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(71) **Applicant: HANON SYSTEMS** [KR/KR]; 95, Sinilseo-ro, Daedeok-gu, Daejeon 34325 (KR).

(72) **Inventors: DURRANI, Navid**; Maiglockchenweg 21, 50170 Kerpen (DE). **HOTZEL, Martin**; Feldstr. 53, 40882 Ratingen (DE).

(74) **Agent: HONESTY & JR PARTNERS INTELLECTUAL PROPERTY LAW GROUP**; 5F, 615 Sunreung-ro, Gangnam-gu, Seoul 06103 (KR).

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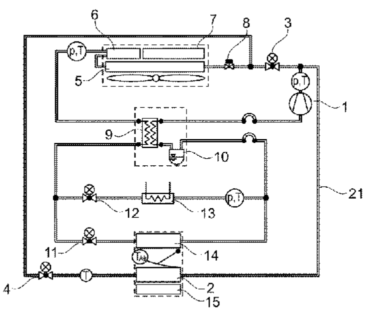
(54) **Title:** HEAT PUMP ARRANGEMENT FOR BATTERY ELECTRIC VEHICLES WITH R744 AS A REFRIGERANT AND METHODS FOR OPERATING THE HEAT PUMP ARRANGEMENT



(57) **Abstract:** The invention relates to a heat pump arrangement for battery electric vehicles with R744 as a refrigerant, having a refrigerant circuit with a compressor, a first expansion member, a first shut-off valve, a first external gas cooler, a second external gas cooler, an internal heat exchanger, a third expansion member, an evaporator and an accumulator, wherein parallel to the evaporator and to the third expansion member, a chiller with an associated fourth expansion member is arranged in the refrigerant circuit, and a heating gas cooler and a second expansion member are arranged in a heating gas cooler section, wherein the heating gas cooler section is arranged starting from the compressor and ending between the first expansion member and the first shut-off valve, and methods for operating the heat pump arrangement.

Description

Title of Invention: HEAT PUMP ARRANGEMENT FOR BATTERY ELECTRIC VEHICLES WITH R744 AS A REFRIGERANT AND METHODS FOR OPERATING THE HEAT PUMP ARRANGEMENT

Technical Field

[1] The invention relates to a heat pump arrangement for battery-operated vehicles with R744 as a refrigerant.

[2] The invention further relates to methods for operating the heat pump arrangement in selected operating modes, wherein the refrigerant circuit of the heat pump arrangement also comprises the cooling of the vehicle cabin and thus constitutes a combined heat pump and refrigeration system.

Background Art

[3] Electric battery-operated vehicles generate relatively little waste heat and thus, in such vehicles, there is a regular need to generate heat efficiently for heating the vehicle cabin and to make it available in a sufficient amount and at an appropriate temperature level.

[4] However, heat management systems for battery electric vehicles (BEVs) must allow for flexible operation within a wide range of operating conditions. The operation of the vehicle and thus of the heat management system is influenced by various factors, such as ambient and driving conditions, comfort for drivers and passengers, and the component operation with requirements for the high-voltage battery, the electric drive section and the control devices.

[5] With regard to these aspects, the heat management of a vehicle must enable comfort functions, such as interior air conditioning, within a desired temperature range and at the same time ensure safe operation of the vehicle, such as, for example, the demisting or de-icing of the windscreen.

[6] Modern heat management systems for battery electric vehicles allow for the incorporation of various heat sources and heat sinks, both via the refrigerant circuit and via the coolant circuit, to enable efficient and dynamic operation of the heating and cooling system and to ensure situation-dependent thermal performance during cooling and heating for various applications.

[7] For example, DE 10 2019 109 796 A1 discloses a heat flow management device and a method for operating a heat flow management device which has a refrigerant circuit

and a drive section coolant circuit as well as a heating section heat transfer medium circuit.

[8] DE 10 2016 100 971 A1 relates to a climate control system for a vehicle with a heat pump subsystem and DE 10 2008 062 176 A1 discloses a mechanism and a method for tempering electrical elements of a motor vehicle.

[9] US 2019/0344640 A1 discloses a heat management device for a vehicle which comprises a heat pump.

[10] DE 10 2020 111 505 A1 relates to a heat pump arrangement for battery-operated vehicles and a method for operating a heat pump arrangement, wherein the utilisation of the waste heat of the vehicle requires multiple chillers to couple the refrigerant circuit and the heat transfer circuit.

[11] The systems mentioned above are mechanically complicated and complex, which entails various disadvantages.

[12] In the prior art, a heat management system is known from DE 10 2021 131 215 A1 which overcomes a large part of the disadvantages. This heat pump arrangement has a system architecture which enables flexible, high-performance and efficient operation, while also reducing the number of components.

[13] However, it is disadvantageous that the use of this heat management system is limited to the refrigerants R134a or R1234yf and is not suitable for operation with the refrigerant R744.

Disclosure of Invention

Technical Problem

[14] The object of the invention is to provide a heat pump arrangement adapted to the particularities of the refrigerant CO2, which moreover overcomes further limitations.

Solution to Problem

[15] The object is achieved by a subject-matter and a method having the features of the independent patent claims. Developments are specified in the dependent patent claims.

[16] In particular, the object of the invention is achieved by a heat pump arrangement for battery electric vehicles with R744 as a refrigerant, having a refrigerant circuit with a compressor, a first expansion member, a first shut-off valve, a first external gas cooler, a second external gas cooler, an internal heat exchanger, a third expansion member, an evaporator and an accumulator, wherein a chiller with an associated fourth expansion member is arranged in the refrigerant circuit parallel to the evaporator and to the third expansion member, and a heating gas cooler and an expansion member are arranged in a heating gas cooler section, wherein the heating gas cooler section is arranged starting from the compressor and ending between the first expansion member and the first shut-off valve. For the purposes of the invention, a chiller is understood to mean

a heat exchanger which serves to cool the battery and, if applicable, the drive section and further components of the vehicle, the chiller always functionally absorbing heat as waste heat. The absorbed waste heat is then transferred to the environment in the cooling mode of the system or used in the heat pump mode for heating the vehicle cabin or for de-icing the heat exchangers.

[17] The invention is advantageously developed in that a bypass section with a second shut-off valve is arranged in the refrigerant circuit starting between the first expansion member and the first shut-off valve and ending between the internal heat exchanger and a fourth expansion member.

[18] In this way, a bypass of the external gas coolers and the hot side of the internal heat exchanger is implemented.

[19] A chiller with an associated and thus upstream fourth expansion member is preferably arranged parallel to the evaporator with an associated expansion member.

[20] With reference to the description of the invention, an expansion member associated with a heat exchanger in the function of an evaporator or chiller is correspondingly connected upstream in this functional refrigerant flow direction.

[21] Preferably, the first external gas cooler and the second external gas cooler as well as a water cooler are arranged in a cooling module with a fan.

[22] According to an advantageous embodiment of the invention, the evaporator and the heating gas cooler as well as a PTC air heater are arranged in an air conditioning unit of a vehicle. The cabin air flow may additionally be electrically heated via the PTC air heater in operating states where the heat pump output is not sufficient for heating.

[23] Advantageously, in the refrigerant flow direction downstream of the compressor and upstream of the first expansion member and upstream of the heating gas cooler, a water-cooled gas cooler is arranged. This makes it possible to tap heat at the final compression temperature level and thus heat at the highest temperature level of the refrigerant circuit.

[24] To air-condition the vehicle cabin uniformly in larger vehicles, a rear evaporator with an associated fifth expansion member is preferably arranged parallel to the evaporator for the front region with an associated third expansion member.

[25] The rear evaporator for cooling and a heating heat exchanger for heating the air for the rear region are preferably arranged in a rear air conditioning unit of a vehicle.

[26] The object of the invention is achieved by multiple methods for different ambient conditions and operating states, which are specified below.

[27] The object of the invention is achieved by a method for operating a device specified above, wherein, in the vehicle cabin cooling mode, at high ambient temperatures of 30°C to more than 40°C, the refrigerant R744 is compressed in the compressor, is subsequently passed and cooled via the opened first expansion member and the opened

first shut-off valve into the first external gas cooler and the second external gas cooler, is cooled in the internal heat exchanger and is subsequently expanded in the third expansion member, after which the refrigerant is evaporated in the evaporator and is drawn in via the accumulator and the internal heat exchanger by the compressor.

[28] The components of the device are specified in the refrigerant flow direction, unless stated otherwise.

[29] The method sequence in the vehicle cabin cooling mode with active battery cooling in the chiller at high ambient temperatures of 30°C to more than 40°C is preferably such that the refrigerant R744 is compressed in the compressor, is subsequently passed and cooled via the opened first expansion member and the opened first shut-off valve into the first external gas cooler and the second external gas cooler, is cooled in the internal heat exchanger and is subsequently expanded in the third expansion member, after which the refrigerant is evaporated in the evaporator and is drawn in via the accumulator and the internal heat exchanger by the compressor, wherein the chiller with the associated fourth expansion member is connected in parallel to the evaporator with the associated third expansion member.

[30] The method sequence with active battery cooling in the chiller at high ambient temperatures of 30°C to more than 40°C is preferably such that the refrigerant R744 is compressed in the compressor, is subsequently passed and cooled via the opened first expansion member and the opened first shut-off valve into the first external gas cooler and the second external gas cooler, is cooled in the internal heat exchanger and is subsequently expanded in the fourth expansion member, after which the refrigerant is evaporated in the chiller and is drawn in via the accumulator and the internal heat exchanger by the compressor.

[31] The method sequence in the reheating mode at mild ambient temperatures of 15°C to 30°C is preferably such that the refrigerant R744 is compressed in the compressor and a first refrigerant partial flow is subsequently expanded via the first expansion member and passed via the opened first shut-off valve into the first external gas cooler and the second external gas cooler, is cooled in the internal heat exchanger and is subsequently expanded in the third expansion member, after which the refrigerant is evaporated in the evaporator and is drawn in via the accumulator and the internal heat exchanger by the compressor, wherein a second refrigerant partial flow is passed via the heating gas cooler section through the heating gas cooler downstream of the compressor, is subsequently expanded in the second expansion member and is combined with the first refrigerant partial flow downstream of the first expansion member.

[32] In the case of vehicle air conditioning, a reheating mode is understood to mean that the air to be supplied to the vehicle cabin is first cooled and dehumidified in the air conditioning unit and is subsequently heated to a desired temperature. By reducing the

humidity of the vehicle cabin air, misting of the vehicle windows from the inside is reduced or prevented.

[33] In this mode, the refrigerant flows through the air-cooled external gas coolers, wherein the heat for cooling or condensation of the refrigerant is released to the ambient air. The heat emission to the ambient air is regulated via the expansion members before entry into the external gas coolers. The refrigerant is expanded to a medium pressure level into the external gas coolers.

[34] The refrigerant flow is expanded into the evaporator with the expansion member arranged upstream of the evaporator to cool the air flowing through the evaporator into the vehicle cabin. Subsequently, the vehicle cabin air in the air conditioning unit of the vehicle is heated again by the heating gas cooler of the air conditioning unit. The heat flow in the heating gas cooler, which is required for heating the air flow to the cabin again, is lower than the heat flow extracted from the air flow in the evaporator. The heat extraction described above and the optionally associated humidity extraction from the vehicle cabin air in the evaporator and the subsequent heating of the vehicle cabin air to the desired temperature for the vehicle cabin in the heating gas cooler is referred to as reheating.

[35] The method sequence in the reheating mode with active battery cooling at mild ambient temperatures of 15°C to 30°C is preferably such that the refrigerant R744 is compressed in the compressor and a first refrigerant partial flow is subsequently expanded via the first expansion member and passed via the opened first shut-off valve into the first external gas cooler and the second external gas cooler, is cooled in the internal heat exchanger and is subsequently expanded in the third expansion member, after which the refrigerant is evaporated in the evaporator and is drawn in via the accumulator and the internal heat exchanger by the compressor, wherein a second refrigerant partial flow is passed via the heating gas cooler section through the heating gas cooler downstream of the compressor, is subsequently expanded in the second expansion member and is combined with the first refrigerant partial flow downstream of the first expansion member, wherein the chiller with the associated fourth expansion member is connected in parallel to the evaporator with the associated third expansion member.

[36] The method sequence in the reheating mode of the heat pump with dehumidification and vehicle cabin heating at ambient temperatures of 2°C to 15°C is preferably such that the refrigerant R744 is compressed in the compressor and passed downstream of the compressor via the heating gas cooler section through the heating gas cooler, is subsequently expanded in the second expansion member and subsequently passed via the opened first shut-off valve into the first external gas cooler and the second external gas cooler, is cooled in the internal heat exchanger and is subsequently expanded in the

third expansion member, after which the refrigerant is evaporated in the evaporator and is drawn in via the accumulator and the internal heat exchanger by the compressor.

[37] The method sequence for the vehicle cabin heating in the heat pump mode with battery cooling at ambient temperatures of 2°C to 15°C is preferably such that the refrigerant R744 is compressed in the compressor and passed downstream of the compressor via the heating gas cooler section through the heating gas cooler, is subsequently expanded in the second expansion member and is subsequently passed via the opened shut-off valve into the first external gas cooler and the second external gas cooler, is cooled in the internal heat exchanger and is subsequently expanded in the third expansion member, after which the refrigerant is evaporated in the evaporator and is drawn in via the accumulator and the internal heat exchanger by the compressor, wherein the chiller with the associated fourth expansion member is connected in parallel to the evaporator with the associated third expansion member.

[38] The method sequence for the vehicle cabin heating in the heat pump mode with battery cooling at cold ambient temperatures of -20°C to +10°C is preferably such that the refrigerant R744 is compressed in the compressor and passed downstream of the compressor via the heating gas cooler section through the heating gas cooler, is subsequently expanded in the second expansion member and is subsequently passed via the opened first shut-off valve into the first external gas cooler and the second external gas cooler, is cooled in the internal heat exchanger and is subsequently expanded in the fourth expansion member, after which the refrigerant is evaporated in the chiller and is drawn in via the accumulator and the internal heat exchanger by the compressor.

[39] The method sequence for the vehicle cabin heating and waste heat utilisation in the heat pump mode with battery cooling at cold ambient temperatures of -20°C to +10°C is preferably such that the refrigerant R744 is compressed in the compressor and passed downstream of the compressor via the heating gas cooler section through the heating gas cooler, is subsequently expanded in the second expansion member and is subsequently passed via the opened fourth expansion member and the chiller and is drawn in via the accumulator and the internal heat exchanger by the compressor.

[40] The method sequence for the vehicle cabin heating and waste heat utilisation in the heat pump mode with battery cooling at cold ambient temperatures of -20°C to +10°C is preferably such that the refrigerant R744 is compressed in the compressor and is passed downstream of the compressor via the heating gas cooler section through the heating gas cooler, is subsequently expanded in the second expansion member and is subsequently passed via the opened first shut-off valve into the first external gas cooler and the second external gas cooler, is cooled in the internal heat exchanger and

is subsequently passed via the opened fourth expansion member and the chiller and is drawn in via the accumulator and the internal heat exchanger by the compressor.

[41] The method sequence for the vehicle cabin heating and waste heat utilisation in the heat pump mode with battery cooling at cold ambient temperatures of -20°C to +10°C is preferably such that the refrigerant R744 is compressed in the compressor and is passed downstream of the compressor via the heating gas cooler section through the heating gas cooler, is subsequently expanded in the second expansion member and a first refrigerant partial flow is subsequently passed via the opened first shut-off valve into the first external gas cooler and the second external gas cooler, is cooled in the internal heat exchanger and is subsequently passed via the opened fourth expansion member and the chiller and is drawn in via the accumulator and the internal heat exchanger by the compressor, wherein a second refrigerant partial flow is passed via the opened second shut-off valve and is combined with the first refrigerant partial flow upstream of the chiller.

[42] The method sequence for the vehicle cabin heating and waste heat utilisation in the heat pump mode with battery cooling at cold ambient temperatures of -20°C to +10°C is preferably such that the refrigerant R744 is compressed in the compressor and is passed downstream of the compressor via the heating gas cooler section through the heating gas cooler, is subsequently expanded in the second expansion member and is subsequently passed via the opened first shut-off valve into the first external gas cooler and the second external gas cooler, is cooled in the internal heat exchanger and is subsequently passed via the opened fourth expansion member and the chiller and is drawn in via the accumulator and the internal heat exchanger by the compressor.

[43] The method sequence for the vehicle cabin heating in the heat pump mode without battery cooling at cold ambient temperatures of -20°C to +10°C is preferably such that the refrigerant R744 is compressed in the compressor and is passed downstream of the compressor via the heating gas cooler section through the heating gas cooler, is subsequently expanded in the second expansion member and is subsequently passed via the opened first shut-off valve into the first external gas cooler and the second external gas cooler, is cooled in the internal heat exchanger and is subsequently passed via the opened fourth expansion member and the chiller without heat absorption and is drawn in via the accumulator and the internal heat exchanger by the compressor.

[44] The method sequence for the de-icing of the gas coolers with active battery cooling in the chiller at low ambient temperatures of -20°C to +10°C is preferably such that the refrigerant R744 is compressed in the compressor, is subsequently passed and cooled via the opened first expansion member and the opened first shut-off valve into the first external gas cooler and the second external gas cooler, is cooled in the internal heat exchanger and is subsequently expanded in the fourth expansion member, after which

the refrigerant is evaporated in the chiller and is drawn in via the accumulator and the internal heat exchanger by the compressor.

[45] The concept of the invention is to provide a refrigerant circuit for cooling and heating electric vehicles, which is operable with the refrigerant R744.

[46] The refrigerant circuit includes a chiller by which heat may be absorbed from multiple coolant circuits, if applicable.

[47] For maximum efficiency during heating operation, the system has a direct heat exchanger in the air conditioning unit, the so-called heating gas cooler. The system architecture allows operation in multiple modes, such as cooling, heating and dehumidifying, with minimal use of expansion and shut-off valves using multiple heat sources, for example from the environment, waste heat from the high-voltage battery, waste heat from the electric drive section, heat from a high-voltage air PTC as well as the coolant heating.

[48] Depending on the operating mode, the coolant flow may be divided into two parallel paths downstream of the compressor. By using the first and second expansion members, the refrigerant mass flow rate through each path may be set individually between a maximum and a minimum flow rate. This function enables a continuous and smooth transition between air conditioning and heat pump operation without having to switch the compressor off.

[49] In pure air conditioning operation, the refrigerant only flows through the external gas cooler, and in heat pump operation, only flows through the heating gas cooler. In addition, in the reheating case, the dehumidification operation, the external gas cooler may be operated at a medium pressure level and the heating gas cooler may be operated at a high pressure level to achieve a desired air outlet temperature of up to 70°C.

Advantageous Effects of Invention

[50] The advantage of the heat pump arrangement according to the invention is a novel system architecture which enables the use of R744 as a refrigerant for high-performance and efficient operation of a heat management system with the smallest number of components.

Brief Description of Drawings

[51] Further details, features, and advantages of embodiments of the invention will become apparent from the following description of exemplary embodiments with reference to the accompanying drawings. In the drawings:

[52] Fig. 1: shows a heat pump arrangement in the system configuration A without a bypass,

[53] Fig. 2: shows a heat pump arrangement in the system configuration B with a bypass of the external gas coolers,

[54] Fig. 3: shows a heat pump arrangement in the system configuration C with a water-cooled gas cooler after compression and without a bypass,

[55] Fig. 4: shows a method flow diagram of a vehicle cabin cooling mode in the system configuration B,

[56] Fig. 5: shows a method flow diagram of a vehicle cabin cooling mode in the system configuration A,

[57] Fig. 6: shows a method flow diagram of a vehicle cabin cooling mode with active battery cooling in the system configuration B,

[58] Fig. 7: shows a method flow diagram of a vehicle cabin cooling mode with active battery cooling in the system configuration A,

[59] Fig. 8: shows a method flow diagram of active cooling in the system configuration B,

[60] Fig. 9: shows a method flow diagram of active battery cooling in the system configuration A,

[61] Fig. 10: shows a method flow diagram of reheating in the system configuration B,

[62] Fig. 11: shows a method flow diagram of reheating in the system configuration A,

[63] Fig. 12: shows a method flow diagram of reheating with active battery cooling in the system configuration B,

[64] Fig. 13: shows a method flow diagram of reheating with active battery cooling in the system configuration A,

[65] Fig. 14: shows a method flow diagram in the reheating mode with dehumidification and vehicle cabin heating in the system configuration B,

[66] Fig. 15: shows a method flow diagram in the reheating mode with dehumidification and vehicle cabin heating in the system configuration A,

[67] Fig. 16: shows a method flow diagram for vehicle cabin heating in the heat pump mode with battery cooling in the system configuration B,

[68] Fig. 17: shows a method flow diagram for vehicle cabin heating in the heat pump mode with battery cooling in the system configuration A,

[69] Fig. 18: shows a method flow diagram for vehicle cabin heating in the heat pump mode with battery cooling in the system configuration B,

[70] Fig. 19: shows a method flow diagram for vehicle cabin heating in the heat pump mode with battery cooling in the system configuration A,

[71] Fig. 20: shows a method flow diagram for vehicle cabin heating and waste heat utilisation in the heat pump mode with battery cooling in the system configuration B,

[72] Fig. 21: shows a method flow diagram for vehicle cabin heating and waste heat utilisation in the heat pump mode with battery cooling in the system configuration A,

[73] Fig. 22: shows a method flow diagram for vehicle cabin heating and waste heat utilisation in the heat pump mode with battery cooling in the system configuration B,

[74] Fig. 23: shows a method flow diagram for vehicle cabin heating and waste heat utilisation in the heat pump mode with battery cooling in the system configuration A,

[75] Fig. 24: shows a method flow diagram for vehicle cabin heating in the heat pump mode without battery cooling in the system configuration B,

[76] Fig. 25: shows a method flow diagram for vehicle cabin heating in the heat pump mode without battery cooling in the system configuration A,

[77] Fig. 26: shows a method flow diagram of de-icing of the gas coolers with active battery cooling in the system configuration B, and

[78] Fig. 27: shows a method flow diagram of de-icing of the gas coolers with active battery cooling in the system configuration A.

Best Mode for Carrying out the Invention

[79] Fig. 1 shows a cost-effective version of a heat pump arrangement as a method flow diagram in the system configuration A. The system configuration A does not exhibit a bypass of the external gas coolers. Here, the refrigerant circuit with the individual components is shown, wherein the coolant circuits of the heat pump arrangement are not shown for the sake of clarity. The heat pump arrangement is functionally characterised in that there is a refrigeration system mode for the cooling and a heat pump mode for the heating of the vehicle cabin. The flow paths of the refrigerant are implemented by switching the shut-off valves and expansion members in the various sections. The refrigerant circuit is first described in the function as a refrigeration system. As such, a compressor 1 is embodied as an electric compressor in battery-electrically driven vehicles. Downstream of the compressor 1, the refrigerant system branches off into a section for the refrigeration system mode and into a heating gas cooler section 21 for the heat pump mode. In the refrigeration system mode, a first expansion member 3 is arranged downstream of the compressor 1 and a first shut-off valve 8 is arranged downstream of a node point. The first shut-off valve 8 may shut off the subsequent cooling module, which consists of a first external gas cooler 5 and a second external gas cooler 6 and, if applicable, a water cooler 7. The water cooler 7 might be integrated into the cooling module as an additional cooling option for the refrigerant. Downstream of the cooling module, a connection to an internal heat exchanger 9 is made on the hot or the high-pressure side of the internal heat exchanger 9. The refrigerant outlet of the hot side of the internal heat exchanger 9 is connected to a third expansion member 11 which is connected upstream of an evaporator 14. A bypass section to the expansion member 11 and the evaporator 14 with a fourth expansion member 12 and a chiller 13 is arranged on the way to the evaporator

section via a node point not specified in detail. Downstream of the evaporator 14, the refrigerant conduit runs via an accumulator 10 and the cold or the low-pressure side of the internal heat exchanger 9 runs to the suction side of the compressor 1.

[80] The heat pump operation is implemented by connecting the compressor 1 to a heating gas cooler 2 via a heating gas cooler section 21. A connection is provided from the heating gas cooler 2 via a second expansion member 4 towards the section of the external gas coolers 5, 6. The refrigerant conduit from the heating gas cooler section 21 is incorporated upstream of the first shut-off valve 8, so that a shut-off of the cooling module with the external gas coolers 5, 6 is possible thereby.

[81] The evaporator 14, the heating gas cooler 2 and a PTC air heater 15 are arranged in an air conditioning unit for air conditioning of a vehicle cabin (not shown in detail).

[82] In all of the figures, pressure and/or temperature sensors which are not specified in detail are shown as circles with the symbols p for pressure and T for temperature.

[83] Fig. 2 shows a heat pump arrangement, which has been explained above with respect to Fig. 1, wherein the heat pump arrangement additionally has a bypass section 22, which is arranged downstream of the first expansion member 3 via a second shut-off valve 16 as a bypass to the first and second external gas coolers 5, 6. This configuration with a bypass of the external gas coolers 5, 6 is referred to as a system configuration B.

[84] In Fig. 3, a heat pump arrangement according to the description in Fig. 1 with respect to a system configuration A is extended by parallelly providing a rear evaporator 18 with an upstream and associated fifth expansion member 17 as a parallel section to the evaporator 14 with a third expansion member 11 and is denoted as a system configuration C. The rear evaporator 18 is integrated into a rear air conditioning unit of a vehicle which has a heating heat exchanger 19 to implement air conditioning with cooling and heating of the air in the rear region of the vehicle cabin. Downstream of the compressor 1, a water-cooled gas cooler 20 is arranged which absorbs heat at a temperature level which is the highest in the refrigerant circuit.

[85] In the following figures description of Figs. 4 to 27, various method modes are disclosed, each with reference to two basic system concepts B and A.

[86] The refrigerant circuit connected in case of the corresponding application is characterised by a double line as the conduit routing. A thin solid line is used to draw the conduits of the system which, in this mode just described, are not passed through by refrigerant, i.e., are inactive. To illustrate the refrigerant flow direction, corresponding arrowheads are additionally added in the conduit diagram where appropriate.

[87] The shut-off valves or the expansion members which are open are represented by outlines of the corresponding component symbol as triangles mirrored at an apex. As

such, with shut-off valves, a complete flow takes place, and the expansion members are in the mode of throttling of the refrigerant.

[88] If a shut-off valve or an expansion member is closed and the refrigerant path is completely shut off thereby, then the component is completely filled, the entire area of the triangles mirrored at the apex being solidly black.

[89] The expansion members, which are set to maximum flow and thus fully open, are shown as an outline of the triangles mirrored at the apex and the circle without a cross. In the manner described, the state of the components is additionally derivable from the figures.

[90] Fig. 4 and Fig. 5 show the method flow diagram for the vehicle cabin cooling at high ambient temperatures of 30°C to 40°C or even beyond. Fig. 4 shows the flow diagram according to the system configuration B with a refrigeration system which has a bypass section to the external gas coolers 5, 6, whereas Fig. 5 shows the system configuration A which has no bypass section. However, for the procedure of vehicle cabin cooling, the bypass section is without a function, so that Figs. 4 and 5 can be described together.

[91] The vehicle cabin cooling mode of the refrigerant circuit is described starting with the compression of the refrigerant in the compressor 1. In the exemplary embodiment, the compressor 1 is embodied as a so-called electric compressor. The compressed refrigerant gas, which is at the final compression temperature, flows through the opened first expansion member 3 and the opened first shut-off valve 8 and enters the cooling module, which is composed of the first external gas cooler 5, the second external gas cooler 6 and a water cooler 7 with associated fans not specified in detail. The refrigerant flows through the first external gas cooler 5 and the second external gas cooler 6 while emitting heat and subsequently reaches the internal heat exchanger 9, where heat is emitted at a high pressure to the cold gas flow at low pressure upstream of the compressor 1. The refrigerant gas at high pressure downstream of the internal heat exchanger 9 is expanded in the third expansion member 11 and evaporated in the evaporator 14 of the air conditioning unit while absorbing heat and thus cooling the vehicle cabin air flow. The cold refrigerant vapour reaches the accumulator 10, possibly with liquid fractions of oil and refrigerant. The refrigerant gas flows through the internal heat exchanger 9 on the low-pressure side and is drawn in by the compressor 1; the circuit is thus closed.

[92] This cooling process is implemented with system configurations B and A according to Figs. 4 and 5. The shut-off valves and expansion members, which are not mentioned in more detail, are in the closed state.

[93] Figs. 6 and 7 show the mode of vehicle cabin cooling with additional active battery cooling and, optionally, drive section and component cooling in the system

configurations B and A. In the following, the term battery cooling represents the selective or cumulative cooling of the battery, the drive section or other components of the vehicle. This covers ambient temperatures of 30°C to 40°C and beyond. To obtain an optimum performance of the battery, it is necessary and reasonable under certain circumstances to cool the battery at high temperatures, which is accomplished by a cooling circuit which emits heat via the chiller 13 to the refrigerant circuit. The refrigerant circuit is connected analogously to the circuit in Figs. 4 and 5 with the additional feature that the parallel section with the fourth expansion member 12 and the chiller 13 is connected to the third expansion member 11 and the evaporator 14. In this way, two refrigeration loads, the chiller 13 for the battery cooling and the evaporator 14 for the vehicle cabin air cooling, are supplied with refrigeration by the refrigerant circuit.

[94] Figs. 8 and 9 illustrate the mode of active battery cooling without cooling of the vehicle cabin air in the system configurations B and A. The circuit is connected analogously to the circuit according to Figs. 6 and 7, with the difference that the refrigerant section is deactivated by the evaporator of the refrigeration system and the associated expansion member, which is implemented by closing the associated expansion member.

[95] Figs. 10 and 11 show the reheating mode at mild ambient temperatures of 15°C to 30°C in the various system configurations B and A, with and without a bypass of the external gas coolers 5, 6. In the reheating mode shown, after compression of the total refrigerant flow in the compressor 1, the refrigerant is divided into two refrigerant partial flows. A first refrigerant partial flow flows through the first expansion member 3, in which the first refrigerant partial flow is expanded. The second refrigerant partial flow flows downstream of the compressor 1 via the heating gas cooler section 21 to the heating gas cooler 2, which emits heat to the vehicle cabin air flow. The second refrigerant partial flow is then expanded in the second expansion member 4 and is subsequently combined with the first refrigerant partial flow. The total refrigerant flow then flows through the first external gas cooler 5, the second external gas cooler 6 and the internal heat exchanger 9 at medium pressure. In the third expansion member 11, the total refrigerant flow is throttled to low pressure, and in the evaporator 14, heat is absorbed from the vehicle cabin air flow and the refrigerant is evaporated. As such, the vehicle cabin air flow in the air conditioning unit of the vehicle is first cooled and dehumidified in a defined manner, after which the vehicle cabin air flow is heated by the heating gas cooler 2 to the correspondingly desired temperature. Hence, in the reheating mode, a dried vehicle cabin air flow is made available which is temperature-controlled as per the wishes of the occupants.

[96] Figs. 12 and 13 show the reheating mode at mild ambient temperatures of 15°C to 30°C with the various system configurations B and A, with and without a bypass of the external gas coolers 5, 6, each in the variation with active battery cooling. As such, the method flow diagram of Figs. 10 and 11 is connected in parallel by the parallel refrigerant section through the fourth expansion member 12 and the chiller 13 to the third expansion member 11 and the evaporator 14. As described, the reheating mode is effective by parallel operation of the evaporation and cooling as well as dehumidification of the vehicle cabin air in the air conditioning unit by the evaporator 14 and the subsequent heating of the air to the desired vehicle cabin air temperature by the heating gas cooler 2.

[97] Figs. 14 and 15 show a method variation with the cabin heating with dehumidification in the heat pump operation at cold ambient temperatures of 2°C to 15°C. There, the refrigerant is compressed in the compressor 1 and flows via the heating gas cooler section 21 to the heating gas cooler 2, where the hot refrigerant emits heat to the vehicle cabin air flow. The refrigerant is subsequently expanded to medium pressure in the second expansion member 4 and is passed via the opened first shut-off valve 8 to absorb heat in the heat pump mode via the first external gas cooler 5 and the second external gas cooler 6. Subsequently, the refrigerant flows via the internal heat exchanger 9, is expanded to low pressure in the third expansion member 11 and is evaporated in the evaporator 14. The absorbed heat cools the vehicle cabin air flow in the air conditioning unit of the vehicle, which is thus cooled and dehumidified, after which the vehicle cabin air flow, as described above, is heated by the heating gas cooler 2 to the corresponding desired vehicle cabin temperature.

[98] Figs. 16 and 17 show the process described above with respect to Figs. 14 and 15 in the method flow diagram, the process being extended by an active battery cooling by parallel connection of the fourth expansion member 12 with the chiller 13 to the third expansion member 11 and the evaporator 14.

[99] Figs. 18 and 19 show the method flow diagram according to Figs. 16 and 17 reduced by the refrigerant section through the evaporator in the system configurations B and A. In this method sequence, the vehicle cabin is heated via the heating gas cooler 2 and the heat absorption takes place after expansion to medium pressure in the second expansion member 4 in the first external gas cooler 5 and the second external gas cooler 6 as well as after further expansion to low pressure in the fourth expansion member 12 by heat absorption in the chiller 13, after which the refrigerant is drawn in via the accumulator 10 and the internal heat exchanger 9 on the low-pressure side by the compressor 1. As such, the refrigerant circuit is passed to the heating gas cooler 2 as a total refrigerant mass flow via the heating gas cooler section 21 without dividing the refrigerant mass flows.

[100] Advantageously, this method sequence is usable at very cold temperatures of -20°C to +10°C.

[101] Fig. 20 shows a method for the vehicle cabin heating using waste heat via the drive section as well as the battery cooling in the system configuration B with a bypass, wherein first the gaseous refrigerant is compressed in the compressor 1 and is passed via the heating gas cooler 2 for heat emission in the air conditioning unit of the vehicle. Subsequently, the refrigerant in the second expansion member 4 is expanded to low pressure and is passed via the opened second shut-off valve 16 and the bypass section 22 as well as the opened fourth expansion member 12 to the chiller 13 for heat absorption. Subsequently, the refrigerant is collected in the accumulator 10 and passed via the internal heat exchanger 9 on the low-pressure side and drawn in by the compressor 1.

[102] In the version of the refrigeration system according to Fig. 21, this method is implemented without the bypass section 22 shown in Fig. 20 in the system configuration A. As such, the total refrigerant flow is compressed by the compressor 1 and is passed via the heating gas cooler section 21 into the heating gas cooler 2 for heat emission to the vehicle cabin air in the air conditioning unit of the vehicle. Upon expansion of the refrigerant flow in the second expansion member 4 to low pressure, the refrigerant is now passed via the opened first shut-off valve 8 into the first external gas cooler 5 and subsequently into the second external gas cooler 6, after which the refrigerant is passed via the internal heat exchanger 9 to the opened fourth expansion member 12 with the subsequent chiller 13. The refrigerant gas is finally drawn in by the compressor 1 via the accumulator 10 as well as the internal heat exchanger 9.

[103] Fig. 22 shows the method for vehicle cabin heating with heat absorption from waste heat from the battery cooling and, if applicable, the vehicle drive section via the chiller 13 in the system configuration B. In the compressor 1, the refrigerant is compressed and passed via the heating gas cooler section 21 into the heating gas cooler 2 of the air conditioning unit for emitting heat to the vehicle cabin air flow. Subsequently, the refrigerant is expanded to low pressure in the second expansion member 4, after which the total refrigerant flow is divided into a first partial flow and a second partial flow. The first refrigerant partial flow flows via the opened first shut-off valve 8 and the external gas coolers 5, 6 as well as the internal heat exchanger 9. The second refrigerant partial flow flows via the opened second shut-off valve 16 via the bypass section 22 and is subsequently recombined with the first refrigerant partial flow. The total refrigerant flow then flows through the opened fourth expansion member 12 and the chiller 13. Subsequently, the refrigerant flows via the accumulator 10, the internal heat exchanger 9 and is drawn in by the compressor 1. This method sequence is carried out at very cold temperatures of up to -20°C to +10°C.

[104] In the system configuration A according to Fig. 23, the method described with respect to Fig. 22 or these method parameters are implemented without the division of the total refrigerant flow for lack of a bypass section 22 according to Fig. 22. As such, according to Fig. 23, the total refrigerant flow is compressed in the compressor 1, being passed to the heating gas cooler 2 via the heating gas cooler section 21. Subsequently, the refrigerant flow in the second expansion member 4 is expanded and passed via the opened first shut-off valve 8 into the external gas coolers 5, 6. Then, the passing of the refrigerant flow via the internal heat exchanger 9 as well as the opened fourth expansion member 12 and the heat absorption in the chiller 13 are carried out. Subsequently, the refrigerant flow flows through the accumulator 10, the internal heat exchanger 9 and is drawn in by the compressor 1.

[105] Figs. 24 and 25 again show an analogous method sequence for the two system configurations B and A, wherein the vehicle cabin heating is essentially accomplished by the heat absorption from the external gas coolers 5, 6. Hence, the method sequence in Fig. 24 is carried out analogously to the method sequence according to Fig. 23, except for no heat being absorbed in the chiller 13, and all the heat being absorbed from the environment via the external gas coolers 5, 6.

[106] This takes place at very cold temperatures of -20°C to +10°C.

[107] Figs. 26 and 27 show the de-icing of the first and second external gas coolers 5, 6 by the use of waste heat from the battery cooling and of the electric drive section in the system configurations B and A. The refrigerant is compressed in the compressor 1. Subsequently, the hot coolant gas flow is passed via the opened first expansion member 3 and the opened first shut-off valve 8 into the external gas coolers 5, 6. Hence, the superheated refrigerant gas flow leads to intensive heating of the external gas coolers 5, 6, as a result of which they defrost and de-ice. The refrigerant gas flow flows under high pressure via the internal heat exchanger 9, is expanded to low pressure in the fourth expansion member 12, and heat is absorbed from the chiller 13 from the battery cooling and the drive section cooling. The refrigerant passes through the accumulator 10, the internal heat exchanger 9 on the low-pressure side and is finally drawn in by the compressor 1.

[108] The difference between the system configuration A according to Fig. 1, also referred to as the “cost-efficient version”, and the system configuration B according to Fig. 2, also referred to as the “performance version”, is the bypass to the external gas coolers 5, 6, consisting of two refrigerant conduits and the second shut-off valve 16. As a result, the total refrigerant mass flow may be divided in two parallel paths in the combined heat pump mode or in the pure water heat pump mode. This makes it possible to either divide or completely shut off the refrigerant mass flow through the external gas coolers.

[109] Both system variations may optionally be extended for use with one or more rear air conditioning units, each consisting of a rear evaporator and a heating heat exchanger. In this case, a water-cooled gas cooler is used directly downstream of the compressor to transfer heat from the refrigerant circuit via a coolant circuit to the air through the rear heating heat exchanger. The coolant circuit (not shown) is connected to the water-cooled gas cooler and the heating heat exchanger. An additional fifth expansion member serves to control or shut off the refrigerant mass flow through the rear evaporator.

Claims

[Claim 1] A heat pump arrangement for battery electric vehicles with R744 as a refrigerant,
- having a refrigerant circuit with a compressor (1), a first expansion member (3), a first shut-off valve (8), a first external gas cooler (5), a second external gas cooler (6), an internal heat exchanger (9), a third expansion member (11), an evaporator (14) and an accumulator (10), wherein
- parallel to the evaporator (14) and to the third expansion member (11), a chiller (13) with an associated fourth expansion member (12) is arranged in the refrigerant circuit, and
- a heating gas cooler (2) and a second expansion member (4) are arranged in a heating gas cooler section (21), wherein the heating gas cooler section (21) is arranged starting from the compressor (1) and ending between the first expansion member (3) and the first shut-off valve (8).

[Claim 2] The heat pump arrangement according to claim 1, characterised in that a bypass section (22) with a second shut-off valve (16) is arranged in the refrigerant circuit starting between the first expansion member (3) and the first shut-off valve (8) and ending between the internal heat exchanger (9) and a fourth expansion member (12).

[Claim 3] The heat pump arrangement according to claim 1 or 2, characterised in that a chiller (13) with an associated fourth expansion member (12) is arranged parallel to the evaporator (14) with an associated third expansion member (11).

[Claim 4] The heat pump arrangement according to any one of claims 1 to 3, characterised in that the first external gas cooler (5) and the second external gas cooler (6) as well as a water cooler (7) are arranged in a cooling module with a fan.

[Claim 5] The heat pump arrangement according to any one of claims 1 to 4, characterised in that the evaporator (14) and the heating gas cooler (2) as well as a PTC air heater (15) are arranged in an air conditioning unit of a vehicle.

[Claim 6] The heat pump arrangement according to any one of claims 1 to 5, characterised in that, in the refrigerant flow direction downstream of the compressor (1) and upstream of the first expansion member

(3) and upstream of the heating gas cooler (2), a water-cooled gas cooler (20) is arranged.

[Claim 7] The heat pump arrangement according to any one of claims 1 to 6, characterised in that a rear evaporator (18) with an associated fifth expansion member (17) is arranged parallel to the evaporator (14) with an associated third expansion member (11).

[Claim 8] The heat pump arrangement according to claim 7, characterised in that the rear evaporator (18) and a heating heat exchanger (19) are arranged in a rear air conditioning unit of a vehicle.

[Claim 9] A method for operating a device according to any one of claims 1 to 8, characterised in that, in the vehicle cabin cooling mode at high ambient temperatures of 30°C to more than 40°C, the refrigerant R744 is compressed in the compressor (1), is subsequently passed and cooled via the opened first expansion member (3) and the opened first shut-off valve (8) into the first external gas cooler (5) and the second external gas cooler (6), is cooled in the internal heat exchanger (9) and is subsequently expanded in the third expansion member (11), after which the refrigerant is evaporated in the evaporator (14) and is drawn in via the accumulator (10) and the internal heat exchanger (9) by the compressor (1).

[Claim 10] A method for operating a device according to any one of claims 1 to 8, characterised in that, in the vehicle cabin cooling mode with active battery cooling in the chiller (13) at high ambient temperatures of 30°C to more than 40°C, the refrigerant R744 is compressed in the compressor (1), is subsequently passed and cooled via the opened first expansion member (3) and the opened first shut-off valve (8) into the first external gas cooler (5) and the second external gas cooler (6), is cooled in the internal heat exchanger (9) and is subsequently expanded in the third expansion member (11), after which the refrigerant is evaporated in the evaporator (14) and is drawn in via the accumulator (10) and the internal heat exchanger (9) by the compressor (1), wherein the chiller (13) with the associated fourth expansion member (12) is connected in parallel to the evaporator (14) with the associated third expansion member (11).

[Claim 11] A method for operating a device according to any one of claims 1 to 8, characterised in that, with active battery cooling in the chiller (13) at high ambient temperatures of 30°C to more than 40°C, the refrigerant R744 is compressed in the compressor (1), is subsequently passed and cooled via the opened first expansion member (3) and the opened first shut-off valve (8) into the first external gas cooler (5) and the second external gas cooler (6), is cooled in the internal heat exchanger (9) and is subsequently expanded in the fourth expansion member (12), after which the refrigerant is evaporated in the chiller (13) and is drawn in via the accumulator (10) and the internal heat exchanger (9) by the compressor (1).

[Claim 12] A method for operating a device according to any one of claims 1 to 8, characterised in that, in the reheating mode at mild ambient temperatures of 15°C to 30°C, the refrigerant R744 is compressed in the compressor (1), and a first refrigerant partial flow is subsequently expanded via the first expansion member (3) and passed via the opened first shut-off valve (8) into the first external gas cooler (5) and the second external gas cooler (6), is cooled in the internal heat exchanger (9) and is subsequently expanded in the third expansion member (11), after which the refrigerant is evaporated in the evaporator (14) and is drawn in via the accumulator (10) and the internal heat exchanger (9) by the compressor (1), wherein a second refrigerant partial flow is passed downstream of the evaporator (1) via the heating gas cooler section (21) through the heating gas cooler (2), is subsequently expanded in the second expansion member (4) and is combined with the first refrigerator partial flow downstream of the first expansion member (3).

[Claim 13] A method for operating a device according to any one of claims 1 to 8, characterised in that, in the reheating with active battery cooling at mild ambient temperatures of 15°C to 30°C, the refrigerant R744 is compressed in the compressor (1), and a first refrigerant partial flow is subsequently expanded via the first expansion member (3) and passed via the opened first shut-off valve (8) into the first external gas cooler (5) and the second external gas cooler (6), is cooled in the internal heat exchanger (9) and is subsequently expanded in the third expansion member (11), after which the refrigerant is evaporated in the evaporator (14) and is drawn in via the accumulator (10) and the internal heat exchanger (9) by the compressor (1), wherein a second refrigerant partial flow is passed downstream of the evaporator (1) via the heating gas cooler section (21) through the heating gas cooler (2), is subsequently expanded in the second expansion member (4) and is combined with the first refrigerator partial flow downstream of the first expansion member (3), wherein the chiller (13) with the associated fourth expansion member (12) is connected in parallel to the evaporator (14) with the associated third expansion member (11).

[Claim 14] A method for operating a device according to any one of claims 1 to 8, characterised in that, in the reheating mode of the heat pump with dehumidification and vehicle cabin heating at ambient temperatures of 2°C to 15°C, the refrigerant R744 is compressed in the compressor (1) and is passed downstream of the evaporator (1) via the heating gas cooler section (21) through the heating gas cooler (2), is subsequently expanded in the second expansion member (4) and is subsequently passed via the opened first shut-off valve (8) into the first external gas cooler (5) and the second external gas cooler (6), is cooled in the internal heat exchanger (9) and is subsequently expanded in the third expansion member (11), after which the refrigerant is evaporated in the evaporator (14) and is drawn in via the accumulator (10) and the internal heat exchanger (9) by the compressor (1).

[Claim 15] A method for operating a device according to any one of claims 1 to 8, characterised in that, with the vehicle cabin heating in the heat pump mode with battery cooling at ambient temperatures of 2°C to 15°C, the refrigerant R744 is compressed in the compressor (1) and is passed downstream of the evaporator (1) via the heating gas cooler section (21) through the heating gas cooler (2), is subsequently expanded in the second expansion member (4) and is subsequently passed via the opened first shut-off valve (8) into the first external gas cooler (5) and the second external gas cooler (6), is cooled in the internal heat exchanger (9) and is subsequently expanded in the third expansion member (11), after which the refrigerant is evaporated in the evaporator (14) and is drawn in via the accumulator (10) and the internal heat exchanger (9) by the compressor (1), wherein the chiller (13) with the associated fourth expansion member (12) is connected in parallel to the evaporator (14) with the associated third expansion member (11).

[Claim 16] A method for operating a device according to any one of claims 1 to 8, characterised in that, with the vehicle cabin heating in the heat pump mode with battery cooling at cold ambient temperatures of -20°C to +10°C, the refrigerant R744 is compressed in the compressor (1) and is passed downstream of the evaporator (1) via the heating gas cooler section (21) through the heating gas cooler (2), is subsequently expanded in the second expansion member (4) and is subsequently passed via the opened first shut-off valve (8) into the first external gas cooler (5) and the second external gas cooler (6), is cooled in the internal heat exchanger (9) and is subsequently expanded in the fourth expansion member (12), after which the refrigerant is evaporated in the chiller (13) and is drawn in via the accumulator (10) and the internal heat exchanger (9) by the compressor (1).

[Claim 17] A method for operating a device according to any one of claims 1 to 8, characterised in that, with the vehicle cabin heating and waste heat utilisation in the heat pump mode with battery cooling at cold ambient temperatures of -20°C to +10°C, the refrigerant R744 is compressed in the compressor (1) and is passed downstream of the evaporator (1) via the heating gas cooler section (21) through the heating gas cooler (2), is subsequently expanded in the second expansion member (4) and is subsequently passed via the opened fourth expansion member (12) and the chiller (13) and is drawn in via the accumulator (10) and the internal heat exchanger (9) by the compressor (1).

[Claim 18] A method for operating a device according to any one of claims 1 to 8, characterised in that, with vehicle cabin heating and waste heat utilisation in the heat pump mode with battery cooling at cold ambient temperatures of -20°C to +10°C, the refrigerant R744 is compressed in the compressor (1) and is passed downstream of the evaporator (1) via the heating gas cooler section (21) through the heating gas cooler (2), is subsequently expanded in the second expansion member (4) and is subsequently passed via the opened first shut-off valve (8) into the first external gas cooler (5) and the second external gas cooler (6), is cooled in the internal heat exchanger (9) and is subsequently passed via the opened fourth expansion member (12) and the chiller (13) and is drawn in via the accumulator (10) and the internal heat exchanger (9) by the compressor (1).

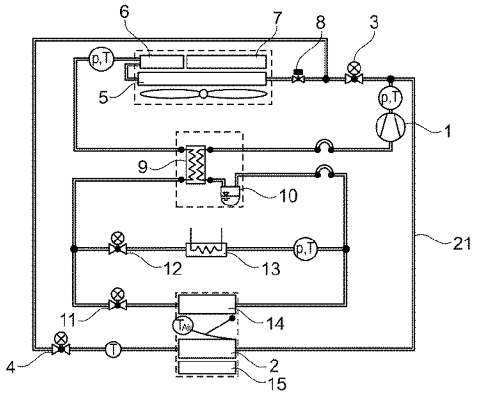
[Claim 19] A method for operating a device according to any one of claims 1 to 8, characterised in that, with the vehicle cabin heating and waste heat utilisation in the heat pump mode with battery cooling at cold ambient temperatures of -20°C to +10°C, the refrigerant R744 is compressed in the compressor (1) and is passed downstream of the evaporator (1) via the heating gas cooler section (21) through the heating gas cooler (2), is subsequently expanded in the second expansion member (4), and a first refrigerant partial flow is subsequently passed via the opened first shut-off valve (8) into the first external gas cooler (5) and the second external gas cooler (6), is cooled in the internal heat exchanger (9) and is subsequently passed via the opened fourth expansion member (12) and the chiller (13) and is drawn in via the accumulator (10) and the internal heat exchanger (9) by the compressor (1), wherein a second refrigerant partial flow is passed via the opened second shut-off valve (16) and is combined with the first refrigerant partial flow upstream of the chiller (13).

[Claim 20] A method for operating a device according to any one of claims 1 to 8, characterised in that, with the vehicle cabin heating and waste heat utilisation in the heat pump mode with battery cooling at cold ambient temperatures of -20°C to +10°C, the refrigerant R744 is compressed in the compressor (1) and is passed downstream of the evaporator (1) via the heating gas cooler section (21) through the heating gas cooler (2), is subsequently expanded in the second expansion member (4) and is subsequently passed via the opened first shut-off valve (8) into the first external gas cooler (5) and the second external gas cooler (6), is cooled in the internal heat exchanger (9) and is subsequently passed via the opened fourth expansion member (12) and the chiller (13) and is drawn in via the accumulator (10) and the internal heat exchanger (9) by the compressor (1).

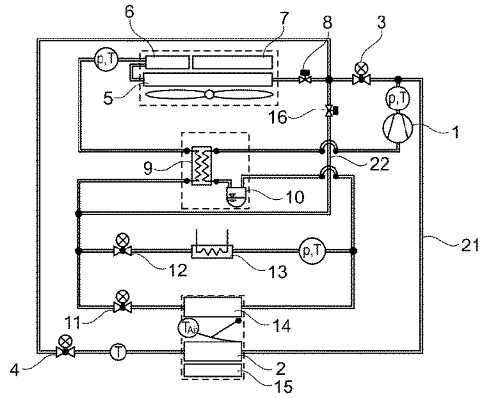
[Claim 21] A method for operating a device according to any one of claims 1 to 8, characterised in that, with the vehicle cabin heating in the heat pump mode without battery cooling at cold ambient temperatures of -20°C to +10°C, the refrigerant R744 is compressed in the compressor (1) and is passed downstream of the evaporator (1) via the heating gas cooler section (21) through the heating gas cooler (2), is subsequently expanded in the second expansion member (4) and is subsequently passed via the opened first shut-off valve (8) into the first external gas cooler (5) and the second external gas cooler (6), is cooled in the internal heat exchanger (9) and is subsequently passed via the opened fourth expansion member (12) and the chiller (13) without heat absorption and is drawn in via the accumulator (10) and the internal heat exchanger (9) by the compressor (1).

[Claim 22] A method for operating a device according to any one of claims 1 to 8, characterised in that, with the de-icing of the external gas cooler (5, 6) with active battery cooling in the chiller (13) at low ambient temperatures of -20°C to +10°C, the refrigerant R744 is compressed in the compressor (1), is subsequently passed and cooled via the opened first expansion member (3) and the opened first shut-off valve (8) into the first external gas cooler (5) and the second external gas cooler (6), is cooled in the internal heat exchanger (9) and is subsequently expanded in the fourth expansion member (12), after which the refrigerant is evaporated in the chiller (13) and is drawn in via the accumulator (10) and the internal heat exchanger (9) by the compressor (1).

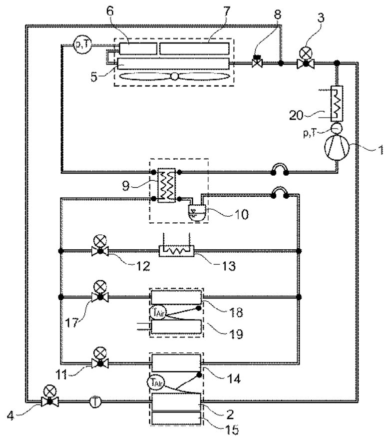
[Fig. 1]



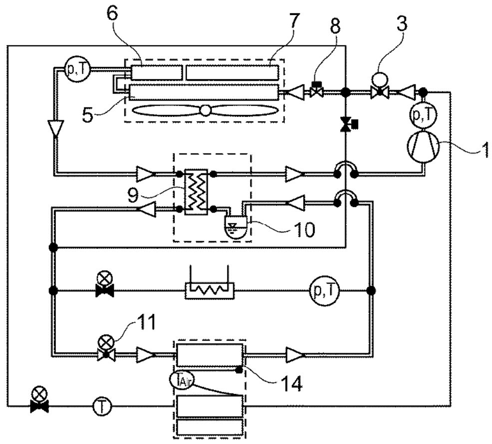
[Fig. 2]



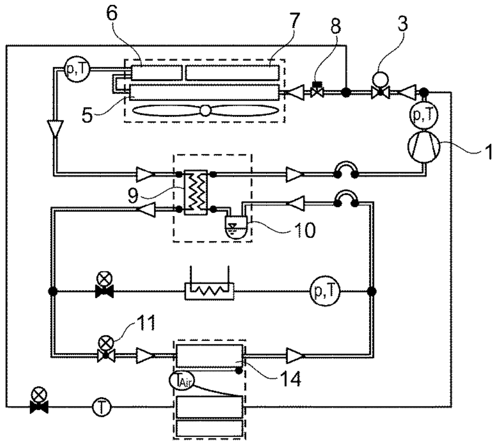
[Fig. 3]



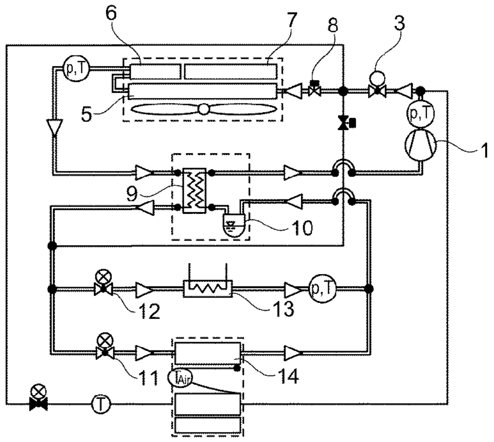
[Fig. 4]



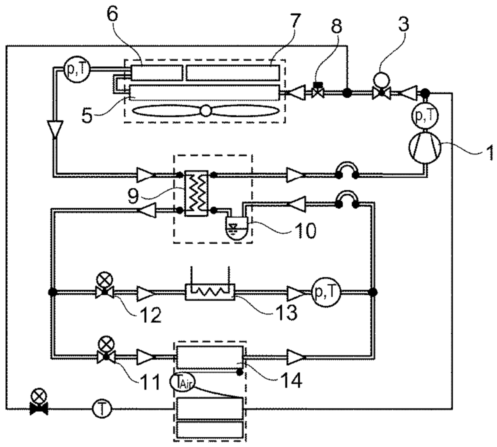
[Fig. 5]



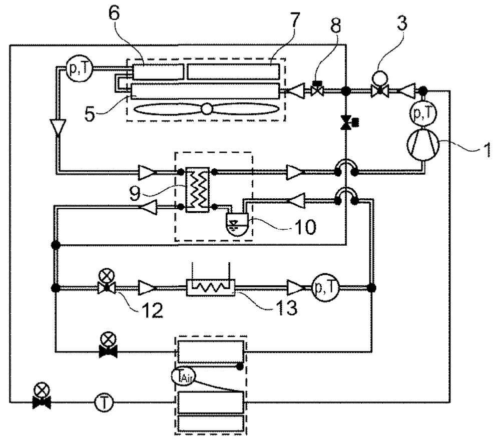
[Fig. 6]



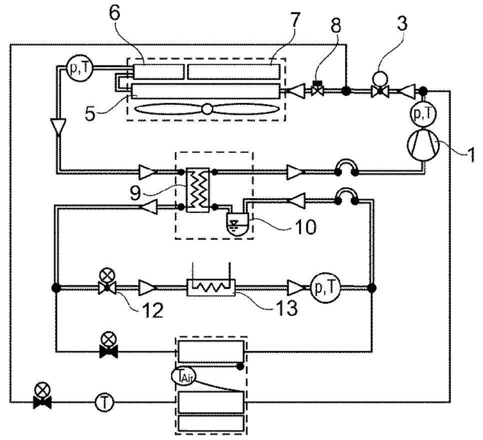
[Fig. 7]



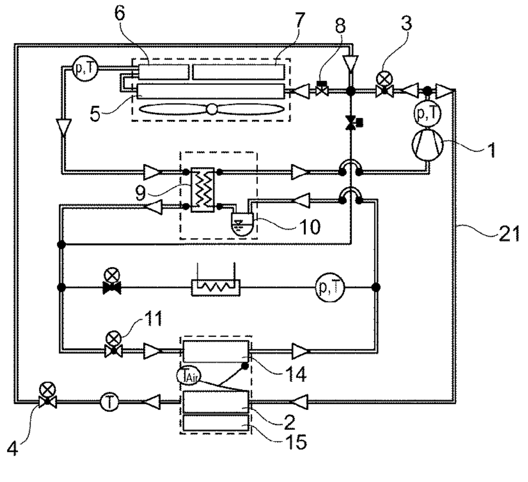
[Fig. 8]



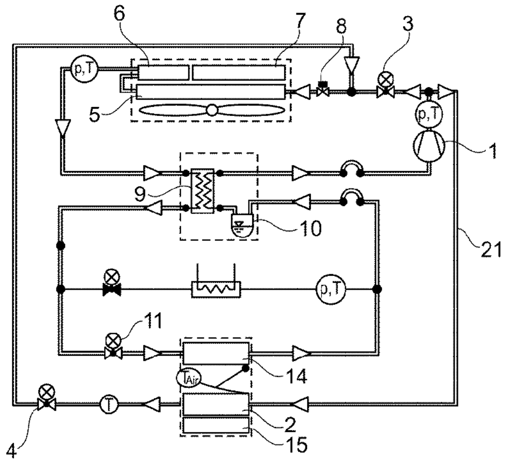
[Fig. 9]



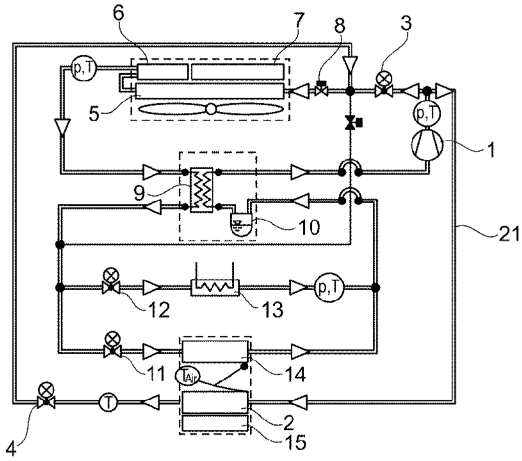
[Fig. 10]



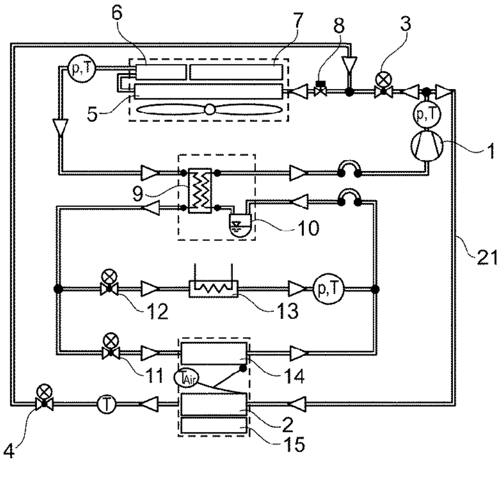
[Fig. 11]



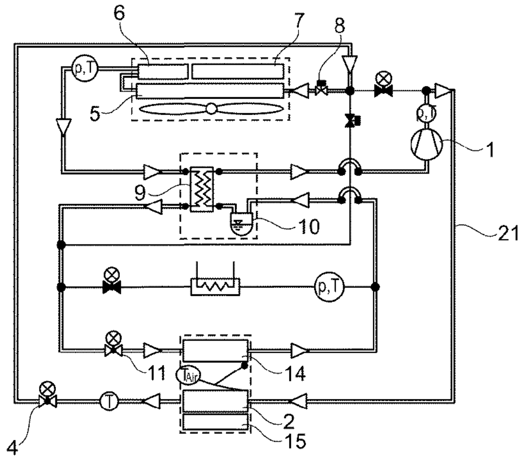
[Fig. 12]



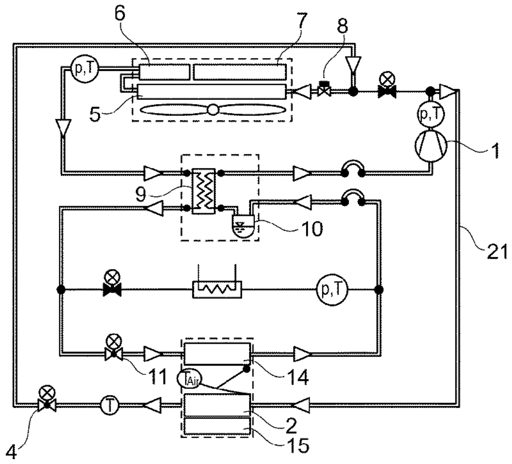
[Fig. 13]



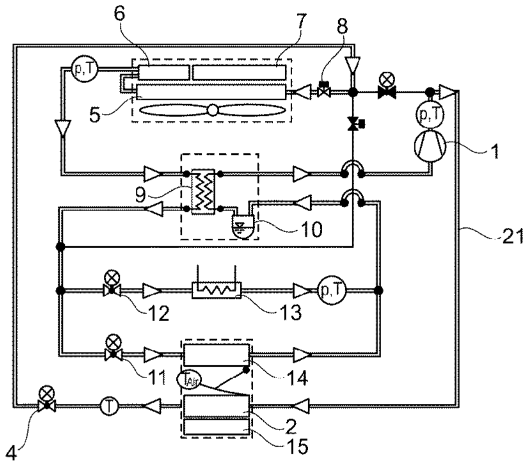
[Fig. 14]



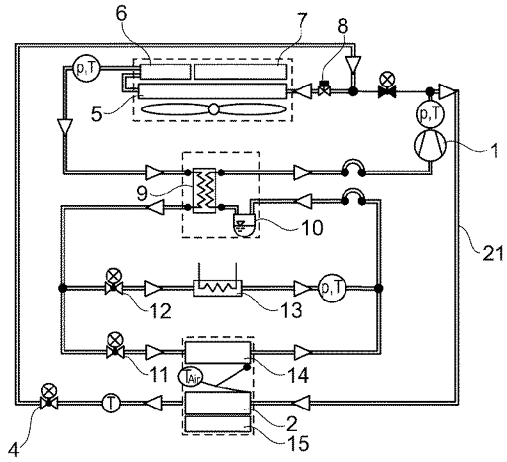
[Fig. 15]



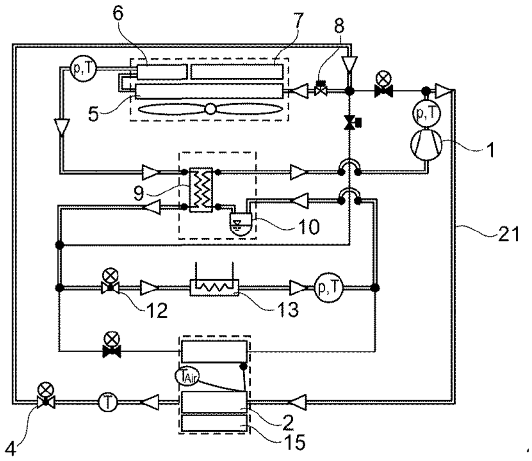
[Fig. 16]



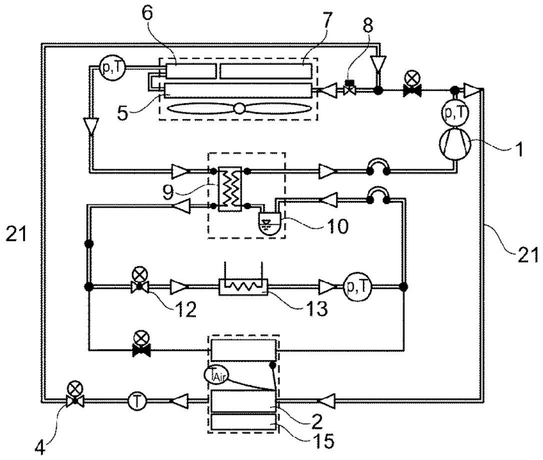
[Fig. 17]



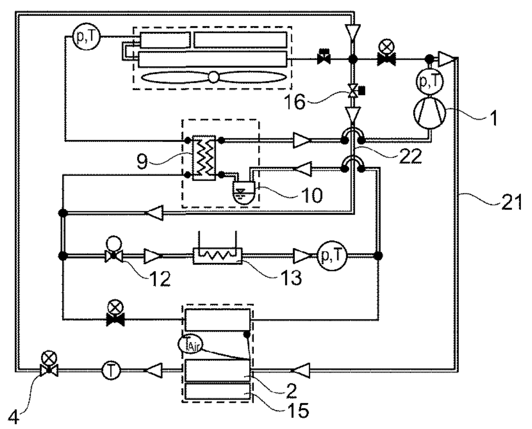
[Fig. 18]



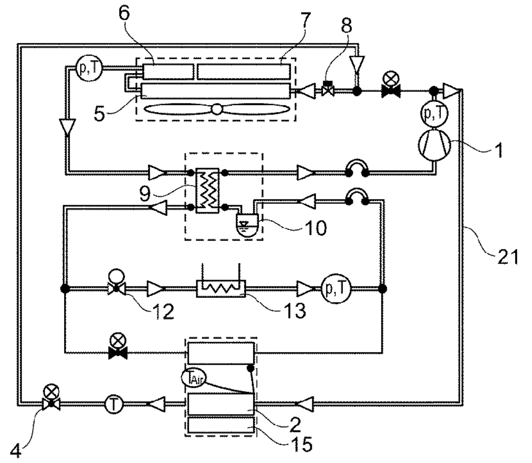
[Fig. 19]



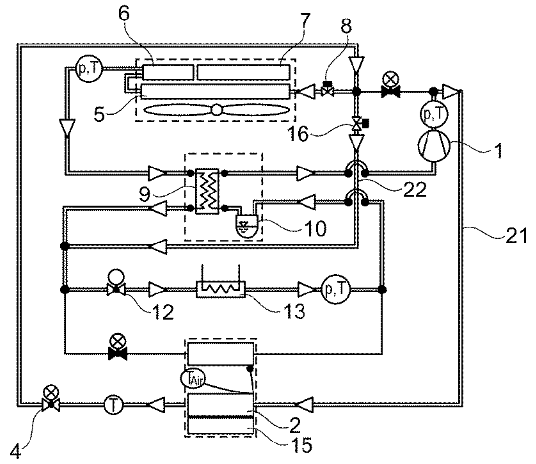
[Fig. 20]



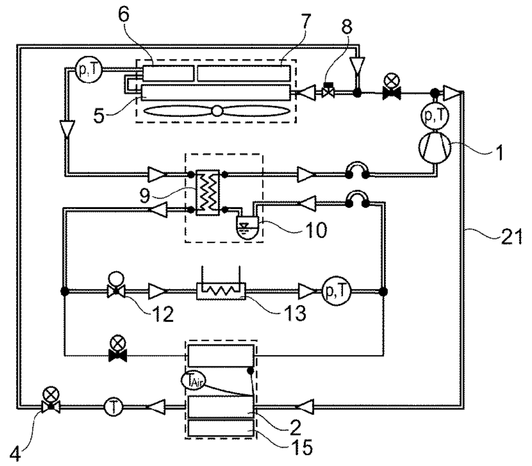
[Fig. 21]



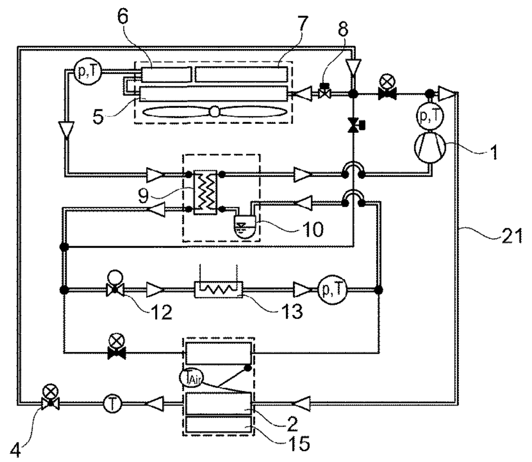
[Fig. 22]



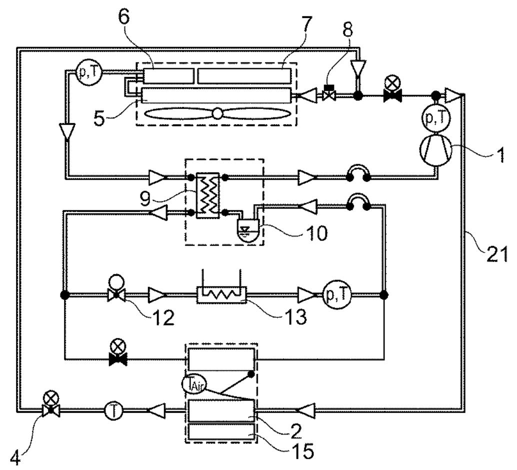
[Fig. 23]



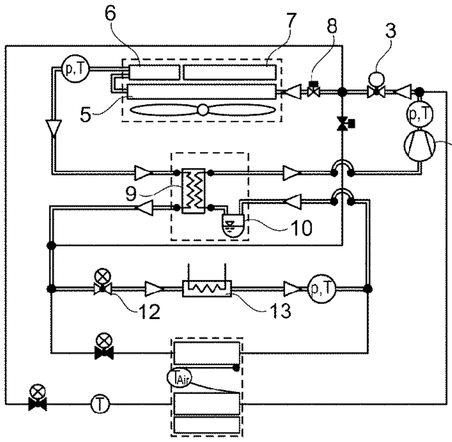
[Fig. 24]



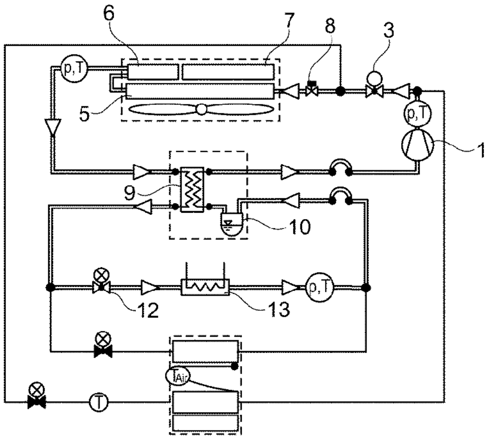
[Fig. 25]



[Fig. 26]



[Fig. 27]



INTERNATIONAL SEARCH REPORT

International application No.
PCT/KR2024/007269

A. CLASSIFICATION OF SUBJECT MATTER

B60H 1/32(2006.01)i; **B60H 1/00**(2006.01)i; **B60H 1/22**(2006.01)i; **F25B 9/00**(2006.01)i; **F25B 5/02**(2006.01)i; **F25B 6/04**(2006.01)i; **F25B 41/20**(2021.01)i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

B60H 1/32(2006.01); B60H 1/00(2006.01); B60H 1/14(2006.01); B60L 58/27(2019.01); F25B 49/02(2006.01); F25D 21/12(2006.01); H01M 10/613(2014.01)

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Korean utility models and applications for utility models
Japanese utility models and applications for utility models

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

eKOMPASS(KIPO internal) & Keywords: heat pump, refrigerant, R744, circuit, compressor, expansion, shut-off, valve, external cooler, evaporator, accumulator, chiller

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	WO 2022-008112 A1 (AUDI AG) 13 January 2022 (2022-01-13) page 7, line 25 - page 10, line 2, page 14, lines 2-15, page 17, lines 14-22 and figure 4	1-22
Y	KR 10-2318996 B1 (HANON SYSTEMS) 01 November 2021 (2021-11-01) paragraphs [0025], [0027]-[0028], [0040], claim 1, and figure 4	1-22
Y	KR 10-2022-0170462 A (HYUNDAI MOTOR COMPANY et al.) 30 December 2022 (2022-12-30) paragraphs [0032], [0035], [0044] and figure 1	7,8
Y	US 2020-0220236 A1 (HANON SYSTEMS) 09 July 2020 (2020-07-09) paragraph [0091] and figure 1	10,11,13,22
Y	US 2021-0310721 A1 (FORD GLOBAL TECHNOLOGIES, L.L.C.) 07 October 2021 (2021-10-07) paragraph [0015] and figure 1	22

☑ Further documents are listed in the continuation of Box C. ☑ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"D" document cited by the applicant in the international application
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search **07 October 2024**	Date of mailing of the international search report **08 October 2024**
Name and mailing address of the ISA/KR **Korean Intellectual Property Office** **189 Cheongsa-ro, Seo-gu, Daejeon** **35208, Republic of Korea** Facsimile No. **+82-42-481-8578**	Authorized officer **PARK, Tae Wook** Telephone No. **+82-42-481-3405**

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2016-0082805 A1 (HALLA VISTEON CLIMATE CONTROL CORP.) 24 March 2016 (2016-03-24) paragraphs [0050]-[0085] and figures 2-5	1-22
A	US 2020-0269654 A1 (AUDI AG.) 27 August 2020 (2020-08-27) paragraphs [0062]-[0125] and figures 1-4	1-22

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

Group I: claims 1-10 are directed to a heat pump arrangement for battery electric vehicles with R744 as a refrigerant and a method for operating a device according to any one of claims 1 to 8 in the vehicle cabin cooling mode.
Group II: claims 11, 22 are directed to a method for operating a device according to any one of claims 1 to 8 with active battery cooling in the chiller.
Group III: claims 12-14 are directed to a method for operating a device according to any one of claims 1 to 8 in the reheating mode.
Group IV: claims 15-16, 21 are directed a method for operating a device according to any one of claims 1 to 8 with the vehicle cabin heating in the heat pump mode.
Group V: claims 17-20 are directed to a method for operating a device according to any one of claims 1 to 8 with the vehicle cabin heating and waste heat utilisation in the heat pump mode.

1. ☑ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2. ☐ As all searchable claims could be searched without effort justifying additional fees, this Authority did not invite payment of additional fees.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.

☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.

☑ No protest accompanied the payment of additional search fees.

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/KR2024/007269

Patent document cited in search report	Publication date (day/month/year)	Patent family member(s)	Publication date (day/month/year)
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		EP 4175839 A1	10 May 2023
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KR 10-2318996 B1	01 November 2021	KR 10-2016-0133028 A	22 November 2016
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		DE 102019100096 B4	28 January 2021
		KR 10-2020-0085217 A	14 July 2020
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		DE 102020106174 A1	10 September 2020
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		DE 102014113526 A1	24 March 2016
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		DE 102017218424 A1	18 April 2019
		EP 3697635 A1	26 August 2020
		EP 3697635 B1	08 December 2021
		US 11279205 B2	22 March 2022
		WO 2019-076615 A1	25 April 2019