required to be below a maximum permissible temperature T_{max} (for example 70° C.) after the cooling of the electric converter.

(7) In order to dissipate the heat that needs to be removed, each of the circuits comprises an exchanger intended for an exchange of heat between an external air flow and, respectively, the refrigerant fluid and the liquid coolant. In order to optimize thermal efficiency, the ideal would be for each exchanger to be able to have passing through it an ambient air flow, namely an air flow that has not already passed through another exchanger, the purpose of this being to avoid the temperature of the air flow passing through the exchanger then situated further downstream being higher than the ambient temperature as a result of having been heated by the exchanger upstream of it.

(8) That said, in a vehicle, these exchangers, which incidentally are known as front-end exchangers, are generally positioned at the front of the vehicle, behind the radiator grille, and the surface area available is limited. It is therefore necessary to position the exchangers one behind another in the direction of circulation of the air flow, and only one of them, situated furthest upstream, will be able to benefit from the ambient air, the air flow passing through the one situated further downstream then being at a temperature higher than the temperature of the ambient air.

(9) A first option is therefore to prioritize the cooling of the liquid-coolant circuit by positioning the associated front-end exchanger foremost, namely upstream according to the direction in which the air flow circulates. The cooling of the refrigerant fluid is then limited, and the components of that circuit, particularly the compressor thereof, then need to be oversized, in order to have the necessary cooling power available to them.

(10) Another option is to prioritize the cooling of the refrigerant-fluid circuit by positioning the associated front-end exchanger foremost, namely upstream according to the direction in which the air flow circulates. That said, it is then the cooling of the heat-transfer fluid that is limited.

(11) An alternative solution, corresponding to an unpublished patent application in the name of the applicant company, has been envisioned. This consists in sharing the foremost position between two exchangers, namely an exchanger associated with the refrigerant-fluid circuit and an exchanger associated with the liquid-coolant circuit, and in assigning second place to an exchanger dedicated to the refrigerant fluid. Although it affords a significant improvement, this solution can be improved still further.

(12) The invention seeks to at least partially alleviate the aforementioned problems and to this end proposes, in a first aspect, a circuit for the thermal regulation of a vehicle, said circuit comprising a first and a second heat exchanger which are situated in series in a direction in which an air flow intended to pass through them in this order circulates, said circuit comprising a third heat exchanger through which an ambient air flow is intended to pass, said circuit being configured to allow a refrigerant fluid to circulate in series through the first and third exchangers and a heat-transfer fluid to circulate through the second exchanger.

(13) What is meant by an “ambient air flow” is an air flow which has passed neither through the first exchanger nor through the second exchanger before passing through the third exchanger. In other words, the air flow concerned is at ambient temperature, namely at the temperature of the air outside the vehicle, when it passes through the third exchanger, because it has not been heated by another exchanger beforehand.

(14) In that way, the invention provides a high level of heat dissipating power in relation to the refrigerant-fluid circuit, being able in particular to provide one or more operating points corresponding to severe conditions of use, such as the rapid charging of an energy storage device, and doing so by virtue of the third heat exchanger which supplements the dissipation power of the first exchanger, and doing so all the more effectively given that the third exchanger is intended to exchange heat with ambient air. At the same time, the heat-dissipation capabilities of the heat-transfer fluid circuit are maintained by virtue of the second exchanger which is able to have an increased frontal surface area in comparison with a situation in which it shares the available frontal surface area with another exchanger.

(15) The circuit according to the invention can also comprise the following features, taken individually or according to any technically possible combination forming as many embodiments of the invention: said circuit is configured so that the circulation of the heat-transfer fluid allows a cooling of one or more components of an electric powertrain of the vehicle, said circuit is configured so that the series circulation of the refrigerant fluid through the first and third exchangers provide so-called rapid cooling of an electrical energy storage device and/or thermal treatment of an interior of the vehicle. said first and second heat exchangers are intended to be positioned on the front face of the vehicle, said first and second heat exchangers have substantially identical frontal surface areas, said third exchanger has a frontal surface area smaller than that of the first and/or second exchangers, said third exchanger is intended to be positioned on the front face of the vehicle, upstream of the first and second exchangers according to the direction of circulation of the air flow passing through them, said circuit comprises a fourth exchanger, configured to have the heat-transfer fluid passing through it, said circuit is configured to also selectively allow the heat-transfer fluid to circulate through the second exchanger and the heat-transfer fluid to circulate through the second and the fourth heat exchanger, the circulation of the heat-transfer fluid through the second heat exchanger and through the fourth heat exchanger is in series, the third exchanger and the fourth exchanger are positioned side-by-side in the direction of circulation of the air flow, said third exchanger and said fourth exchanger, considered together, have a frontal surface area substantially identical to the frontal surface area of said first and/or of said second heat exchanger, said circuit comprises at least one valve for directing the heat-transfer fluid downstream of the second exchanger selectively, according to the direction of circulation of said heat-transfer fluid, toward said fourth exchanger or toward the component or components of the electric powertrain of the vehicle, said circuit is configured to selectively allow the refrigerant

fluid to circulate through the first exchanger, or the refrigerant fluid to circulate in series through the first and third exchangers, said circuit is configured so that circulation of the refrigerant fluid through the first heat exchanger provides so-called operational cooling of the electrical storage device and/or thermal treatment of an interior of the vehicle, said circuit comprises a fifth exchanger, referred to as a bi-fluid heat exchanger, configured to allow an exchange of heat between said refrigerant fluid and said heat-transfer fluid, said circuit comprises a heating radiator intended to have the heat-transfer fluid passing through it, said circuit being configured so that the heat-transfer fluid circulating through the bi-fluid exchanger circulates through said radiator, in at least one mode of operation of said circuit, said circuit is configured so that, in at least one mode of operation, said fifth exchanger is situated upstream of said first exchanger in the direction of circulation of the refrigerant fluid, said circuit comprises a bottle configured for separating the vapor phase and the liquid phase of said refrigerant fluid, said bottle is incorporated into said first exchanger, said bottle is situated between said first and said third exchanger, in the direction of circulation of the refrigerant fluid.

(16) In another aspect of the invention, the applicant has noted that, given the different times at which the rapid charging of the battery and the conditions of operation at maximum power occur, there is another approach that can be taken for optimizing the dissipation of heat.

(17) Thus, according to another aspect of the invention, the invention relates to a method for controlling a circuit for the thermal regulation of a vehicle, said circuit comprising a first and a second heat exchanger which are situated in series in a direction in which an air flow intended to pass through them in this order circulates, said circuit further comprising an additional heat exchanger situated upstream of the first heat exchanger according to the direction of circulation of the air flow, said circuit being configured to allow a refrigerant fluid to circulate through the first exchanger and a heat-transfer fluid to circulate through the second exchanger and through the additional exchanger, said method comprising a step in which a flow of the heat-transfer fluid in the additional exchanger is generated or increased according to the mode of operation of the circuit.

(18) In other words, according to this aspect of the invention, the heat exchanger that is situated foremost, namely the additional heat exchanger, does not always have the heat-transfer fluid passing through it. It therefore does not heat the incident air flow. It is therefore possible to maintain a good heat-dissipation capability for the refrigerant fluid when the additional heat exchanger does not have the heat-transfer fluid passing through it, for example when the vehicle is stationary and the vehicle electrical storage device needs to be cooled. Conversely, when the additional heat exchanger does have the heat-transfer fluid passing through it, the dissipation power afforded by the heat-transfer fluid is optimized and allows the cooling of the vehicle powertrain, even under the most severe conditions such as operation at maximum power. max.

(19) The method according to the invention can also comprise the following features, taken individually or according to any technically possible combination forming as many embodiments of the invention: said circuit is configured in such a way that the air flow passing through said additional heat exchanger is an ambient air flow, said method comprises a step of controlling at least one parameter relating to the heat-transfer fluid, said parameter is the temperature of the heat-transfer fluid, the step in which the flow of the heat-transfer fluid in the additional exchanger is generated or increased is performed according to a value of said parameter, the step in which the flow of the heat-transfer fluid in the additional exchanger is generated or increased is performed by comparing the value of the parameter against a threshold value, said circuit is configured so that the circulation of the heat-transfer fluid allows a cooling of one or more components of an electric powertrain of the vehicle, said circuit is configured so that the circulation of the heat-transfer fluid allows a cooling of an electric converter intended to convert a DC electric current delivered by an electrical storage device into an AC current for powering an electric motor capable of causing said vehicle to move, the step in which the flow of the heat-transfer fluid in the additional exchanger is generated or increased occurs if the temperature of the heat-transfer fluid is slightly below, equal to

or greater than the maximum permissible temperature, said method comprises a step of selectively allowing a circulation of the heat-transfer fluid through the second exchanger and a circulation of the heat-transfer fluid through the second exchanger and through the additional heat exchanger, said circuit comprises at least one valve for directing the heat-transfer fluid downstream of the second exchanger selectively, according to the direction of circulation of said heat-transfer fluid, toward said additional heat exchanger or toward the component or components of the electric powertrain of the vehicle, said step in which the flow of the heat-transfer fluid in the additional exchanger is generated or increased comprises a step of opening/closing said valve, in an all-or-nothing mode and/or partially, said valve is formed by a thermostat and/or by an electronically controlled valve, the circulation of the heat-transfer fluid through the second heat exchanger and through the additional heat exchanger is in series, said first and second heat exchangers have substantially identical frontal surface areas, said additional exchanger has a frontal surface area smaller than or equal to that of the first and/or second exchangers, said first and second heat exchangers as well as said additional exchanger are intended to be positioned on the front face of the vehicle, the cooling fluid is cooled in the following sub-steps: a sub-step (a) wherein said air flow is generated and/or accelerated using a motor-fan unit, and/or a sub-step (b) wherein a cross section for the passage of said air flow is increased by opening one or more mobile flaps or shutters intended to limit a flow rate of said air flow, a sub-step (c) wherein the flow of the heat-transfer fluid through said additional heat exchanger is generated and/or increased. the order of said sub-steps is modified according to the speed of the vehicle, when the vehicle speed is above a threshold speed, there is an envisioned initial situation in which the flaps or shutters are closed so that the cross section for the passage of said air flow is nil or minimal when the vehicle speed is above the threshold speed, sub-step (c) is performed first of all, followed by sub-step (b) if that is still not enough to achieve a required setpoint when the vehicle is stationary and/or when the vehicle speed is below the threshold speed, sub-step (a) is performed first of all, and then, if that is still not enough to achieve a required setpoint, sub-step (c) is performed, when the vehicle is stationary and/or when the vehicle speed is below the threshold speed, sub-step (b) is performed if the setpoint has not been achieved at the end of sub-step (a), and then sub-step (c) is performed, if the setpoint has not been achieved at the end of sub-step (b), the load on a refrigerant-fluid circulation loop is reduced if the setpoint is not achieved despite implementation of sub-steps (a), (b) and (c), said threshold speed of the vehicle is adapted according to the ambient temperature, said circuit comprises an exchanger, known as a bi-fluid exchanger, configured to allow an exchange of heat between said refrigerant fluid and said heat-transfer fluid, said circuit comprises a heating radiator intended to have the heat-transfer fluid passing through it, said circuit being configured so that the heat-transfer fluid circulating through the bi-fluid exchanger circulates through said radiator, in at least one mode of operation of said circuit, said circuit is configured so that, in at least one mode of operation, the bi-fluid exchanger is situated upstream of said first exchanger in the direction of circulation of the refrigerant fluid, said circuit comprises a bottle configured for separating the vapor phase and the liquid phase of said refrigerant fluid, said bottle is incorporated into said first exchanger.

(20) This aspect of the invention can be combined with the first aspect of the invention. Said circuit then comprises the third heat exchanger as described above. In addition, the additional heat exchanger corresponds to the fourth exchanger of said first aspect of the invention.

(21) The invention also relates to a heat exchange module comprising the first, the second as well as the third heat exchanger and/or the fourth exchanger, namely the additional heat exchanger of the circuit described above. Advantageously, said module further comprises the valve that allows the selective directing of the heat-transfer fluid downstream of the second exchanger.

Description

- (1) Further features and advantages of the invention will become apparent from reading the following detailed description, for an understanding of which reference is made to the appended drawings, in which:
- (2) FIG. 1 schematically illustrates one exemplary embodiment of a first circuit according to the invention comprising a loop for the circulation of a refrigerant fluid and a loop for the circulation of a heat-transfer fluid,
- (3) FIG. 2 schematically illustrates the circulation of the various fluids according to a first mode of operation of the circuit of FIG. 1
- (4) FIG. 3 schematically illustrates the circulation of the various fluids according to a second mode of operation of the circuit of FIG. 1
- (5) FIG. 4 schematically illustrates the circulation of the various fluids according to a third mode of operation of the circuit of FIG. 1
- (6) FIG. 5 is a flow diagram illustrating one exemplary embodiment of a control method according to the invention.
- (7) As illustrated in FIGS. 1 to 4, the invention relates to a thermal regulation circuit for a vehicle, particularly a motor vehicle. It comprises in this instance a loop, particularly a closed loop, for the circulation of a refrigerant fluid and a loop, particularly a closed loop, for heat-transfer fluid.
- (8) The terms upstream and downstream used in the following description refer to the direction of circulation of the fluid in question, that is to say the refrigerant fluid, the heat-transfer fluid, a flow of air external to an interior of the vehicle and/or an interior air flow sent to the interior of the vehicle.
- (9) In FIG. 1, the refrigerant-fluid loop is illustrated in solid line and the heat-transfer fluid loop is illustrated in chain line. In FIGS. 2 to 4, for each of the loops, the portions through which their respective fluid is passing are shown in solid line and the portions without circulating fluid are shown in dotted line. Moreover, the circulation of the refrigerant fluid is illustrated with its direction of circulation indicated by arrows. Use is also made of solid line of different line thicknesses. More specifically, the thickest lines correspond to high-pressure portions, the intermediate-thickness lines correspond to intermediate portions and the thinnest lines correspond to low-pressure portions of the refrigerant-fluid loop.
- (10) The identifiers “first”, “second”, etc. used hereinafter are not intended to indicate a level of hierarchy of or to order the terms they accompany. These identifiers serve to distinguish the terms which they accompany and can be interchanged without narrowing the scope of the invention.
- (11) The refrigerant fluid is, for example, a fluid capable of transitioning from a liquid phase to a gas phase and vice versa under the temperature and pressure conditions of the circuit. It may be a fluid known by the name of R134a or a fluid known by the name of R1234yf. It may even be a fluid that remains essentially in the gaseous state, such as R744.
- (12) The heat-transfer fluid is, for example, a liquid, notably water with the addition of an antifreeze such as glycol.
- (13) Said circuit comprises a first heat exchanger 2, a second heat exchanger 4 and a third heat exchanger 6. Said circuit is configured to allow the refrigerant fluid to circulate in series through the first and third exchangers 2 and 6, and the heat-transfer fluid to circulate through the second exchanger 4. In other words, in this instance, the first and third exchangers are in the refrigerant-fluid circulation loop and the second exchanger 4 is in the heat-transfer fluid loop.
- (14) Furthermore, the first exchanger 2 and the third exchanger 6 are situated in series in a direction of circulation of an air flow, illustrated by an arrow identified F1, which flow is intended to pass through them in that order. For its part, the third heat exchanger 6 is intended to have passing through it an ambient air flow, in other words air that has not yet been heated by the first and/or the second exchangers 2 and/or 4. As will be detailed later on, in the embodiment illustrated, this is the same air flow F1 as passes through the first and second exchangers 2, 4, the air flow F1 therefore

passing, in this order, through the third exchanger **6**, the first exchanger **2** and the second exchanger **4**.

(15) By placing the first and third heat exchangers **2** and **6** in series with respect to the refrigerant fluid, a high heat-dissipation power is obtained, especially when the third exchanger **6** has fresh air passing through it and therefore cools the refrigerant fluid all the more effectively. The latter fluid can thus be used to cool various components or regions of the vehicle, even under the most severe conditions of use of the circuit. Furthermore, the second exchanger **4** can be used for cooling other components using the heat-transfer fluid, this being with the possibility of exhibiting a large frontal surface area because it is situated downstream of the first exchanger **2** in the direction of circulation of the air flow. This frontal surface area therefore does not interfere with that of the third exchanger **6** which is positioned either upstream of the first exchanger **2** in the direction of circulation of the air flow or elsewhere in the vehicle provided that it can have an ambient air flow passing through it.

(16) As will be expanded upon later on, the circuit may be configured so that the passage of the refrigerant fluid in series through the first and third exchangers **2** and **6** does not occur systematically but only in certain modes of operation. Such is the case in the example illustrated, in which series circulation occurs in the modes of operation of FIGS. **2** and **4** but not in the mode of operation of FIG. **3**.

(17) The first exchanger **2** is formed for example of a gas cooler or condenser. The third exchanger **6** is configured, for example, to perform supercooling of said refrigerant fluid after it has passed through the gas cooler or condenser. These may, for example, be the exchangers comprising a heat exchange core bundle of tubes and fins. The tubes are intended for the circulation of the refrigerant fluid. The fins are in contact with the tubes and are intended to have the air flow pass through them. Said condenser has one or more passes for the circulation of the refrigerant fluid.

(18) Said circuit is configured here so that the circulation of the heat-transfer fluid can be used, for example, to cool one or more components of an electric powertrain of the vehicle, such as an electric motor **8**, capable of causing said vehicle to move, and an associated electric converter **10**, intended to convert the DC electrical current delivered by an electrical storage device into AC current for powering the electric motor **8**. To do that, the heat-transfer fluid circulation loop advantageously comprises a first leg **12** passing in this order according to the direction of circulation of the heat-transfer fluid through the electric converter **10** and the electric motor **8**. As an alternative, the converter **10** and/or the motor **8** do not have the heat-transfer fluid passing through them directly, but are passed through by an auxiliary fluid, said auxiliary fluid exchanging heat with the heat-transfer fluid by means of a heat exchanger connected to the component concerned by a specific auxiliary-fluid circulation loop.

(19) In the embodiment illustrated, such cooling occurs in the mode of operation illustrated in FIG. **2**.

(20) Said circuit is furthermore in this instance configured so that circulation in series of the refrigerant fluid through the first and third exchangers **2** and **6** provides so-called rapid cooling of the electrical energy storage device and/or thermal treatment of an interior of the vehicle. The electrical energy storage device is not depicted as such. It may be in direct contact with a component of the refrigerant-fluid circulation loop such as a cooler **14**. As an alternative, it may be cooled by an auxiliary fluid, itself exchanging heat with the refrigerant fluid, for example by means of said cooler **14**. In the embodiment illustrated, the associated mode of operation, referred to as rapid cooling of the electrical energy storage device, is encountered, FIG. **4**.

(21) As a preference, said first and second heat exchangers **2**, **4** are intended to be positioned on the front face of the vehicle, for example behind the radiator grille thereof. They advantageously have substantially identical frontal surface areas, particularly so that each can occupy the largest available area. What is meant by frontal surface area is the surface area of the exchanger in a plane perpendicular to the air flow **F1**, namely in a plane substantially parallel to the radiator grille.

(22) Advantageously, as already mentioned, said third exchanger **6** is also intended to be positioned on the front face of the vehicle and have the air flow **F1** passing through it. It is therefore situated upstream of the first and second exchangers **2** and **4**, in the direction of circulation of the air flow.

(23) With such a location, said third exchanger **6** has a frontal surface area smaller than that of the first and/or second exchangers **2**, **4**. That said, this feature could also apply when the third exchanger **6** is sited at another location. In this regard, said third exchanger **6** may be situated, for example, in a wheel arch. Its frontal surface area is then tailored to the space available.

(24) Advantageously, said circuit comprises a fourth exchanger **16** which in this instance is positioned next to the third exchanger **6** so that the third and fourth exchangers **6** and **16** have said air flow **F1** passing through them in parallel. As a preference, said third exchanger **6** and said fourth exchanger **16**, considered together, have a frontal surface area substantially identical to the frontal surface area of said first and second heat exchangers **2** and **4**.

(25) The second exchanger **4** is formed, for example, of a cooling radiator. It may be qualified as a low-temperature radiator. The fourth exchanger **16** is configured, for example, to perform additional cooling of said heat-transfer fluid. It may be qualified as a very-low-temperature exchanger. These may, for example, be exchangers comprising a heat exchange core bundle of tubes and fins. The tubes are intended for the circulation of the cooling fluid. The fins are in contact with the tubes and are intended to have the air flow pass through them.

(26) Said circuit is configured to also selectively allow the heat-transfer fluid to circulate through the second exchanger **4**, without passing through the fourth exchanger **16**, as is the case in FIG. **4**, and the heat-transfer fluid to circulate through the second and the fourth heat exchangers **4** and **16**, as is the case in FIGS. **2** and **3**. In other words, in this instance, said fourth exchanger **16** is incorporated into the heat-transfer fluid circulation loop. When there is no circulation of heat-transfer fluid in the fourth exchanger **16**, this promotes the effectiveness of the first exchanger **2** because the air flow passing through the latter is then an air flow at ambient temperature, at least over that portion of said first exchanger **2** that lies facing the fourth exchanger **16**. When the heat-transfer fluid is circulating both through the second exchanger **4** and the fourth exchanger **16**, this promotes greater capacity for the heat-transfer fluid circulation loop to dissipate heat at the front face, especially when the fourth exchanger **16** has passing through it a flow of ambient air, as in the embodiment illustrated.

(27) The circulation of the heat-transfer fluid through the second heat exchanger **4** and through the fourth heat exchanger **16** is, in this instance, in series. As an alternative, it is in parallel.

(28) Said circuit further comprises at least one valve **18** for directing the heat-transfer fluid downstream of the second exchanger **4** selectively, according to the direction of circulation of said heat-transfer fluid, toward said fourth exchanger **16**, as in FIGS. **2** and **3**, or directly toward the rest of the circuit, as in FIG. **4**. This is, for example, a three-way valve, in this instance having a first inlet, a second inlet, and a common outlet.

(29) Said first inlet is connected, for example, to a portion **20** of a second leg **22** of the coolant-fluid circulation loop comprising said second exchanger **4**, said portion **20** allowing said fourth exchanger **16** to be bypassed after exiting the second exchanger **4**. Said second inlet is connected to the fourth heat exchanger **16**. Said common outlet is connected in particular to the first leg **12** of said cooling-fluid circulation loop.

(30) As an alternative, said valve **18** comprises a common inlet, a first outlet and a second outlet. The inlet is then connected to the second exchanger **4**, the first outlet to the portion **20** of the second leg **22** of the cooling-fluid circulation loop, and the second outlet to the fourth heat exchanger **16**.

(31) Said valve **18** is notably formed of a thermostat and/or of an electronically controlled valve allowing communication to be established selectively between the first and/or the second inlet of said valve and the common outlet and/or between the common inlet and the first and/or the second outlet.

(32) As mentioned above, as a preference, said circuit is configured to allow the refrigerant fluid to circulate selectively through the first exchanger **2** without passing through the third exchanger **6**, as in FIG. **3**, or the refrigerant fluid to circulate in series through the first and third exchangers **2** and **6**, as in FIGS. **2** and **4**. In that way, it is possible for the third exchanger **6** not to be used systematically, this potentially being advantageous for limiting the pressure drops in the refrigerant-fluid loop when the need to dissipate heat is limited.

(33) Such a mode of operation is for example employed for so-called operational cooling of the electrical storage device, which is to say cooling that requires less dissipation of heat than is required in the case of rapid recharging, and/or for a thermal treatment of the interior of the vehicle. Such is, for example, the case for operation in heat-pump mode, as in FIG. **3**. In such an embodiment, according to the embodiment illustrated, heat energy is taken from the air flow **F1** passing through the first exchanger **2** and restored, as will be expanded upon later, to an air flow illustrated as **F2** that is intended to enter the vehicle interior in order to heat same. Said circuit is thus configured so that the circulation of the refrigerant fluid through the first heat exchanger **2** without passing through the third exchanger **6** allows such a result to be achieved.

(34) As a preference, said circuit comprises a fifth exchanger **24**, known as a bi-fluid exchanger, configured to allow an exchange of heat between said refrigerant fluid in said heat-transfer fluid. Such an exchanger is therefore positioned both in the refrigerant-fluid loop and the cooling-fluid loop. This is, for example, a condenser, notably a condenser of the stacked plates type.

(35) As a preference, said circuit, particularly said heat-transfer fluid circulation loop, comprises a heating radiator **26** through which the heat-transfer fluid is intended to pass. Said circuit is configured so that the heat-transfer fluid circulating in the bi-fluid exchanger **24** circulates through said heating radiator **26**, according to at least one mode of operation of said circuit, notably the heat-pump mode mentioned above.

(36) In this mode, as illustrated in FIG. **3**, the heat energy is taken from the air flow **F1** passing through the first exchanger **2** and transmitted by said exchanger **2** to the refrigerant fluid. This energy is therefore transmitted to the cooling fluid by said fifth exchanger **24** and to the air flow **F2** intended to enter the vehicle interior by the heating radiator **26**.

(37) As a preference, said circuit is configured so that, in at least one mode of operation, said fifth exchanger **24** is situated upstream of said first exchanger **2** according to the direction of circulation of the refrigerant fluid. The modes of operation involved are, for example, an air conditioning mode encountered in FIG. **2** according to the embodiment illustrated, and/or the mode of rapid cooling of the electrical energy storage device (remember this is illustrated in FIG. **4**). Thus, in the modes concerned, the refrigerant fluid experiences all of the following: a pre-cooling in the fifth exchanger **24**, a cooling, possibly with change of phase, in the first exchanger **2** and, if necessary, a supercooling in the third exchanger **6**. The change in enthalpy of the refrigerant fluid is therefore optimized, making it possible to limit the amount of power that has to be supplied to the refrigerant-fluid loop, for the same performance.

(38) Said circuit may comprise a bottle, not illustrated, configured for separating the vapor phase and the liquid phase of said refrigerant fluid. Said bottle is, for example, incorporated into said first exchanger **2** which may, or may not, then comprise one or more supercooling passes within its core bundle. This supercooling combines with the cooling supplied by the third exchanger **6** in the modes of operation in which series circulation through the first and third exchangers **2** and **6** occurs. As an alternative, said bottle is situated between said first and third exchangers **2** and **6**, in the direction of circulation of the refrigerant fluid. Said bottle is advantageously furnished with a filter and/or with a desiccant.

(39) According to the embodiment illustrated, the cooling-fluid circulation loop comprises the first leg **8** and the second leg **22** already mentioned, as well as a third leg **28** and a fourth leg **30**, all of said legs **12**, **22**, **28**, **30** running parallel with one another.

(40) The first leg **12** comprises the electric converter **10** and the electric motor **8**. It further

comprises a first pump **32** for circulating the cooling fluid.

(41) The second leg **22** comprises the second exchanger **4** and the three-way valve **18**. In parallel with its portion **20**, it further comprises a sub-leg **34** equipped with said fourth exchanger **16**.

(42) The third leg **28** comprises the bi-fluid exchanger **26** and a second pump **36** for circulating the heat-transfer fluid.

(43) The fourth leg **30** comprises a first two-way valve **38** and the heating radiator **26**. In this instance it further comprises an electrical heating device **40** for heating the cooling fluid, and which is intended to be used in combination with the heating radiator **26**, if need be.

(44) Said cooling-fluid circulation loop may further comprise a second two-way valve **42**, situated between, on the one hand, the first and second legs **12** and **22** and, on the other hand, the third and fourth legs **28** and **30** on the downstream side of the second pump **36**.

(45) Said circuit, particularly said refrigerant fluid circulation loop, comprises a compression device **50** allowing said refrigerant fluid to be circulated. It will be noted that the compression device **50** can take the form of an electric compressor, that is to say a compressor which comprises a compression mechanism, an electric motor and possibly a controller.

(46) Downstream of said compression device **50**, said refrigerant-fluid circulation loop comprises said bi-fluid exchanger **24**, a third two-way valve **52**, said first exchanger **2**, said third exchanger **6**, a non-return valve **54**, a first pass **56** of an internal exchanger **58** and, in parallel with one another in respective legs, an evaporator **58** and the cooler **14**, and then an accumulator **60** and a second pass **62** of the internal exchanger **58**. These components succeed one another in this order in a sub-loop through which the refrigerant fluid returns to the compression device **50** after having passed through the second pass **62** of the internal exchanger **58**.

(47) Said circuit further comprises a first, a second and a third bypass leg **64**, **66** and **80**, for modifying the path of the refrigerant fluid.

(48) The first bypass leg **64** is situated between a first point of divergence **68** and a first point of convergence **70**. The first point of divergence **68** is situated between the third two-way valve **52** and the first exchanger **2**. The first point of convergence **70** is situated between the non-return valve **54** and the first pass **56** of the internal exchanger **58**. Said first bypass leg **64** comprises a first expansion member **76**. Said expansion member is configured to selectively completely open said first bypass leg **64**, completely close said first bypass leg **64**, or expand the refrigerant fluid circulating through said first bypass leg **64**.

(49) The second bypass leg **66** is situated between a second point of divergence **72** and a second point of convergence **74**. The second point of divergence **72** is situated between the bi-fluid exchanger **24** and the third two-way valve **52**. The second point of convergence **74** is situated between the first pass **56** of the internal exchanger **58** and a portion, in this instance a point, of the above-mentioned sub-loop allowing the evaporator **58** and the cooler **14** to be supplied in parallel. Said second bypass leg **66** comprises a fourth two-way valve **78**.

(50) The third bypass leg **80** is situated between a third point of divergence **82** and a third point of convergence **84**. The third point of divergence **82** is situated between the first exchanger **2** and the third exchanger **6**. The third point of convergence **84** is situated between, on the one hand, a portion, in this instance a point, of the above-mentioned sub-loop allowing the refrigerant fluid leaving the evaporator **58** and leaving the cooler **14** to be collected in parallel and, on the other hand, the accumulator **60**. Said third bypass leg **80** comprises a fifth two-way valve **86**.

(51) The refrigerant-fluid circulation loop further comprises a second and a third expansion member **88** and **90**, these respectively being situated upstream of the evaporator **58** and of the cooler **14** in the associated legs. Said expansion members are configured to selectively completely open said legs, completely close said legs, or expand the refrigerant fluid circulating through said legs.

(52) According to the mode of operation illustrated in FIG. 2, the circuit provides both an air conditioning mode and a mode in which the heat released by the component or components **8**, **10**

of the electric powertrain of the vehicle is dissipated in such a way as to cool the cooling fluid to below the maximum permissible temperature T_{max} downstream of the converter **10**, even in conditions of use such as operation at maximum power.

(53) In this mode of operation, the cooling fluid circulates in the first leg **12**, the second leg **22**, passing via the sub-leg **34**, and in the third leg **28**, but does not circulate through the fourth leg **30**. The three-way valve **18** is open so as to cause the cooling fluid to circulate through the fourth exchanger **16**, as explained above. The first two-way valve **38** is closed. The second two-way valve **42** is open. The first and/or second pumps **32**, **36** are active. Thus, the cooling fluid circulates in loop through the first and second legs **12**, **22** so that the heat released by the components of the powertrain **8**, **10** is dissipated into the air by the second and fourth exchangers **4**, **16**. If the cooling requirements remain limited, the cooling fluid may pass through the bypass portion **20** rather than through the sub-leg **34**. The cooling fluid also circulates through the third leg **28**, in parallel with the first leg **12**, in order to allow cooling of the refrigerant fluid at the bi-fluid exchanger **24**.

(54) Still in this mode of operation, the refrigerant fluid follows the sub-loop mentioned above. The fourth two-way valve **52** is open and said second and third expansion members **88** and **90** operate like an expansion valve. The first expansion member **76** is closed as are the fourth two-way valve **78** and the fifth two-way valve **86**. The dissipation of heat performed by the bi-fluid exchanger **24** into the cooling fluid and by the first and third exchangers **2** and **6** into the air flow **F1**, allows, on the one hand, the cooling of the electrical energy storage device, using the cooler **14** and, on the other hand, the air conditioning of the vehicle interior, using the evaporator **58** which cools the air flow **F2**, notably in phases during which the vehicle is moving.

(55) According to the mode of operation illustrated in FIG. **3**, as already mentioned, the circuit provides a heat-pump mode, in this instance without cooling of the electrical storage device even though a heat-pump mode remains compatible with operational cooling of said storage device using the circuit illustrated.

(56) In this mode of operation, the cooling fluid circulates in the first leg **12**, the second leg **22**, passing via the sub-leg **34**, and in the third leg **28**, and the fourth leg **30**. The three-way valve **18** is open so as to cause the cooling fluid to circulate through the fourth exchanger **16**, as explained above. The first two-way valve **38** and the second two-way valve **42** are open. The first and/or second pumps **32**, **36** are active. Thus, the cooling fluid circulates in a loop in the third and the fourth leg **28** and **30** so that the heat transmitted by the bi-fluid exchanger **24** is dissipated into the air flow **F2** by the heating radiator **26** to warm the vehicle interior. Circulation through the first leg **12** is in parallel with the circulation in the third leg **28**, so as to recover the heat released by the components of the electric powertrain **8**, **10**. As an alternative, the circulation of the cooling fluid through the second leg **22** may be shut off, in this instance using said three-way valve **18**.

(57) Still in this mode of operation, the refrigerant fluid follows a different path than that of the sub-loop mentioned above. The third two-way valve **52** is closed as are said second and third expansion members **88** and **90**. The first expansion member **76** operates as an expansion valve. The fourth two-way valve **78** and the fifth two-way valve **86** are open. Downstream of the compression device **50**, the refrigerant fluid thus passes in succession through said bi-fluid exchanger **24**, the fifth two-way valve **52**, the first pass **56** of the internal exchanger **58**, the first expansion member **76**, said first exchanger **2**, said sixth valve **86** and then the accumulator **60** and a second pass **62** of the internal exchanger **58**. The first exchanger **2** therefore operates as an evaporator and collects heat from the air flow **F1**, which heat will be transmitted to the air flow **F2** by the bi-fluid exchanger **24** and the heating radiator **26**.

(58) According to the mode of operation illustrated in FIG. **4**, as already mentioned, the circuit provides rapid cooling of the energy storage device. Such operation generally occurs when the vehicle is stationary and the other cooling requirements or heating requirements are generally low.

(59) In this mode of operation, the cooling fluid circulates in the second leg **22**, passing via the portion **20**, and in the third leg **28**, but circulates through neither the first leg **12** nor the fourth leg

30. The three-way valve **18** is open so as to cause the cooling fluid to circulate through the portion **20**, as explained above. The first two-way valve **38** is closed. The second two-way valve **42** is open. The first part **32** is inactive whereas the second pump **36** is active. In that way, the cooling fluid circulates in a loop through the second leg **12** and the third leg **28** so as to provide a minimum flow of cooling fluid through the bi-fluid exchanger **24** so that said cooling fluid does not begin to boil under the effect of the heat dissipated by the refrigerant fluid.

(60) Still this mode of operation, the refrigerant fluid follows the same path as in the case of FIG. 2, namely the sub-loop mentioned above. The dissipation of heat performed by the bi-fluid exchanger **24** into the cooling fluid and by the first and the third exchangers **2** and **6** into the air flow **F1** allows the rapid cooling of the energy storage device using the cooler **14**.

(61) Another aspect of the invention relates to a method for controlling a circuit for the thermal regulation of a vehicle. This may be the circuit described provided that it comprises said fourth exchanger **16** which is then qualified as an additional exchanger according to this aspect of the invention. That said, more broadly, said method may also apply to configurations without the third exchanger **6**, the remainder of the circuit then advantageously remaining the same.

(62) In the event of the absence of said third exchanger **6**, said additional heat exchanger **16** preferably has a frontal surface area substantially equal to that of the first and/or second heat exchangers **2**, **4**.

(63) According to this other aspect of the invention, said method comprises a step wherein a flow of heat-transfer fluid through the additional exchanger **16** is generated or increased according to the mode of operation of the circuit. In that way, whether or not a third exchanger **6** is available, this encourages the dissipation of heat by the cooling fluid by combining, where necessary, the second exchanger **4** and the additional exchanger **16**, as is the case for example in the mode of operation of FIG. 2, in the way already seen, this being all the more effective when said additional heat exchanger **16** has ambient air flow passing through it.

(64) More specifically, said method comprises a step of selectively allowing a circulation of the heat-transfer fluid through the second exchanger **4**, without it passing through the additional exchanger **16**, and a circulation of the heat-transfer fluid through the second exchanger **4** and through the additional heat exchanger **16**. The heat dissipation power is thus modified according to the requirements.

(65) As a preference, said method comprises a step of controlling at least one parameter relating to the heat-transfer fluid. This in particular is the temperature of the heat-transfer fluid.

(66) The step in which the flow of the heat-transfer fluid in the additional exchanger **16** is generated or increased is performed on the basis of a value of said parameter, notably by comparing the value of the parameter against a threshold value.

(67) By way of example, the step in which the flow of the heat-transfer fluid in the additional exchanger is generated or increased occurs if the temperature of the heat-transfer fluid is slightly below, equal to or greater than the maximum permissible temperature,

(68) Said step in which the flow of the heat-transfer fluid in the additional exchanger is generated or increased in this instance comprises a step of opening/closing said three-way valve **18**, in an all-or-nothing mode and/or partially.

(69) As illustrated in FIG. 5, the cooling fluid is cooled in the following sub-steps: a sub-step (a) wherein said air flow is generated and/or accelerated using a motor-fan unit, and/or a sub-step (b) wherein a cross section for the passage of said air flow is increased by opening one or more mobile flaps or shutters intended to limit a flow rate of said air flow, a sub-step (c) wherein the flow of the heat-transfer fluid through said additional heat exchanger **16** is generated and/or increased.

(70) Advantageously, the order of said sub-steps may moreover be modified according to the speed of the vehicle, notably according to the speed of the vehicle with respect to a threshold speed.

(71) In particular, when the vehicle speed is above the threshold speed, there is an envisioned initial situation in which the flaps or shutters are closed so that the cross section for the passage of said air

flow is nil or minimal.

(72) When the vehicle speed is above the threshold speed, sub-step (c) is performed first of all, followed by sub-step (b) if that is still not enough to achieve a required setpoint. On the other hand, sub-step (a) has very little effect.

(73) Successively, information about the vehicle is acquired in a first step **100**. The flow rate and the temperature of the cooling fluid as well as the speed and the temperature of the air flow **F1** are measured in a second step **102**. Information on the refrigerant-fluid circulation loop is acquired in a third step **104** and then a test is performed to check that the temperature of the liquid coolant is above a setpoint, possibly incorporating a measurement uncertainty, in a fourth step **106**.

(74) If the result of the fourth step **106** is negative, the monitoring continues, looping back to the first step **100**.

(75) If the result of the fourth step **106** is positive, then a test is performed to check if a rotational speed of the motor-fan unit is a maximum speed, in a fifth step **108**.

(76) If the result of the fifth step **108** is negative, then the speed of the motor-fan unit is increased, this being done in a sixth step **110**, and the monitoring continues, looping back to the first step **100**.

(77) If the result of the fifth step **108** is positive, then a test is performed to check whether the flaps or shutters are open to the maximum extent, in a seventh step **112**.

(78) If the result of the seventh step **112** is negative, then the extent to which the flaps or shutters are open is increased, this being done in an eighth step **114**, and the monitoring continues, looping back to the first step **100**.

(79) If the result of the seventh step **112** is positive, then a test is performed to check whether the flow rate through the additional heat exchanger **16** is at a maximum, in a ninth step **116**.

(80) If the result is negative, then the flow rate through the additional heat exchanger **16** is increased, notably using the three-way valve **18** mentioned above, this being done in one or more tenth steps **118**, and the monitoring continues, looping back to the first step **100**.

(81) In other words, when the vehicle is stationary and/or when the vehicle speed is below the threshold speed, sub-step (a) is performed first of all, and then, if that is still not enough to achieve the required setpoint, sub-step (b) is performed, and then, if that is still not enough to achieve the required setpoint, sub-step (c) is performed.

(82) Using such a strategy the possibility of keeping the temperature of the cooling fluid below the maximum permissible temperature T_{max} downstream of the converter **10** is optimized even under operating conditions such as PTC operation at maximum power.

(83) If such a result is not achieved, whether at high or at low speed, it is still possible to reduce the operating load of the refrigerant-fluid circulation loop, for example by limiting a maximum speed of the compression device **50**.

(84) This is illustrated in the embodiment of FIG. 5, for the case of the vehicle moving at low speed, and therefore in an eleventh step **120**. The choice is then made as to whether to prioritize good operation of the vehicle air conditioning, in a twelfth step **122**, or the cooling of the electrical storage device, in a thirteenth step **124**. The circulation of the refrigerant fluid through the exchangers concerned is then adapted in a fourteenth step **126**, following which the monitoring continues, looping back to the first step **100**.

(85) Advantageously, said threshold vehicle speed, namely the speed below or above which the order of steps (a), (b) and (c) varies, may be adjusted according to the ambient temperature.

(86) The invention further relates to a heat exchange module, not illustrated, comprising the first, the second as well as the third heat exchanger **2**, **4** and **6** and/or the fourth exchanger **16**. Said module may furthermore advantageously comprise the three-way valve **18**.

(87) The module comprises, for example, a frame on which said first heat exchanger **2**, second heat exchanger **4**, third heat exchanger **6**, fourth heat exchanger **16** and/or said three-way valve **18** are fixed. Said frame is configured to be fixed directly or indirectly to a chassis of the vehicle.

Claims

1. A thermal regulation circuit for a vehicle, said circuit comprising: a first and a second heat exchanger are situated in series such that an ambient air flow passes through the first heat exchanger prior to passing through the second heat exchanger; and a third heat exchanger, through which the ambient air flow is allowed to pass; said circuit being configured to allow a refrigerant fluid to circulate in series through the first heat exchanger and then the third heat exchangers, and to allow a heat-transfer fluid to circulate through the second heat exchanger, wherein said first and second heat exchangers have substantially identical frontal surface areas with respect to a plane perpendicular to a direction of circulation of the ambient air flow, and wherein said third heat exchanger is also configured to be positioned upstream of the first and the second heat exchangers with respect to the direction of circulation of the ambient air flow.
 2. The circuit as claimed in claim 1, configured so that the circulation of the heat-transfer fluid allows a cooling of one or more components of an electric powertrain of the vehicle and so that the series circulation of the refrigerant fluid through the first and third heat exchangers provides thermal treatment of an interior of the vehicle.
 3. The circuit as claimed in claim 2, further comprising: a fourth heat exchanger, wherein said circuit being configured to allow additionally, selectively permits circulation of the heat-transfer fluid through the second heat exchanger alone or circulation of the heat-transfer fluid through both of the second and fourth heat exchangers, wherein the fourth heat exchanger is configured to be positioned upstream of the first and second heat exchangers with respect to the direction of circulation of the ambient air flow.
 4. The circuit as claimed in claim 1, configured to selectively allow the refrigerant fluid to circulate through the first heat exchanger, or the refrigerant fluid to circulate in series through the first and third heat exchangers.
 5. The circuit as claimed in claim 4, configured so that circulation of the refrigerant fluid through the first heat exchanger provides thermal treatment of an interior of the vehicle.
 6. The circuit as claimed in claim 1, further comprising a fifth heat exchanger configured to allow an exchange of heat between said refrigerant fluid and said heat-transfer fluid; and a heating radiator configured to have the heat-transfer fluid passing through the heating radiator, said circuit being configured so that the heat-transfer fluid circulating through the fifth heat exchanger circulates through said radiator, in at least one mode of operation of said circuit.
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