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(54) UNITARY HEAT PUMP AIR CONDITIONER

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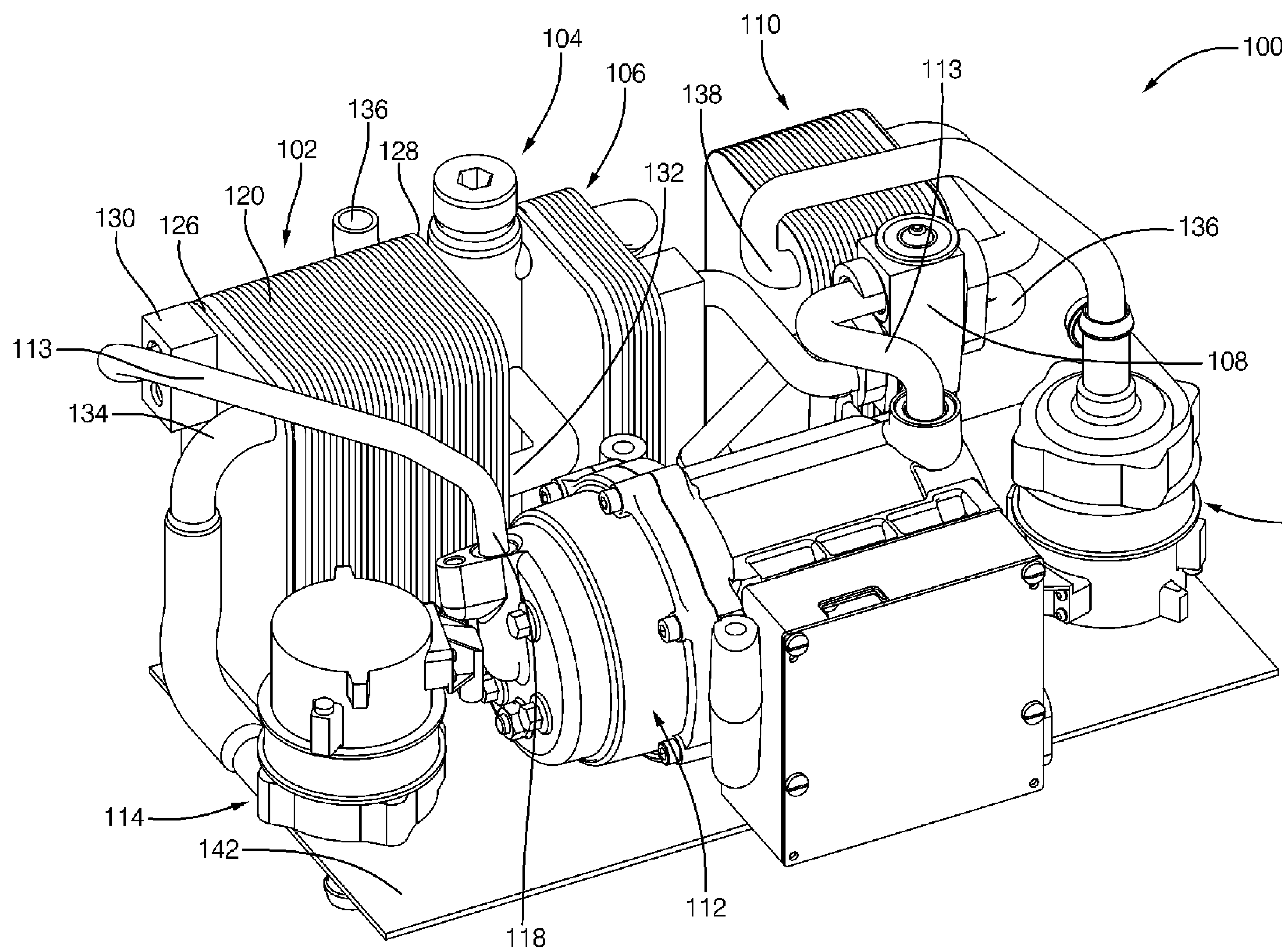
(57) **ABSTRACT**

The disclosure relates to a unitary heat pump air conditioner (Unitary HPAC) that includes a refrigerant loop having a condenser, a refrigerant expansion device, and an evaporator hydraulically connected in series. An electrically driven compressor is provided to circulate a two-phase refrigerant through the refrigerant loop to transfer heat from the evaporator to the condenser. The unitary HPAC also includes a cold side chiller configured to hydraulically connect to a cold side coolant loop and is in thermal communication with the evaporator. The unitary HPAC further includes a hot side chiller configured to hydraulically connect to a hot side coolant loop and is in thermal communication with the condenser. The refrigerant loop transfer heat from the cold side chiller to the hot side chiller, thereby cooling the cold side coolant loop and heating the hot side coolant loop. The components of the unitary HPAC are mounted on a common platform.



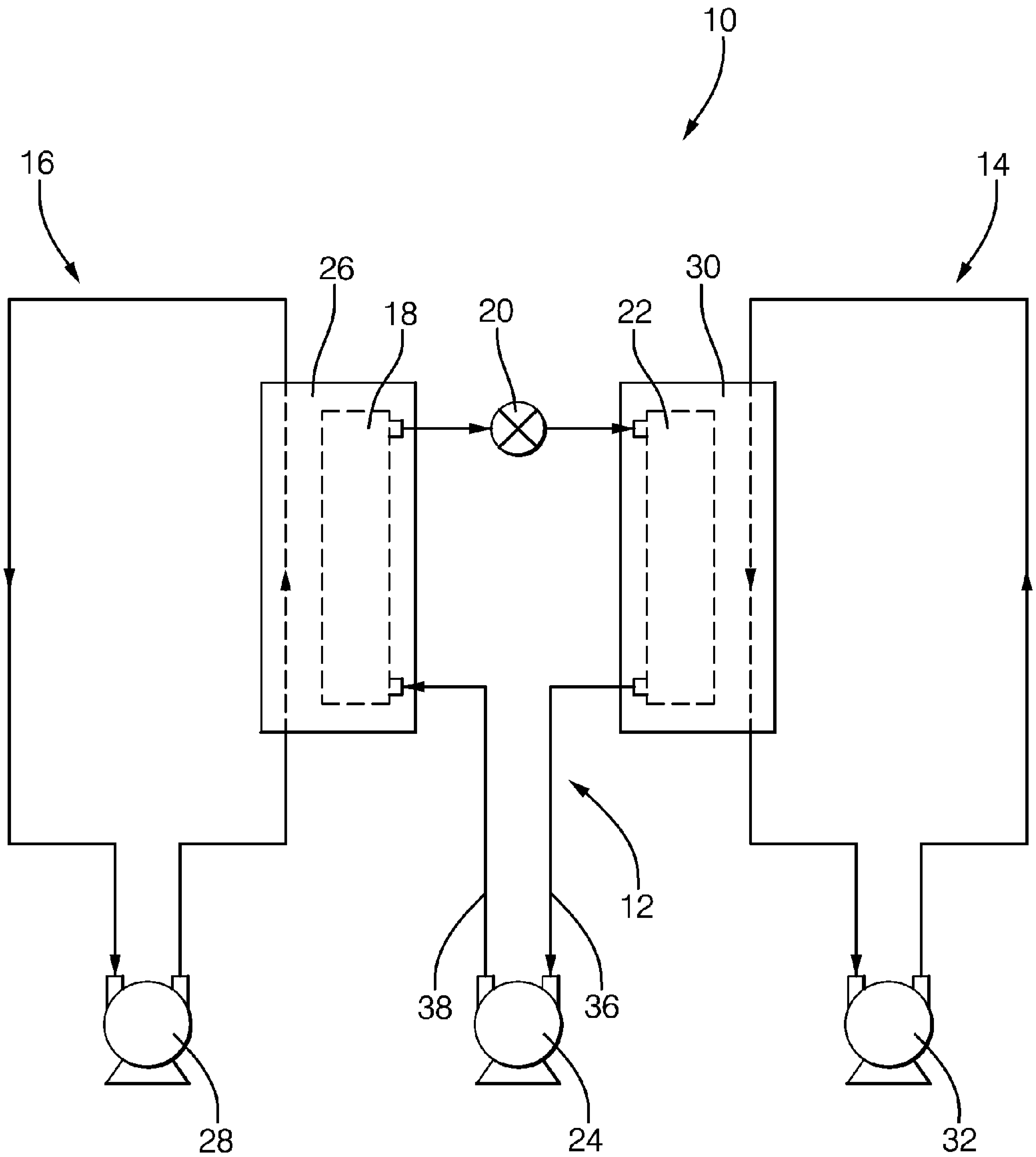


FIG. 1

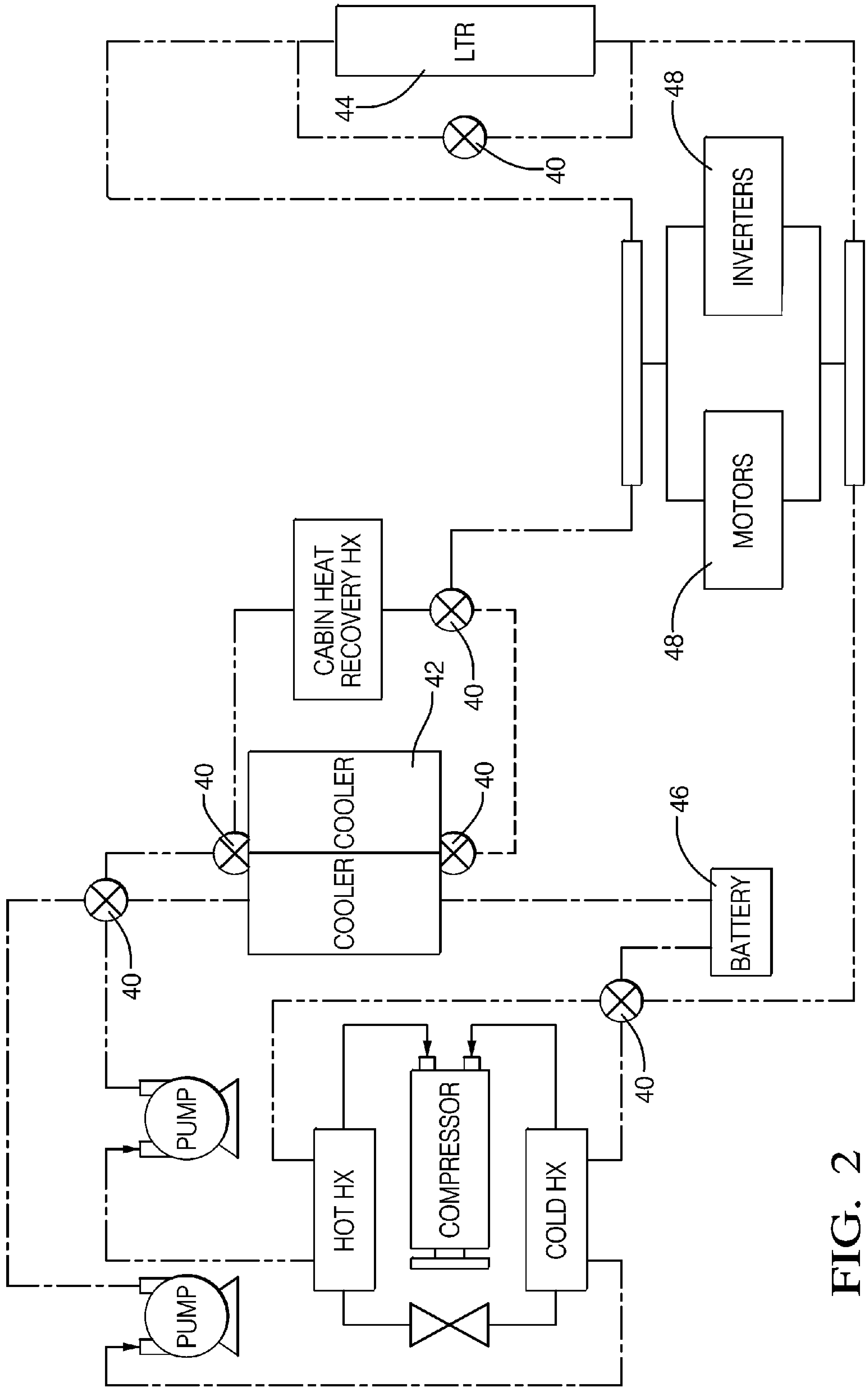
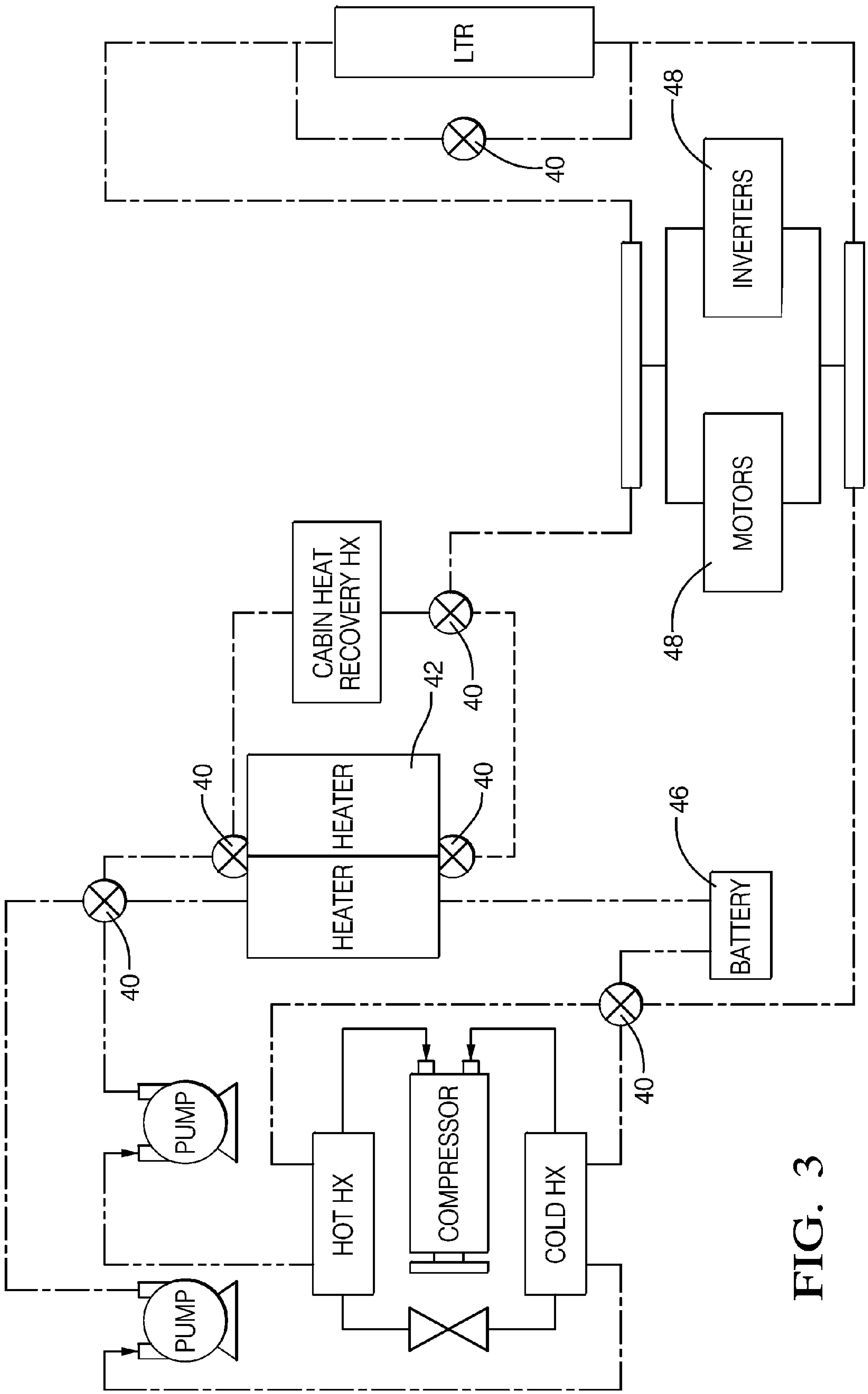

LTR
44
40
48
INVERTERS
MOTORS
48
CABIN HEAT RECOVERY HX
40
42
COOLER
COOLER
40
40
46
BATTERY
40
40
PUMP
PUMP
HOT HX
COMPRESSOR
COLD HX

FIG. 2


LTR
40
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40
42
HEATER
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46
BATTERY
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HOT HX
COMPRESSOR
COLD HX
40

FIG. 3

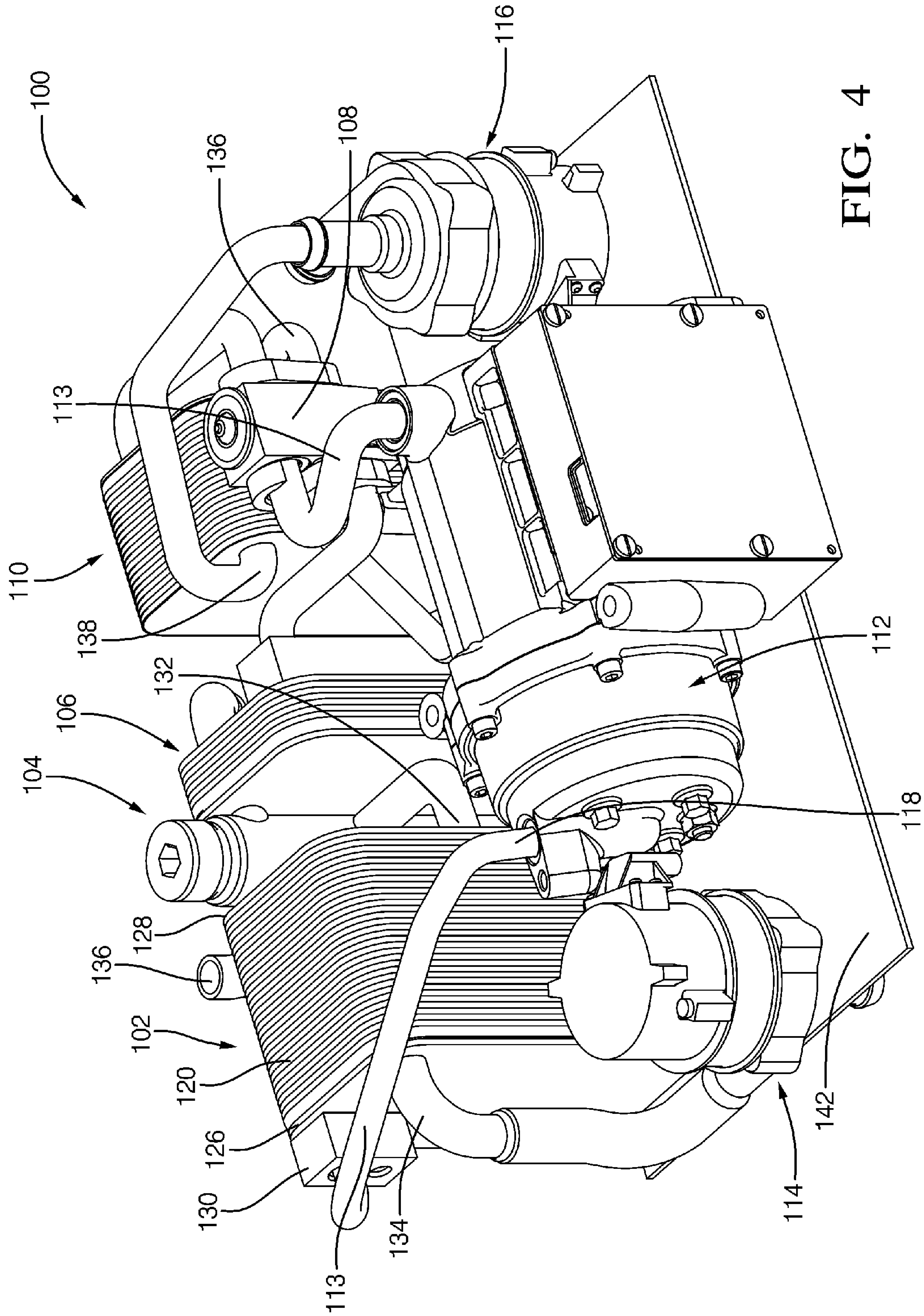
100
116
108
136
113
110
138
132
106
104
112
118
128
136
102
120
126
130
134
113
114
142

FIG. 4

UNITARY HEAT PUMP AIR CONDITIONER

CROSS-REFERENCE TO RELATED APPLICATION

[0001] This application is a national stage application under 35 U.S.C. 371 of PCT Application No. PCT/US2012/025419 having an international filing date of 16 Feb. 2012, which designated the United States, which PCT application claimed the benefit of U.S. Provisional Patent Application Ser. No. 61/443,774, filed Feb. 17, 2011, the entire disclosure of each of which are hereby incorporated by reference.

TECHNICAL FIELD OF INVENTION

[0002] The present invention relates to a heating and air-conditioning system for an automotive vehicle; particularly, to a heat pump air-conditioning system.

BACKGROUND OF INVENTION

[0003] For the comfort of the occupants in the passenger compartment, motor vehicles typically include dedicated air-conditioning systems and heating systems. The heating system includes a heater core located inside a heating, ventilating, and air conditioning (HVAC) module of the vehicle. The heater core is typically a liquid-to-air heat exchanger that supplies thermal energy to the passenger compartment for comfort heating. A heat transfer liquid, such as a glycol based coolant, conveys waste heat from an internal combustion engine to the heater core where the thermal energy from the heat transfer liquid is transferred to the ambient air flowing through the heater core to the passenger compartment. With the advent of greater efficiency internal combustion engines, hybrid vehicles having smaller internal combustion engines, and especially electrically driven vehicles, the amount of thermal energy available to provide comfort to occupants in the passenger compartment may not be adequate.

[0004] To provide supplemental heat to the passenger compartment for vehicles having smaller internal combustion engines, it is known to operate the air-conditioning system in heat pump mode. A typical motor vehicle air-conditioning system includes an evaporator located in the HVAC module and a condenser located in the front engine compartment exposed to outside ambient air. A compressor circulates a two-phase refrigerant through the evaporator where it expands into a low pressure vapor refrigerant by absorbing heat from the passenger compartment. After the low pressure vapor is compressed to a high pressure vapor by the compressor, the vapor phase refrigerant is transferred to the condenser where the high pressure vapor is condensed into a high pressure liquid refrigerant by releasing the heat to the ambient air. The liquid phase is returned to the evaporator through an expansion device which converts the high pressure liquid refrigerant to a low pressure mixture of liquid and vapor refrigerant to continue the cycle. By operating the air-conditioning system in heat pump mode, the refrigerant flow is reversed, in which case the condenser absorbs heat from the outside ambient air by evaporating the liquid phase refrigerant and the evaporator releases the heat to the passenger compartment by condensing the vapor phase refrigerant. One disadvantage to operating the air-conditioning system in heat pump mode, since the low pressure side of the system when used in air conditioning mode would become the high pressure side when used in heat pump mode, is the increase in system complexity due to the requirement of having to reinforce the refrigerant plumbing throughout the system by using thicker gage tubing and fittings. There is also the need to reinforce the evaporator to withstand the high pressure refrigerant, and to install an additional expansion device and receiver together with additional associated plumbing. Another known disadvantage of operating the system in heat pump mode is that in cooler climates, as the surface temperature of the condenser drop below 32° F., any moisture condensed on the surface of the condenser is subject to freezing, therefore potentially reduces the system's efficiency or even damage the condenser.

[0005] Electric heaters are known to be used to provide supplemental heat to the passenger compartment for vehicles using the air-conditioning system as a heat pump. In the coldest of climates, it is known that operating the air-conditioning system in heat pump mode is ineffective; therefore, additional electric heaters are required. However, for hybrid and electrical vehicles, electrical heaters represent an increased current draw that significantly reduces the electric drive range.

[0006] Based on the foregoing, there is need for a heating system that provides supplementary heat to the passenger compartment of a motor vehicle that does not require reversing the refrigerant cycle of the air-conditioning system or detrimentally impact the electric driving range.

SUMMARY OF THE INVENTION

[0007] The present invention relates to Unitary Heat Pump Air Conditioner (Unitary HPAC) for a Unitary HPAC System. The Unitary HPAC may include a refrigerant loop having a condenser for condensing a high pressure vapor refrigerant, a refrigerant expansion device, an evaporator downstream of the condenser for evaporating a low pressure liquid refrigerant, and an electrically driven compressor for receiving a low pressure vapor refrigerant from the evaporator and discharging a high pressure vapor refrigerant to the condenser. The Unitary HPAC further includes a cold side chiller configured to hydraulically connect to a cold side coolant loop, in which the cold side chiller is in thermal communication with the evaporator; a hot side chiller configured to hydraulically connect to a hot side coolant loop, in which the hot side chiller is in thermal communication with the condenser; and electrically driven hot coolant flow and cold coolant flow pumps may be provided to circulate a hot side coolant flow through the hot side chiller and a cold side coolant flow through the cold side chiller, respectively. The cold side chiller, hot side chiller, electrically driven coolant pumps, and components of the refrigerant loop, including the compressor, are mounted on a common platform to provide a compact Unitary HPAC.

[0008] Another embodiment may of the Unitary HPAC may include a plate-type integral condenser/hot side chiller assembly having a hot coolant passageway and a condenser refrigerant passageway in non-contact thermal communication. The unitary HPAC also includes a plate-type sub-cooler assembly having a sub-cooler refrigerant passageway in hydraulic communication with the condenser refrigerant passageway, a plate-type integral evaporator/cold side chiller assembly having a cold coolant passageway and an evaporator refrigerant passageway in hydraulic communication with the sub-cooler refrigerant passageway; and an electrically driven compressor having an inlet in hydraulic communication with the evaporator refrigerant passageway and an outlet in hydraulic communication with the condenser refrigerant passageway.

[0009] The Unitary HPAC system provides a dedicated refrigerant system in which the refrigerant cycle does not need to be reversed in order for the Unitary HPAC system to operate in heat pump mode. The Unitary HPAC system also provides a Unitary HPAC that is compact and easily installed in virtually any compartment of a vehicle that is larger than a bread box or a small tool box. In vehicles with small efficient internal combustion engines, the Unitary HPAC system scavenge heat from waste heat sources, such as the vehicle electronics, and use the waste heat to supplement the heating needs of the passenger compartment. In hybrid and electric vehicles, the Unitary HPAC improves the driving ranges in cold climates by minimizing the use of electric current to power electric heaters and providing heat to the battery packs to maintain an optimal operating temperature. Further features and advantages of the invention will appear more clearly on a reading of the following detailed description of an embodiment of the invention, which is given by way of non-limiting example only and with reference to the accompanying drawings.

BRIEF DESCRIPTION OF DRAWINGS

[0010] This invention will be further described with reference to the accompanying drawings in which:

[0011] FIG. **1** a schematic flow diagram a Unitary Heat Pump Air Conditioner System (Unitary HPAC system) in accordance with the invention.

[0012] FIG. **2** shows an exemplary Unitary HPAC system operating in cooling mode.

[0013] FIG. **3** shows an exemplary Unitary HPAC system operating in heating mode.

[0014] FIG. **4** shows an embodiment of the Unitary HPAC in accordance with the invention.

DETAILED DESCRIPTION OF INVENTION

[0015] Referring to FIGS. **1** through FIG. **4** is a Unitary Heat Pump Air Conditioner System (Unitary HPAC System) and an embodiment of a Unitary HPAC for use in a motor vehicle. The motor vehicle may be that of one with an internal combustion engine, a hybrid vehicle having both an internal combustion engine and an electric drive, or that of an electric vehicle having an electric drive. The Unitary HPAC System is a compact hermetically sealed system that improves the overall efficiency of the heating system and also provides cooling system to the motor vehicle. In hybrid and electric vehicles, the Unitary HPAC improves the driving ranges in cold climates by minimizing the use of electric current to power electric heaters and providing heat to the battery packs to maintain an optimal operating temperature. The Unitary HPAC system provides a dedicated refrigerant system in which the refrigerant cycle does not need to be reversed in order for the Unitary HPAC system to operate in heat pump mode. The Unitary HPAC system also provides a Unitary HPAC that is compact and easily installed in virtually any compartment of a vehicle that is larger than a bread box or a small tool box. Further advantages of the Unitary HPAC System will be readily appreciated by the reading of the disclosure below.

[0016] Shown in FIG. **1** is flow schematic of the Unitary HPAC System **10** having a dedicated refrigerant loop **12** in thermal communication with a cold coolant loop **14** and a hot coolant loop **16**. The main components of the refrigerant loop **12** include a condenser **18**, a refrigerant expansion device **20** such as a thermostatic expansion valve (TXV), and an evaporator **22** hydraulically connected in series. At the heart of the refrigerant loop is a refrigerant compressor **24** located downstream of the evaporator **22** and upstream of the condenser **18**. The compressor **24** is responsible for compressing and transferring a two-phase refrigerant, such as R-134a or R-1234yf, throughout the refrigerant loop **12** of the Unitary HPAC System **10**. The hot coolant loop **16** includes a hot side chiller **26** in thermal communication with the condenser **18** and a hot side coolant pump **28** that circulates a hot side coolant through the hot side chiller **26**. Similarly, the cold coolant loop **14** includes a cold side chiller **30** in thermal communication with the evaporator **22** and a cold side coolant pump **32** that circulates a cold side coolant through the cold side chiller **30**. The hot side chiller **26** and cold side chiller **30** may be that of a water jacket encasing the condenser **18** and evaporator **22**, respectively, or may be part of a plate-type heat exchanger, which is disclosed in greater detail below. The cold coolant loop **14** may absorb waste heat energy from various heat sources throughout the vehicle, such as the waste heat from the internal combustion engine or electronics, thereby cooling the various heat sources. The refrigerant loop **12** transfers the heat energy from the cold coolant loop **14** to the hot coolant loop **16**, which in turn transfers the heat energy to various heat sinks throughout the vehicle, such as an occupant heat exchanger to provide supplemental heat to the passenger compartment. In essence, the Unitary HPAC System **10** effectively captures waste heat energy and puts it to beneficial use within the vehicle.

[0017] The refrigerant cycle of the refrigerant loop **12** is typically the same as that of a dedicated air conditioning system of a motor vehicle operating in cooling mode. A two phase refrigerant is circulated through the refrigerant loop **12** by the compressor **24**, which includes a suction side **36**, also referred to as the low pressure side, and a discharge side **38**, also referred to as the high pressure side. The suction side of the compressor receives a low pressure vapor phase refrigerant from the evaporator **22**, after absorbing heat from the cold side coolant, and compresses it to a high pressure vapor phase refrigerant, which is then discharged to the condenser **18**. As the high pressure vapor phase refrigerant is condensed to a high pressure liquid phase refrigerant in the condenser **18**, heat is transferred to the hot side coolant flowing through the hot side chiller **26**. Exiting the condenser **18**, the high pressure liquid phase refrigerant may pass through a receiver (not shown) to separate any refrigerant vapor, a sub-cooler (not shown) to further cool the liquid phase refrigerant, and then to the TXV **20**, through which the refrigerant begins to expand into a bubbling liquid phase. The bubbling liquid phase refrigerant enters the evaporator **22** and continues to expand into the low pressure vapor refrigerant, which is then cycled back to the suction side **36** of the compressor **24** to repeat the process.

[0018] Referring to FIGS. **2** and **3**, the flow paths of the hot and cold coolant loops throughout the vehicle may be reconfigured based on the cooling and heating needs of the vehicle. The hot and cold coolant loops may include a myriad of interconnecting branches with remotely activated valves **40** at strategic nodes that may be reconfigured to redefine the flow paths of the hot and cold loops to selectively provide hot or cold coolant flow to designated heat exchangers. For example, shown in FIG. **2** is the Unitary HPAC System **10** operating in cooling mode. The cold coolant loop (shown in single dashed lines) is configured to flow to a comfort heat exchanger **42** to cool the air to the occupant compartment and to a battery heat exchanger **46** to cool the batteries, while the hot coolant loop (shown in double dashed lines) is configured to dissipate the heat through an external heat exchanger **44**. Shown in FIG. **3**, in heat pump mode, the hot coolant loop (shown in double dashed lines) may be redirected to the comfort heat exchanger **42** to heat the air to the occupant compartment and to battery heat exchanger **46** to maintain the batteries at an optimal operating temperature, while the cold coolant loop (shown in single dashed lines) is directed to an ancillary heat exchangers **48** to scavenge waste heat from the vehicle's electronics or from the external ambient air. Also, the cold coolant loop may be directed through a cabin heat recovery heat exchanger (CABIN HEAT RECOVERY HX) that is disposed in or near an air outlet of the occupant compartment. The cabin recovery heat exchanger may be that of an air to liquid heat exchanger where the heat energy in the cabin exhaust air may be captured by the Unitary HPAC System **10** to be reused in the comfort heat exchanger **42**. Unlike the known methods of operating an air-conditioning system in heat pump mode, the refrigerant loop **12** of the current invention is never reversed; therefore there is no need to reinforce the refrigerant tubing and fittings throughout the system since the low pressure side **38** of the refrigerant loop **12** is not subject to the high pressure refrigerant.

[0019] Shown in FIG. **4** is a compact Unitary HPAC **100** in accordance with an embodiment of the invention for the Unitary HPAC System **10** disclosed above. The Unitary HPAC **100** shown includes an integral condenser/hot side chiller assembly **102**, a receiver **104**, a sub-cooler **106**, a thermal expansion valve (TXV) **108**, and an integral evaporator/cold side chiller assembly **110**. The Unitary HPAC **100** also includes an electrically driven compressor **112** for the circulation of a typical two-phase refrigerant through a series of refrigerant tubes **113** and electrically driven hot side and cold side coolant pumps **114**, **116** configured to hydraulically connect to the hot coolant loop and cold coolant loop, respectively. The compressor may be that of a compact scroll compressor driven by a permanent magnet motor with neodymium magnets. The liquid coolant used in the hot and coolant loops is generally a mixture of 70% glycol-30% water, which prevents the coolant from freezing or becoming too viscous at the low temperatures needed in integral evaporator/cold side chiller assembly **110**.

[0020] The integral condenser/hot side chiller assembly **102** may be that of a plate-type heat exchanger assembly having a plurality of stamped metal plates **120** stacked and brazed between an upstream end plate **126** and a downstream end plate **128**. The stamped metal plates include features known to those of ordinary skill in the art, such as openings, bosses about selected openings, and flanges, which when stacked, define a condenser refrigerant passageway for high pressure refrigerant flow and a separate hot coolant passageway for hot coolant flow. The plates may include numerous contact points established between adjacent plates to induce turbulence to the fluids flowing therethrough to provide a high heat transfer co-efficient.

[0021] The flows of the hot refrigerant and hot coolant through the integral condenser/hot side chiller assembly **102** are in non-contact thermal communication; in other words, the two fluids are not intermingle, but are in thermal communication with each other, and may be concurrent or countercurrent flow. Heat energy from the higher temperature refrigerant is transferred to the lower temperature hot coolant, thereby increasing the temperature of the hot coolant as it leaves the integral condenser/hot side chiller assembly **102** and returning to the hot coolant loop (not-shown). The upstream end plate **126** includes a refrigerant inlet **130** in fluid communication with the discharge side **118** of the electrically driven compressor **112** and a hot coolant inlet **134** in fluid communication with the hot side coolant pump **116**. The downstream end plate **128** includes a refrigerant outlet **132** in fluid communication with the receiver **104** and a hot coolant outlet **136** configured to hydraulically connect to the hot coolant loop.

[0022] Similarly, the downstream sub-cooler assembly **106** and integral evaporator/cold side chiller assembly **110** may also be plate-type heat exchangers. The integral evaporator/cold side chiller assembly **110** includes a cold coolant inlet **138** and outlet **140**, in which the cold coolant outlet **140** is adapted to hydraulically connect to the cold coolant loop (not shown), an evaporator refrigerant passageway for low pressure refrigerant flow, and a separate cold coolant passageway for cold coolant flow. The flows of the low pressure refrigerant and cold coolant through the integral evaporator/cold side chiller assembly **110** are also in non-contact thermal communication with each other, and may be concurrent or countercurrent flow. Heat energy from the higher temperature cold coolant is transferred to the lower temperature evaporating refrigerant, thereby decreasing the temperature of the cold coolant as it leaves the integral evaporator/cold side chiller assembly **110** and returning to the cold coolant loop (not-shown).

[0023] Unlike a traditional air conditioning system, where the refrigerant side components are remotely dispersed throughout the engine bay and within the HVAC module, the components of the Unitary HPAC **100** including the integral condenser/hot side chiller assembly **102**, receiver **104**, sub-cooler assembly **106**, TXV **108**, integral evaporator/cold side chiller assembly **110**, and electrically driving compressor **112** and coolant pumps **114**, **116** may be all mounted onto a single platform **142** measuring approximately 376 mm by 220 mm. The components may even be enclosed a housing, having a similar sized base and a height of about less than 212 mm, which is approximately the size of a typical bread box, for ease of handling and protection against the environment. The centralized location of the components that form the Unitary HPAC **100** allows the use of shorter length refrigerant tubes **113** which are manufactured from a refrigerant impermeable material, such as stainless steel, aluminum, and/or copper. The shorten length refrigerant impermeable tubes **113** minimizes refrigerant leaks and moister infiltration; thereby allowing the use of a smaller receiver **104**, since a large volume of refrigerant reserve is not required. The reduction of moisture infiltration reduces or eliminates the volume of desiccant needed, resulting in a more compact Unitary HPAC **100**. Due to its compact size, the Unitary HPAC **100** may be installed in virtually any location within the body of a motor vehicle that can fit a bread box, such as within the trunk, under the hood, within the dashboard, or even under the seats.

[0024] While the invention has been described with reference to an exemplary embodiment, it will be understood by those skilled in the art that various changes may be made and equivalents may be substituted for elements thereof without departing from the scope of the invention. In addition, many modifications may be made to adapt a particular situation or material to the teachings of the intentions without departing from the essential scope thereof. Therefore, it is intended that the invention not be limited to the particular embodiment disclosed as the best mode contemplated for carrying out this invention, but that the invention will include all embodiments falling within the scope of the appended claims.

Having described the invention, it is claimed:

1. A unitary heat pump air conditioner (Unitary HPAC) system, comprising:

a refrigerant loop having a condenser for condensing a high pressure vapor refrigerant thereby releasing heat energy, an evaporator downstream of said condenser for evaporating a low pressure liquid refrigerant thereby absorbing heat energy, and a compressor for receiving a low pressure vapor refrigerant from said evaporator and discharging a high pressure vapor refrigerant to said condenser;

a cold side chiller configured to hydraulically connect to a cold side coolant loop having a cold side coolant flow therethrough, wherein said cold side chiller is in thermal communication with said evaporator, whereby heat energy is transferred from the cold side coolant flow to the evaporating refrigerant within said evaporator, thereby cooling the cold side coolant flow; and

a hot side chiller configured to hydraulically connect to a hot side coolant loop having a hot side coolant flow therethrough, whereby heat energy is transferred from the condensing refrigerant in the condenser to the hot side coolant flow, thereby heating the hot side coolant flow.

2. The unitary heat pump air conditioner (Unitary HPAC) of claim **1**, wherein said compressor is electrically driven.

3. The unitary heat pump air conditioner (Unitary HPAC) of claim **2**, further comprising an electrically driven hot coolant flow and cold coolant flow pumps configured to circulate a hot side coolant flow throughout said hot side chiller and a cold side coolant flow through said cold side chiller, respectively.

4. The unitary heat pump air conditioner (Unitary HPAC) of claim **3**, wherein said refrigerant loop further comprises a refrigerant expansion device downstream of said condenser and upstream of said evaporator.

5. The unitary heat pump air conditioner (Unitary HPAC) of claim **4**, wherein said refrigerant loop further comprises a receiver downstream of said condenser and upstream of said refrigerant expansion device.

6. The unitary heat pump air conditioner (Unitary HPAC) of claim **5**, wherein said refrigerant loop further comprises a sub-cooler downstream of said receiver and upstream of said refrigerant expansion device.

7. The unitary heat pump air conditioner (Unitary HPAC) of claim **6**, wherein said compressor, receiver, sub-cooler, refrigerant expansion device, and evaporator of said refrigerant loop, together with said hot side chiller, cold side chiller, and hot and cold side coolant pumps are mounted on a common platform.

8. A unitary heat pump air conditioner (Unitary HPAC), comprising:

a plate-type integral condenser/hot side chiller assembly comprising a hot coolant passageway and a condenser refrigerant passageway, wherein said hot coolant passageway and said condenser refrigerant passageway are in non-contact thermal communication;

a plate-type sub-cooler assembly comprising a sub-cooler refrigerant passageway in hydraulic communication with condenser refrigerant passageway;

a plate-type integral evaporator/cold side chiller assembly comprising a cold coolant passageway and an evaporator refrigerant passageway in hydraulic communication with said sub-cooler passageway;

and an electrically driven compressor having an inlet in hydraulic communication with said evaporator refrigerant passageway and an outlet in hydraulic communication with said condenser refrigerant passageway.

9. The unitary heat pump air conditioner (Unitary HPAC) of claim **8**, further comprising an electrically driven hot side coolant pump in hydraulic communication with said hot coolant passageway of said plate-type integral condenser/hot side chiller assembly and an electrically driven cold side coolant pump in hydraulic communication with said cold coolant passageway of said plate-type integral evaporator/cold side chiller assembly.

10. The unitary heat pump air conditioner (Unitary HPAC) of claim **9**, further comprising a refrigerant expansion device in hydraulic communication with said refrigerant passageway of plate-type sub-cooler and refrigerant passageway of integral evaporator/cold side chiller assembly.

11. The unitary heat pump air conditioner (Unitary HPAC) of claim **10**, further comprising a receiver in hydraulic communication with upstream condenser refrigerant passageway and downstream sub-cooler refrigerant passageway.

12. The unitary heat pump air conditioner (Unitary HPAC) of claim **8**, further comprising hot side coolant and cold side coolant pumps configured to circulate a hot side coolant flow through said hot coolant passageway and a cold side coolant flow through said cold coolant passageway, respectively.

13. The unitary heat pump air conditioner (Unitary HPAC) of claim **11**, wherein said plate-type integral condenser/hot side chiller assembly, said plate-type sub-cooler assembly, said receiver, said plate-type sub-cooler, said plate-type integral evaporator/cold side chiller assembly, said electrically driven compressor, and said hot and cold side coolant pumps are mounted on a common platform.

14. A unitary heat pump air conditioner (Unitary HPAC) system for a motor vehicle, comprising:

a refrigerant loop having a condenser for condensing a high pressure vapor refrigerant thereby releasing heat energy, an evaporator downstream of said condenser for evaporating a low pressure liquid refrigerant thereby absorbing heat energy, and a compressor for receiving a low pressure vapor refrigerant from said evaporator and discharging a high pressure vapor refrigerant to said condenser;

a cold side coolant loop having a cold side coolant flow therethrough and configured to capture waste heat energy from heat sources within the motor vehicle;

a cold side chiller hydraulically connected to said cold side coolant loop, wherein said cold side chiller is in thermal communication with said evaporator, whereby heat energy is transferred from the cold side coolant flow to the evaporating refrigerant within said evaporator, thereby cooling the cold side coolant flow; and

a hot side coolant loop having a hot side coolant flow therethrough and configured to transfer heat energy to heat sinks within the motor vehicle;

a hot side chiller hydraulically connected to said hot side coolant loop having a hot side coolant flow therethrough, whereby heat energy is transferred from the condensing refrigerant in the condenser to the hot side coolant flow, thereby heating the hot side coolant flow;

wherein said cold side coolant includes a cabin heat recovery heat exchanger configured to capture heat energy from the exhaust air from a compartment of said motor vehicle.

* * * * *