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(54) **HVAC SYSTEM**

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H05B 3/34 (2006.01)
G05D 23/00 (2006.01)

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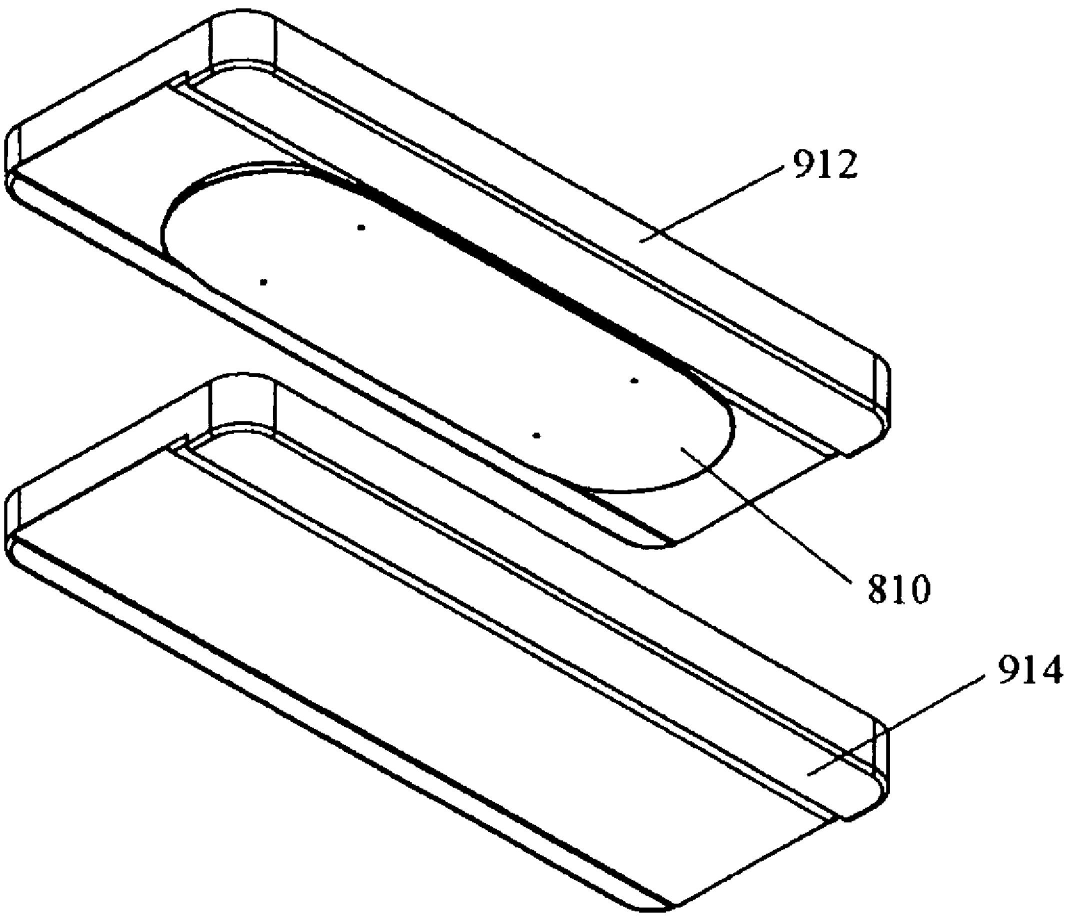
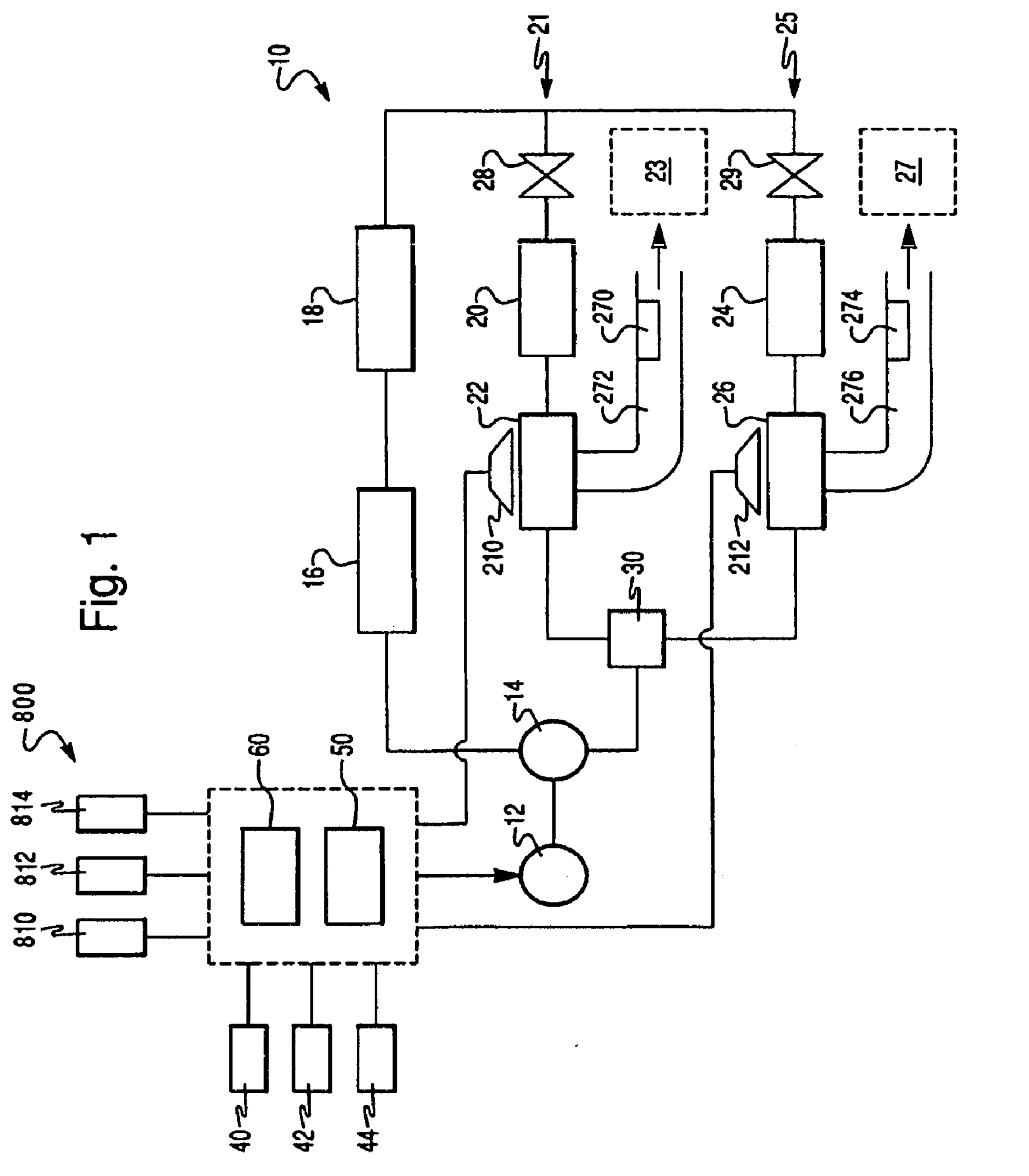
(57) **ABSTRACT**

An HVAC system to be installed in a vehicle may comprise at least one power source; a plurality of heating devices; and a component controller. The component controller may be configured to operate a selected portion of the plurality of heating devices based on user preferences stored in the component controller, available power from the at least one power source, and a desired set point temperature.

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21
25
28
29
23
27
18
20
24
270
274
272
276
22
26
16
210
212
30
14
12
800
814
812
810
60
50
40
42
44
Fig. 1

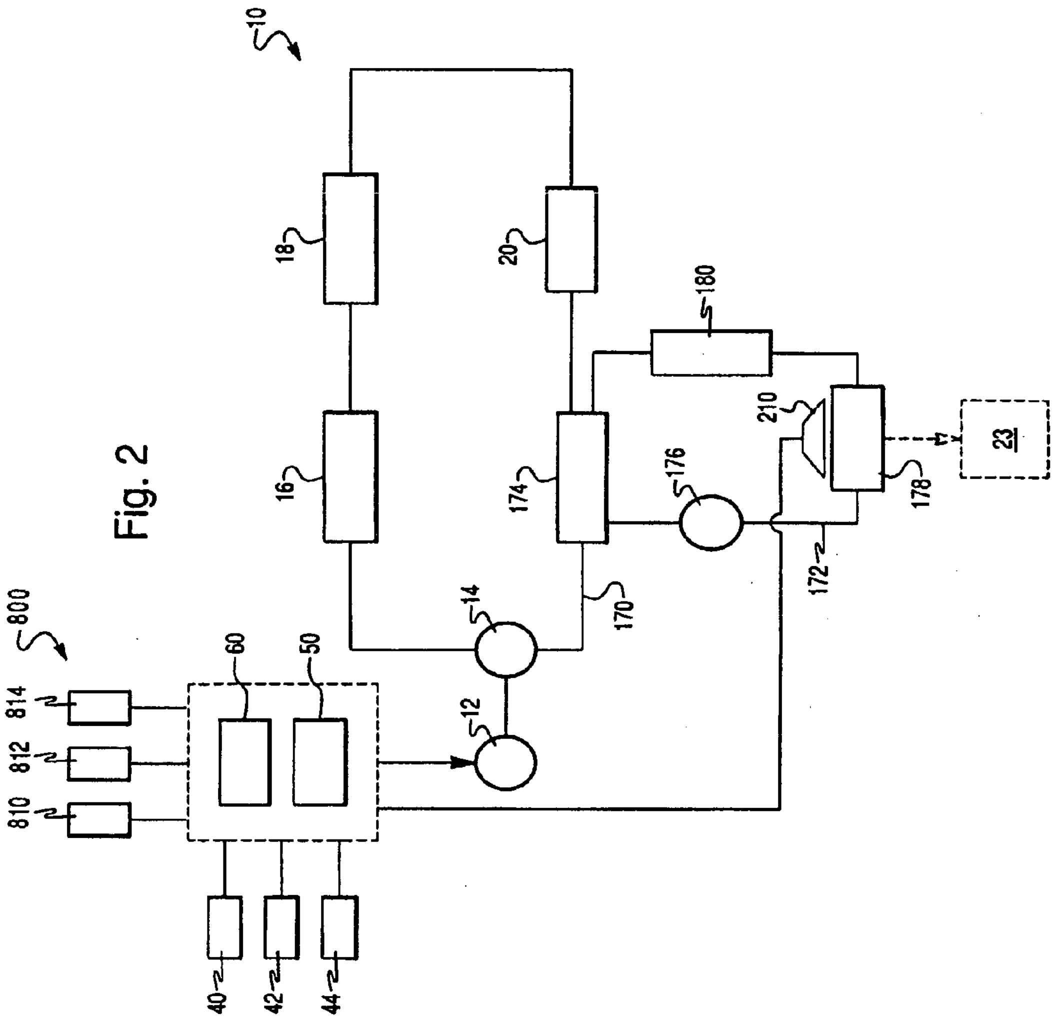

10
18
20
16
174
176
180
210
178
23
170
172
14
12
60
50
800
810
812
814
40
42
44

Fig. 2

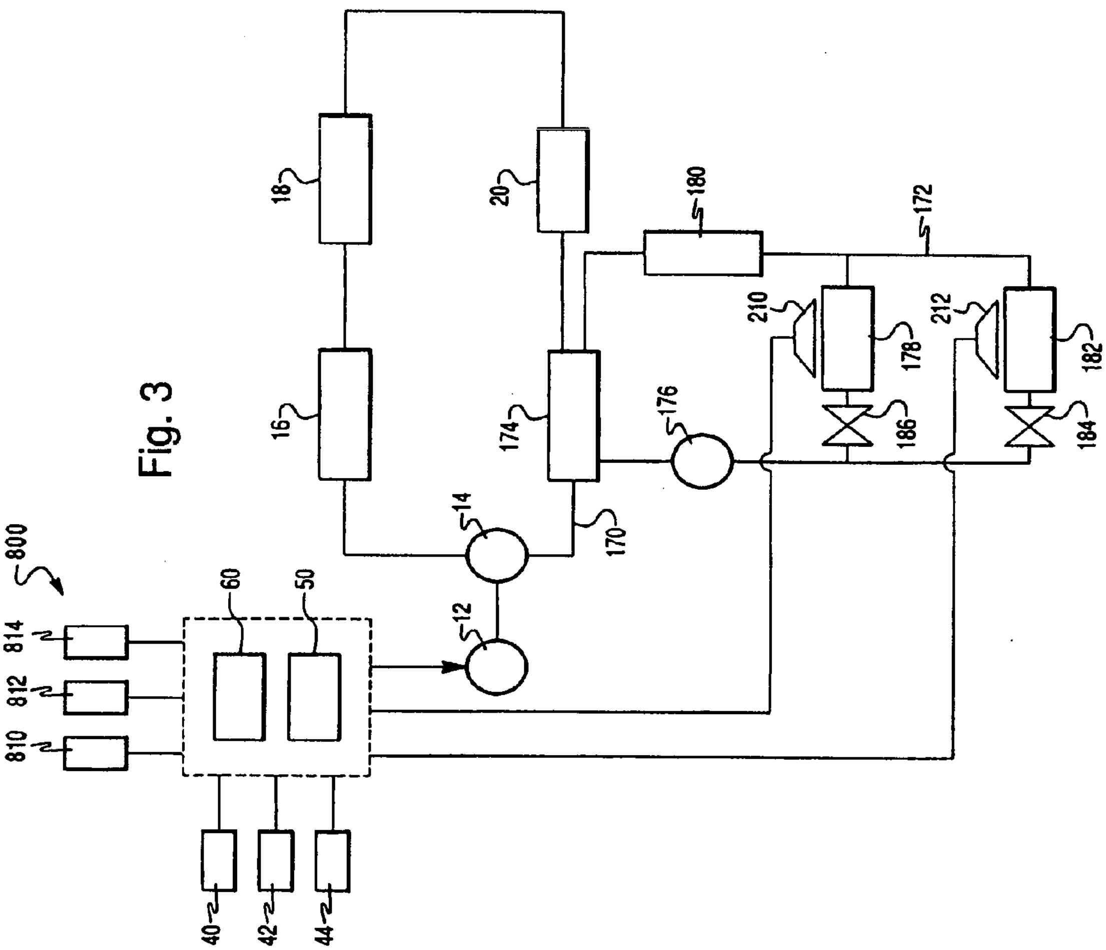

800
810
812
814
60
50
40
42
44
12
14
16
18
20
170
172
174
176
178
180
182
184
186
210
212

Fig. 3

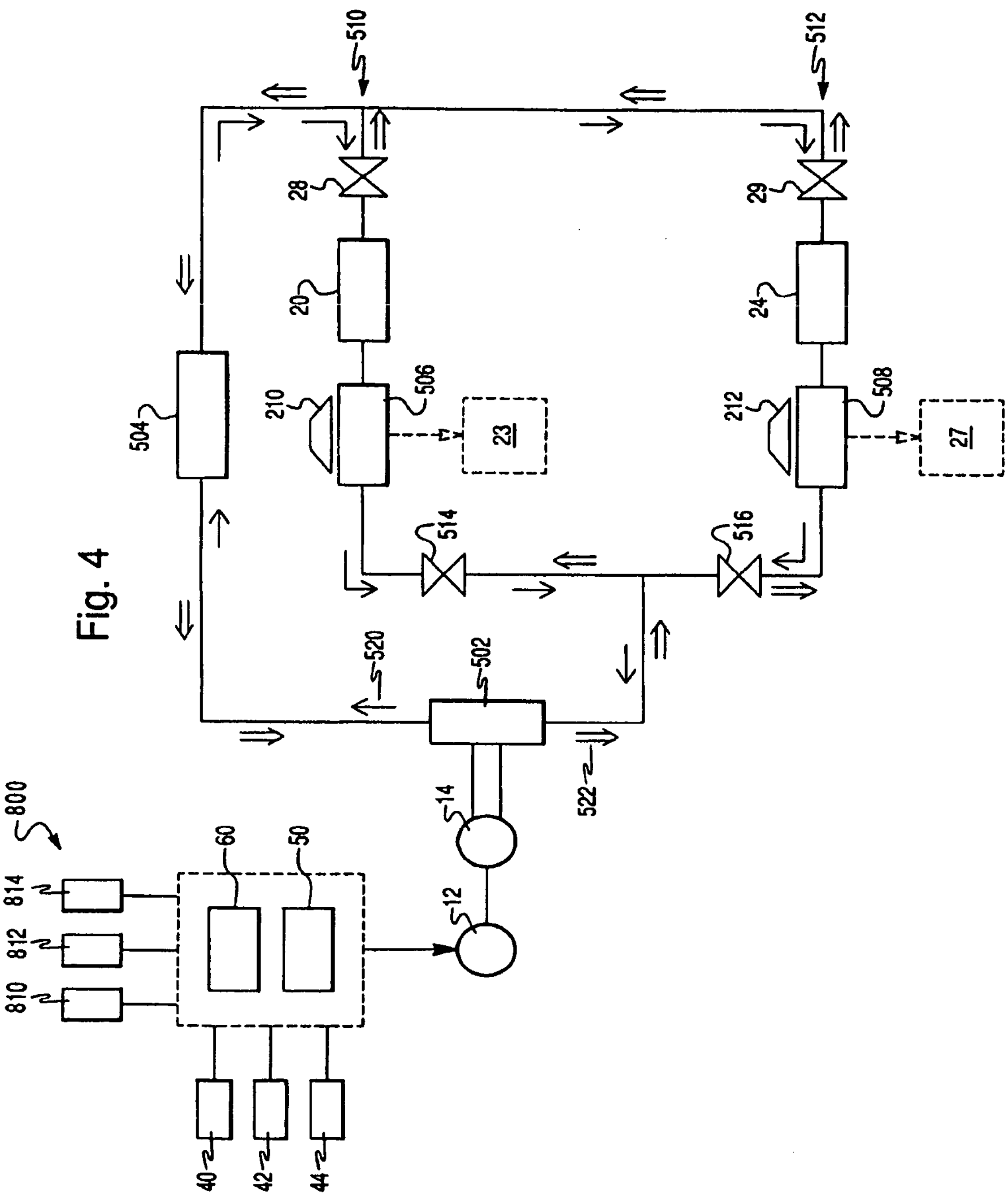

510
512
28
29
20
24
504
210
506
212
508
23
27
514
516
520
502
522
14
12
800
814
812
810
60
50
40
42
44

Fig. 4

Fig. 5(a)

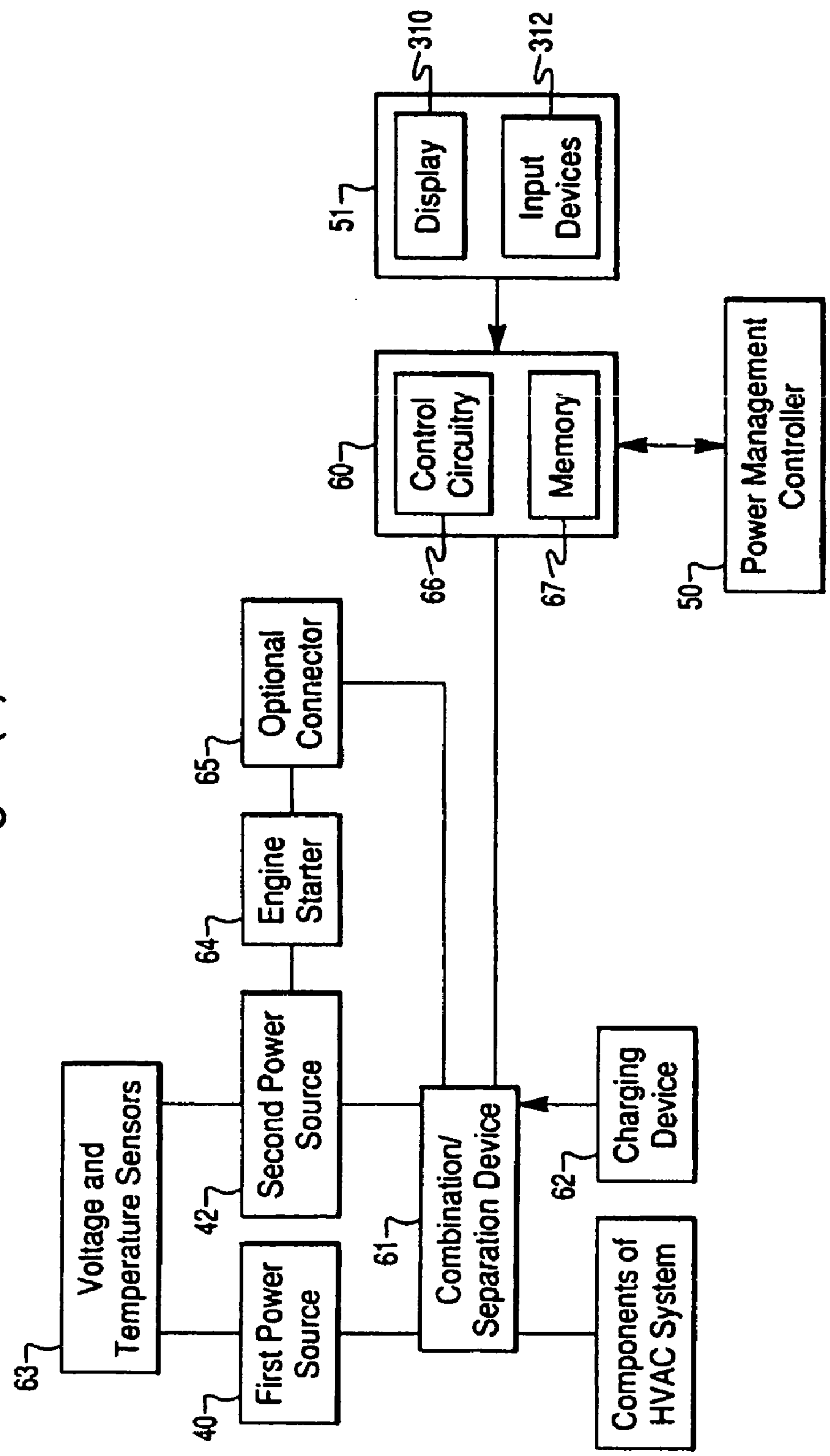

Display
310
Input Devices
312
51
Control Circuitry
Memory
60
66
67
Power Management Controller
50
Optional Connector
65
Engine Starter
64
Second Power Source
42
Voltage and Temperature Sensors
63
First Power Source
40
Combination/ Separation Device
61
Charging Device
62
Components of HVAC System

Fig. 5(b)

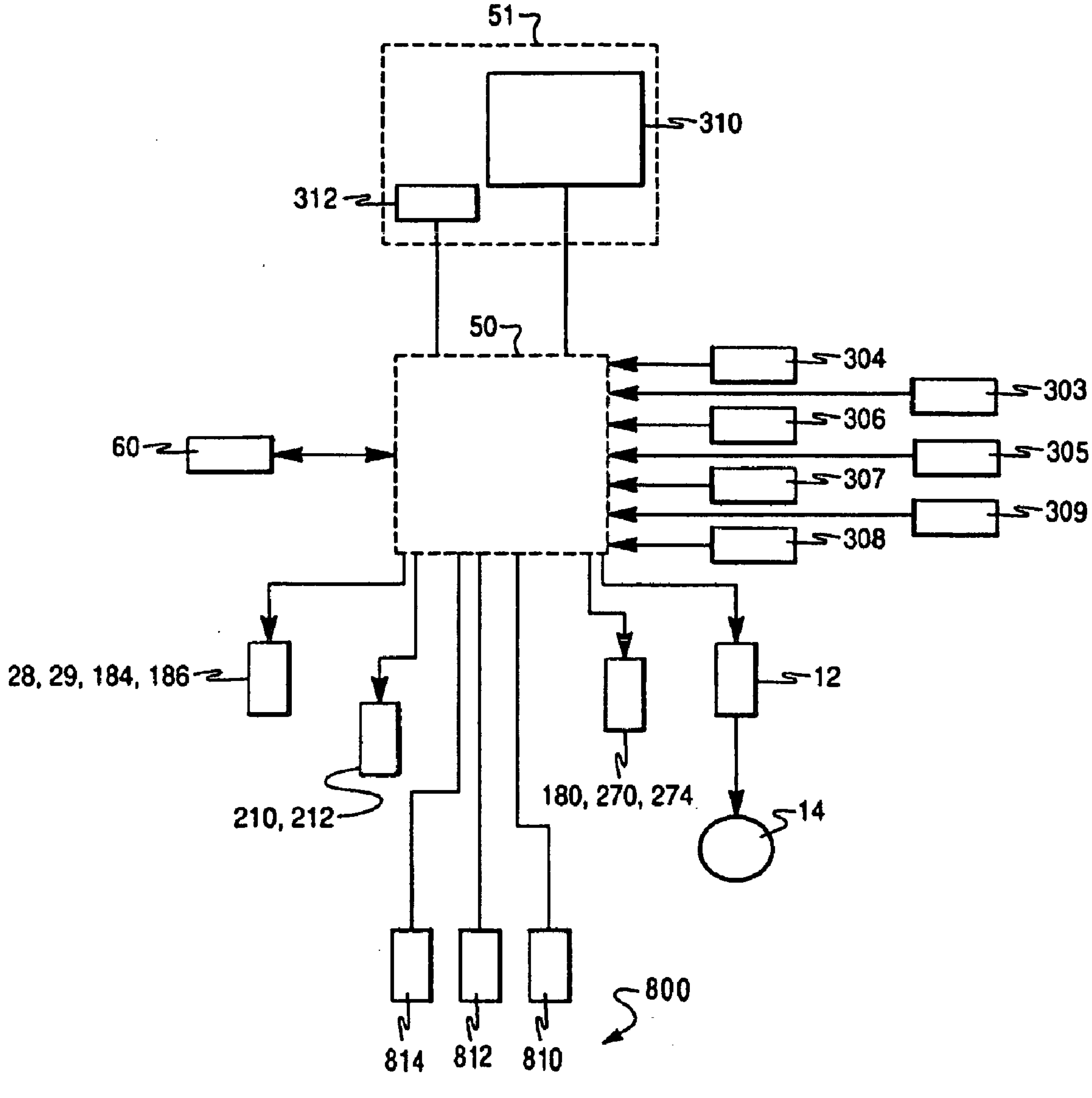

51
310
312
50
304
303
306
305
307
309
308
60
28, 29, 184, 186
12
210, 212
180, 270, 274
14
800
814
812
810

Fig. 6(a)

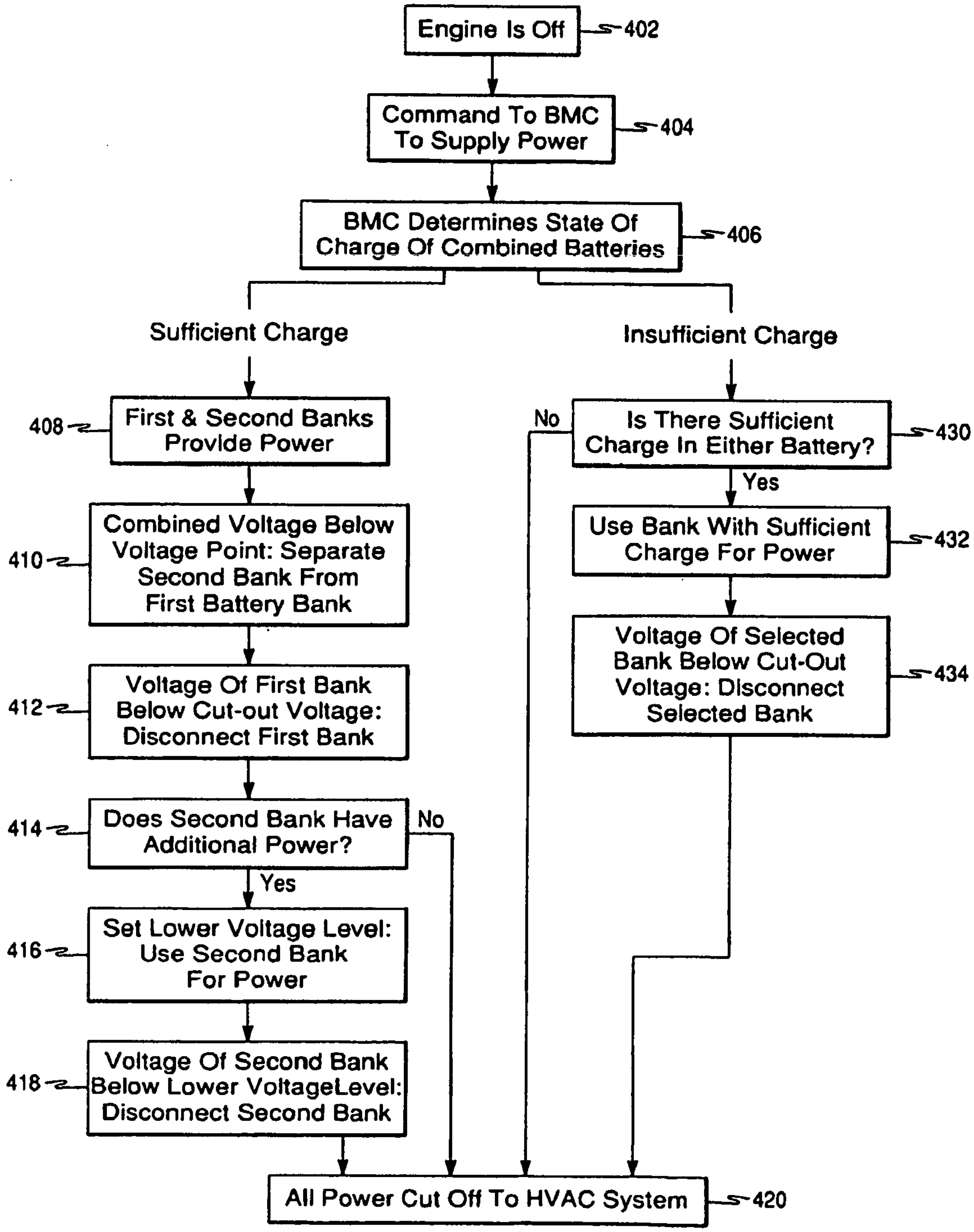

Engine Is Off
402
Command To BMC To Supply Power
404
BMC Determines State Of Charge Of Combined Batteries
406
Sufficient Charge
Insufficient Charge
408
First & Second Banks Provide Power
410
Combined Voltage Below Voltage Point: Separate Second Bank From First Battery Bank
412
Voltage Of First Bank Below Cut-out Voltage: Disconnect First Bank
414
Does Second Bank Have Additional Power?
No
Yes
416
Set Lower Voltage Level: Use Second Bank For Power
418
Voltage Of Second Bank Below Lower VoltageLevel: Disconnect Second Bank
No
Is There Sufficient Charge In Either Battery?
430
Yes
Use Bank With Sufficient Charge For Power
432
Voltage Of Selected Bank Below Cut-Out Voltage: Disconnect Selected Bank
434
All Power Cut Off To HVAC System
420

Fig. 6(b)

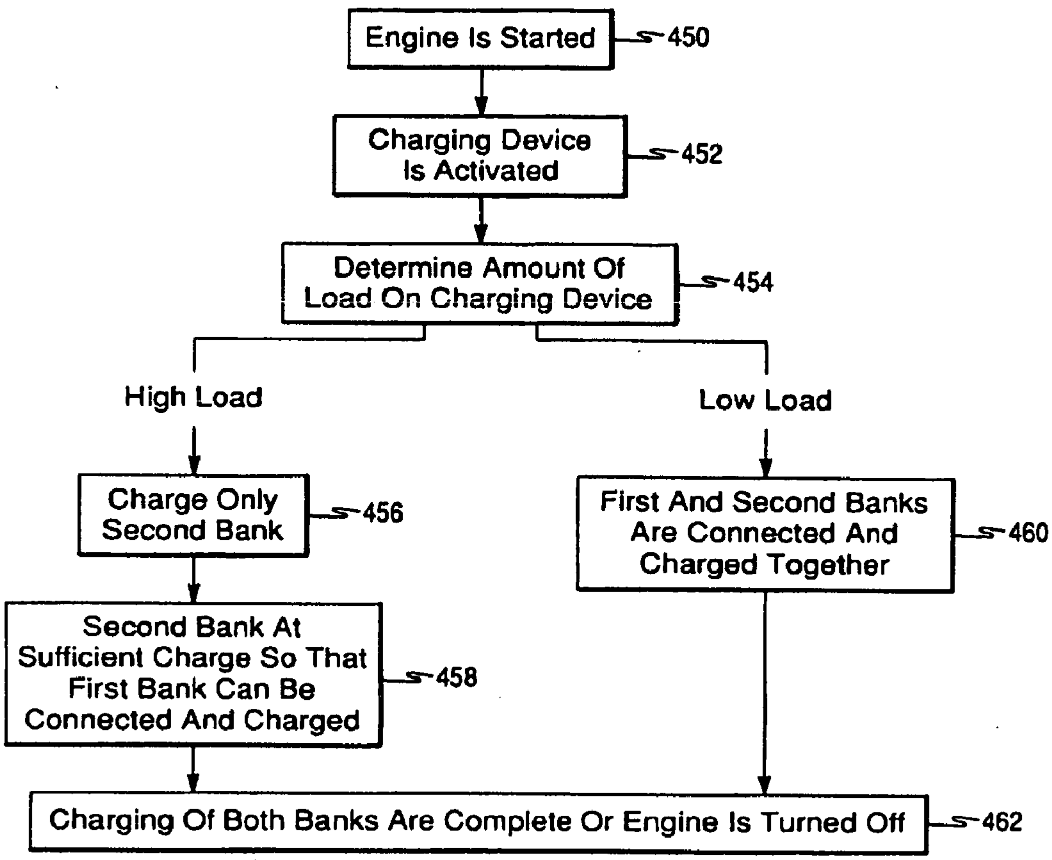

Engine Is Started
450
Charging Device Is Activated
452
Determine Amount Of Load On Charging Device
454
High Load
Low Load
Charge Only Second Bank
456
First And Second Banks Are Connected And Charged Together
460
Second Bank At Sufficient Charge So That First Bank Can Be Connected And Charged
458
Charging Of Both Banks Are Complete Or Engine Is Turned Off
462

Fig. 7

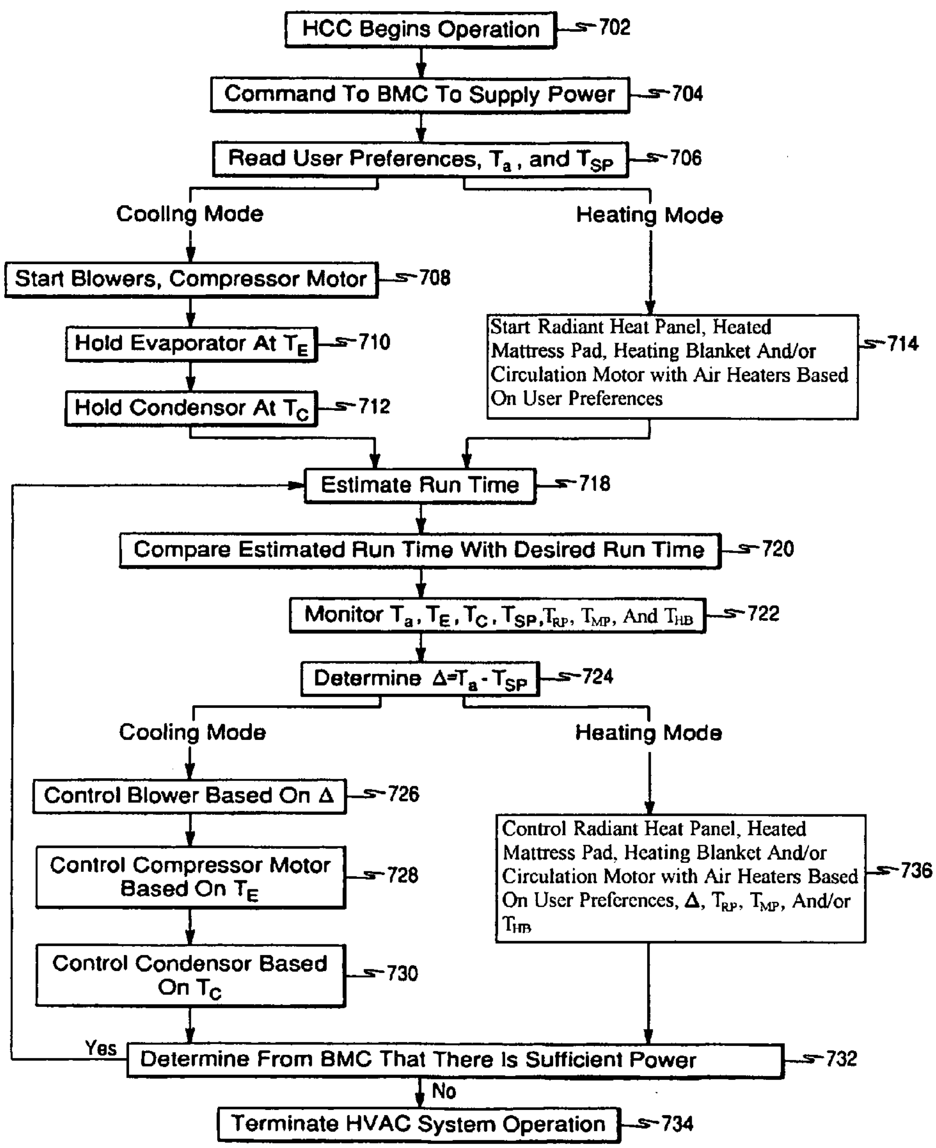
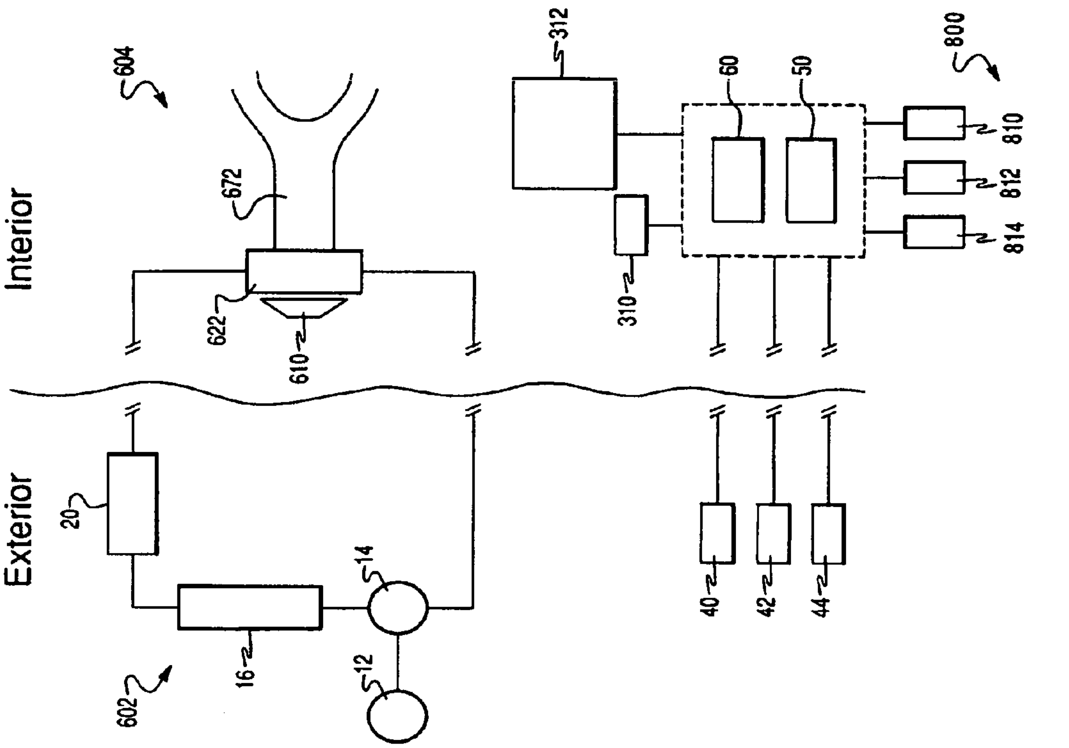

HCC Begins Operation
702
Command To BMC To Supply Power
704
Read User Preferences, T_a, and T_{SP}
706
Cooling Mode
Heating Mode
Start Blowers, Compressor Motor
708
Hold Evaporator At T_E
710
Hold Condensor At T_C
712
Start Radiant Heat Panel, Heated Mattress Pad, Heating Blanket And/or Circulation Motor with Air Heaters Based On User Preferences
714
Estimate Run Time
718
Compare Estimated Run Time With Desired Run Time
720
Monitor T_a, T_E, T_C, T_{SP}, T_{RP}, T_{MP}, And T_{HB}
722
Determine $\Delta = T_a - T_{SP}$
724
Cooling Mode
Heating Mode
Control Blower Based On Δ
726
Control Compressor Motor Based On T_E
728
Control Condensor Based On T_C
730
Control Radiant Heat Panel, Heated Mattress Pad, Heating Blanket And/or Circulation Motor with Air Heaters Based On User Preferences, Δ, T_{RP}, T_{MP}, And/or T_{HB}
736
Yes
Determine From BMC That There Is Sufficient Power
732
No
Terminate HVAC System Operation
734

Fig. 8


Interior
Exterior
604
672
622
610
312
310
60
50
800
810
812
814
602
20
16
14
12
40
42
44

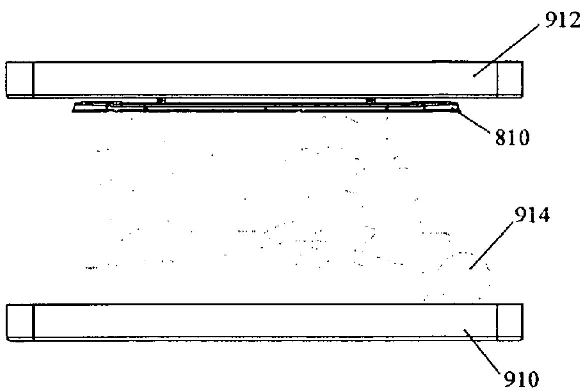


FIG. 9(b)

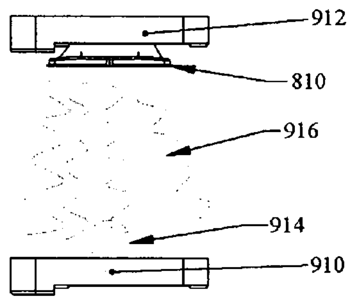


FIG. 9(c)

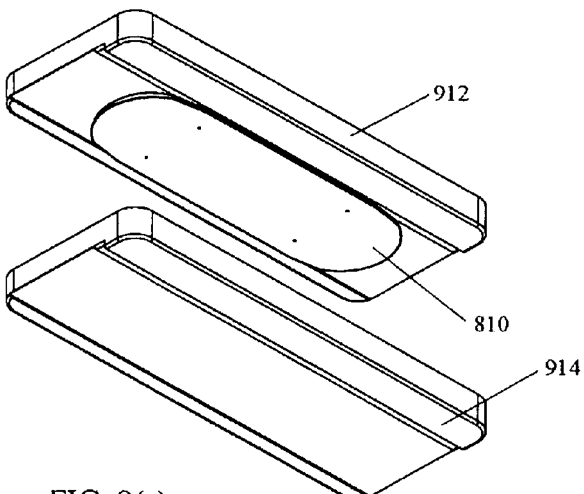


FIG. 9(a)

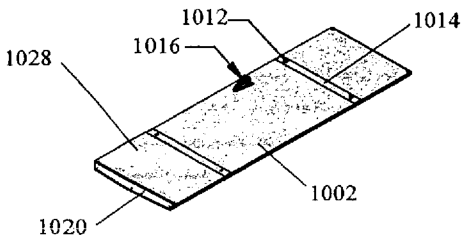


FIG. 11(a)

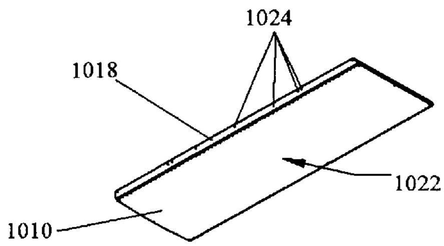


FIG. 11(b)

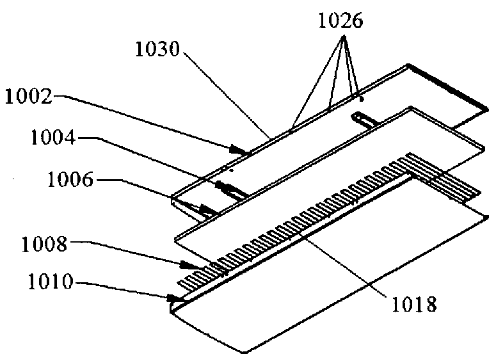


FIG. 10(a)

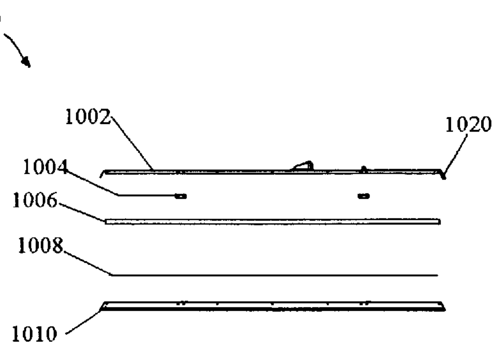


FIG. 10(b)

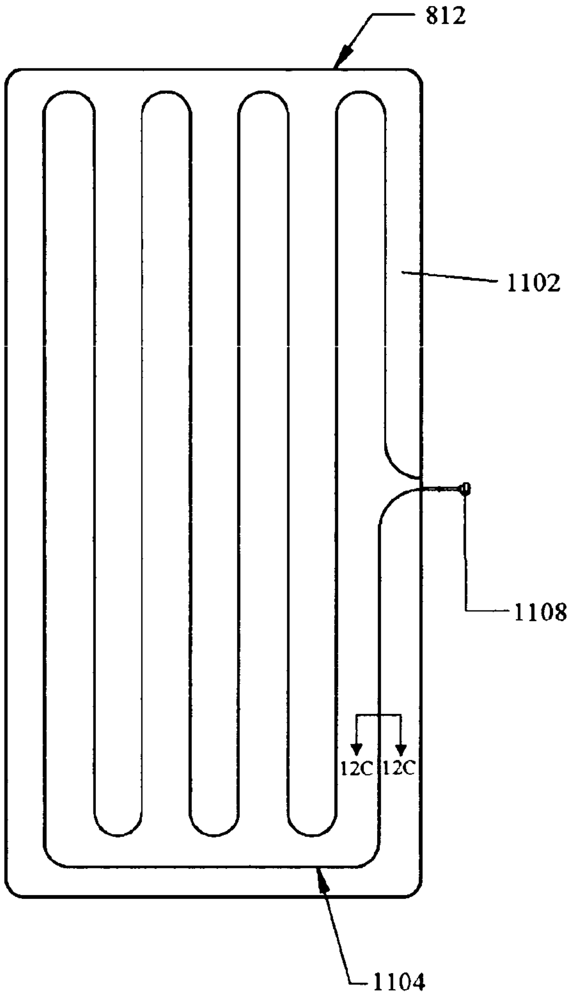


FIG. 12(a)

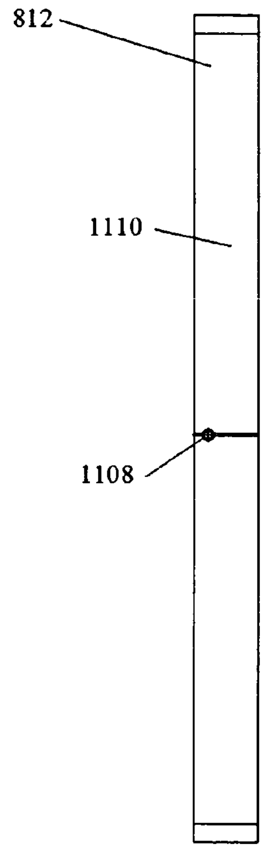


FIG. 12(b)

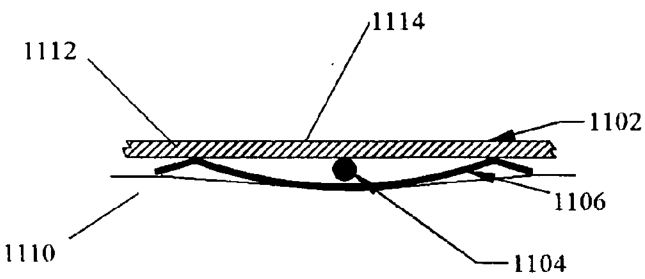


FIG. 12(c)

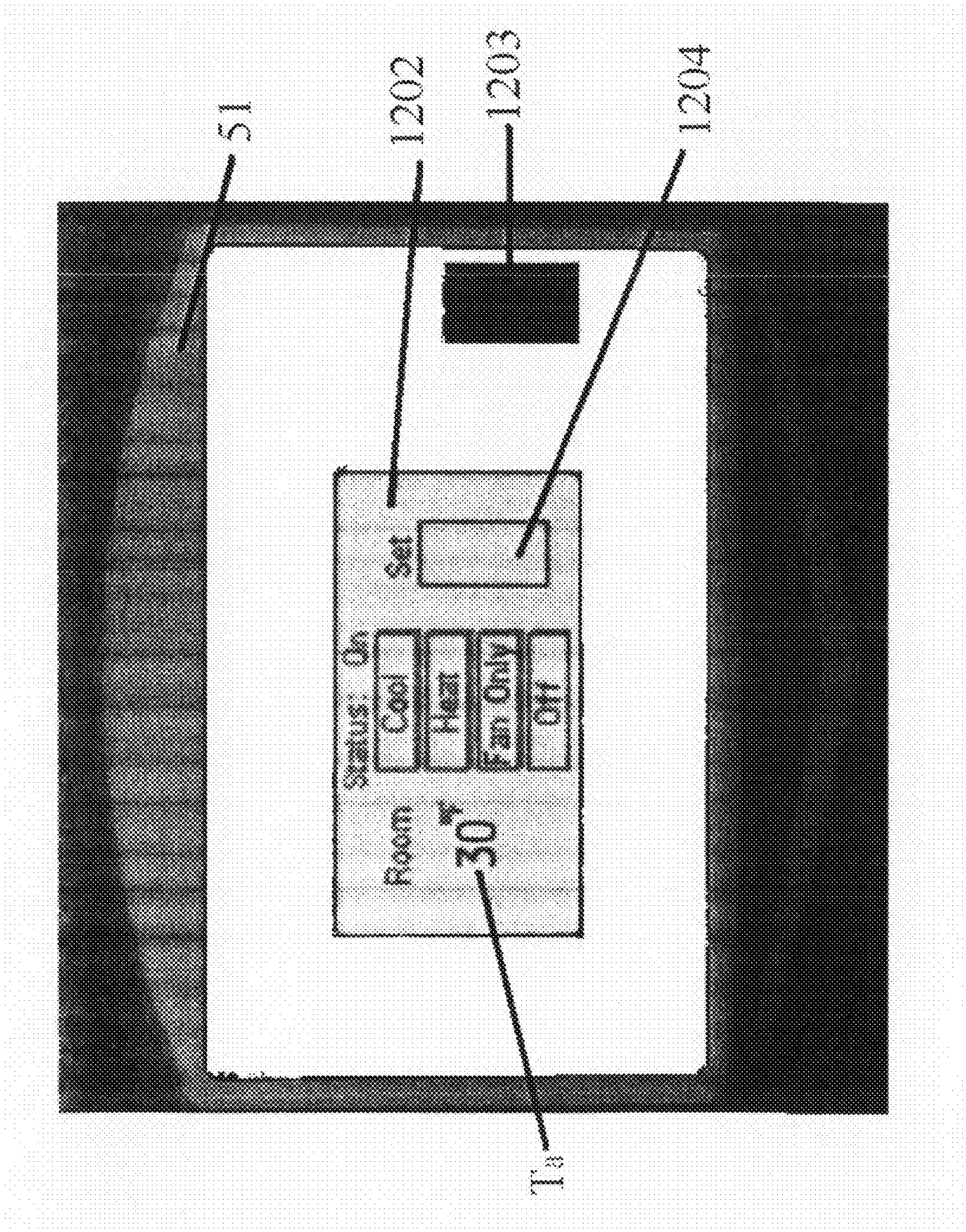

51
1202
1203
1204
Room
30
Status: On
Set
Cool
Heat
Fan Only
Off
Ta

FIG. 13(a)

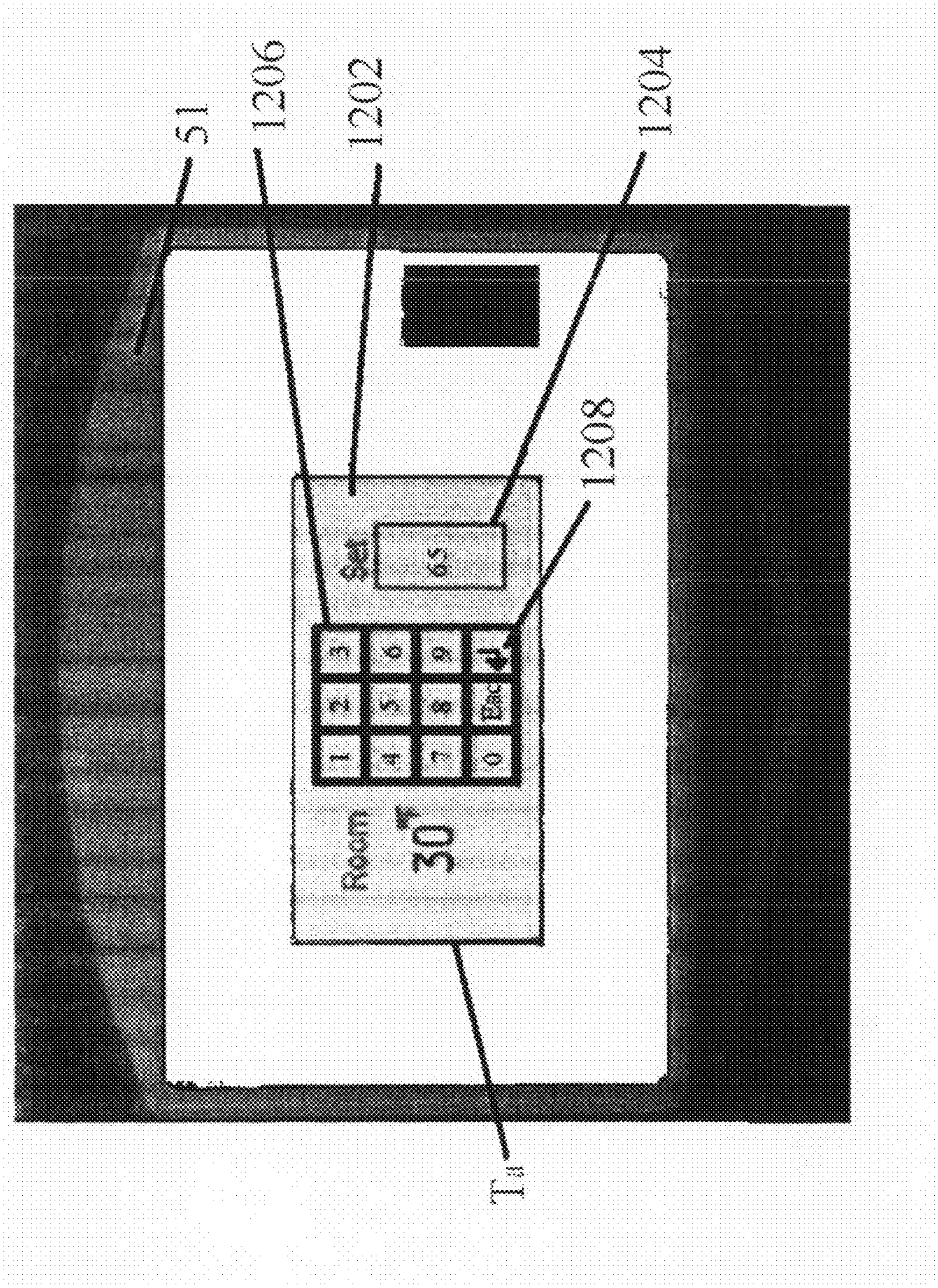


FIG. 13(b)

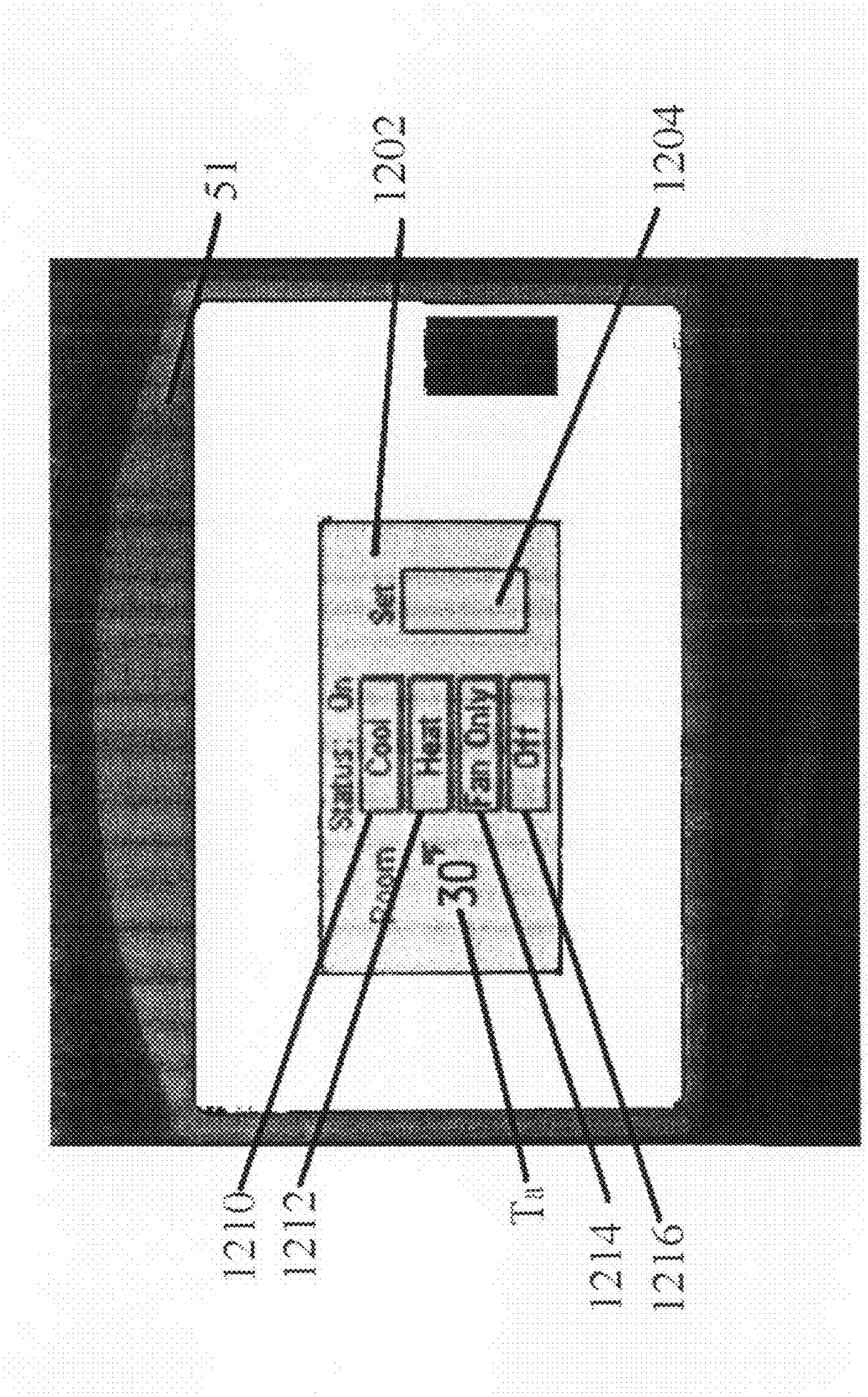

51
1202
1204
Set
Status: On
Cool
Heat
Fan Only
Off
Room
1210
1212
Ta
1214
1216

FIG. 13(c)

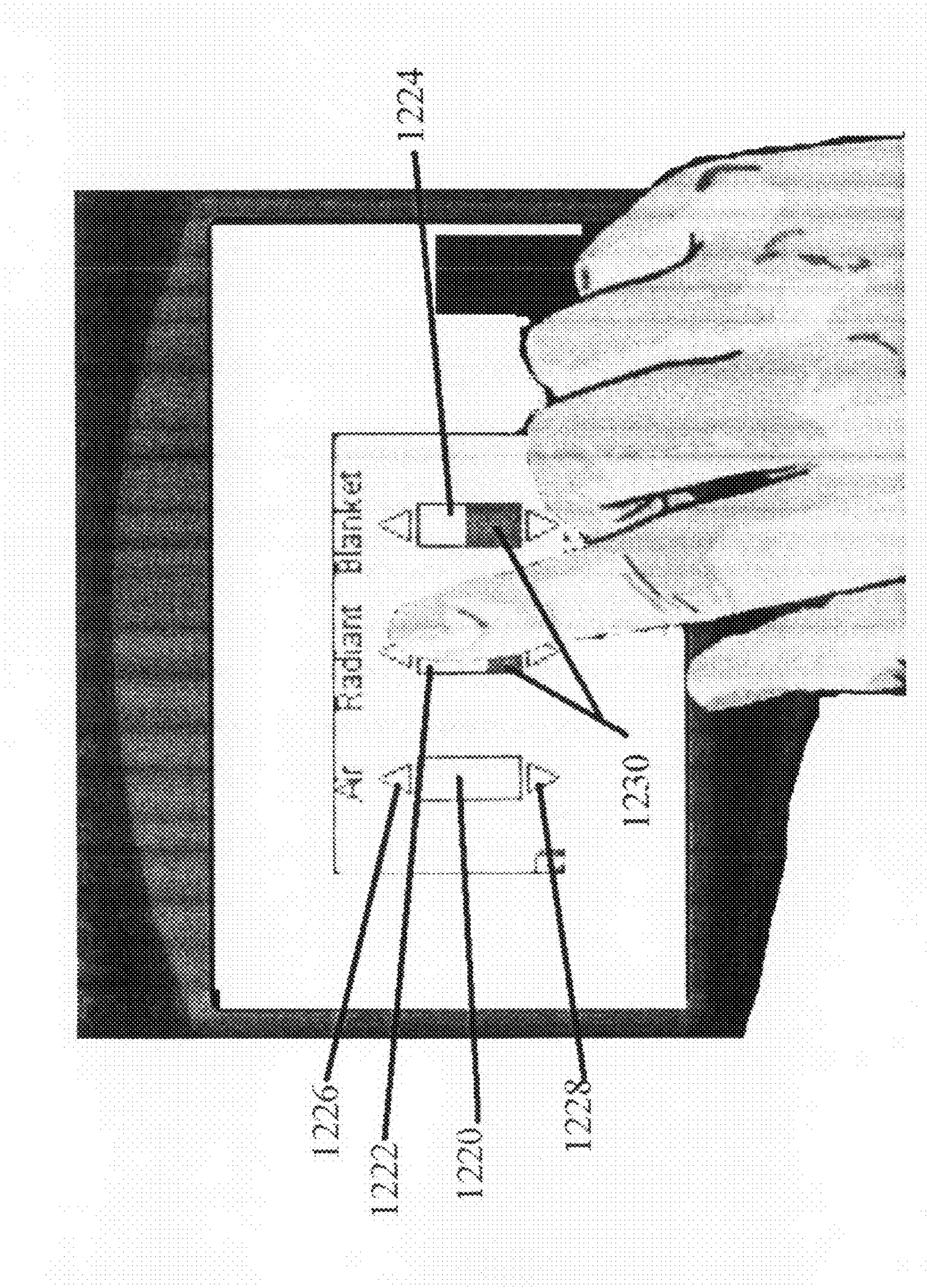


FIG. 13(d)

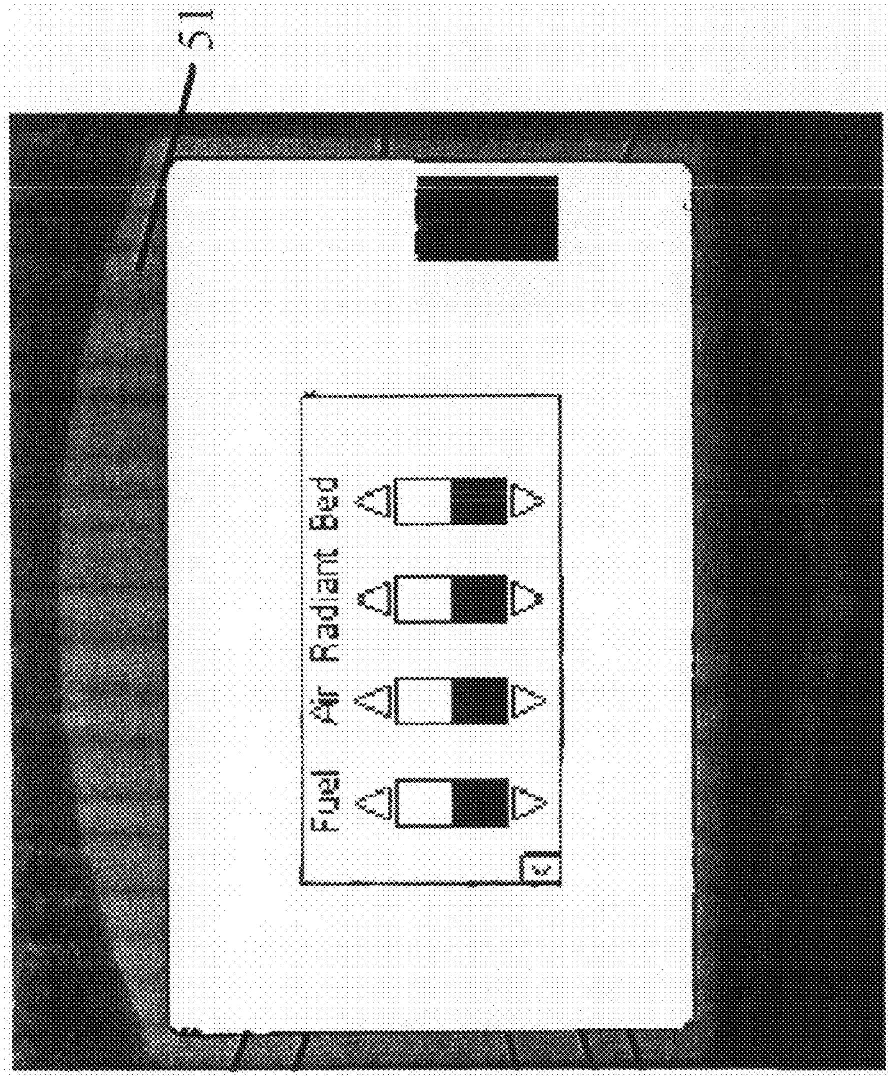


FIG. 14

HVAC SYSTEM

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] The present application claims priority to and the benefit of U.S. Provisional Patent Application No. 61/020,338 filed Jan. 10, 2008. The foregoing provisional application is incorporated by reference herein.

BACKGROUND

[0002] The present invention relates to a heating, ventilation, and air conditioning (HVAC) unit or system to be installed in a vehicle.

[0003] Truck drivers that move goods across the country may be required to pull over at various times along their journey so as to rest so that they do not become too fatigued. Common places for truck drivers to rest include rest stops, toll plazas, and the like. However, these locations usually do not have any accommodations for the drivers, and as a result they usually remain inside the cab of the truck inside a sleeping compartment. To provide the driver with maximum comfort, the sleeping compartment should be temperature controlled so that the environment in the truck is conducive for the driver to get the rest he or she needs.

[0004] Currently, trucks tend to use engine-belt driven compressors for the air conditioning system to circulate and pump refrigerant throughout the vehicle to cool the driving compartments. In addition, an engine-belt driven pump can circulate engine waste heat throughout the driving compartments when heating is required. Unfortunately, these systems have the drawback of not being able to operate when the engine is turned off. As a result, the driver has the choice of either keeping the engine running (which requires additional fuel) so as to run the temperature control system or turning the engine off and not using the air conditioning or heating systems (which can make the driver uncomfortable).

[0005] In view of the above, there is a need to provide an HVAC system which can provide temperature control when the engine is turned off and can provide the necessary power to the heating and cooling system. One option is to use the battery of the truck to power the HVAC system. This option has the drawback that the HVAC system may have to be turned off at a certain point so that the battery does not drain to the point that the vehicle cannot be started.

[0006] Another drawback is that heaters used in the heating system often run on diesel fuel in which engine-belt driven pumps can circulate engine waste heat throughout the driving compartments for heating purposes but these pumps require fuel. Alternatively, a dedicated burner can be used which pulls fuel from the tank (when the engine is not running) and burns it to heat air directly or through circulated water.

[0007] Another drawback is that the replacement of an HVAC system can result in a laborious and costly installation process. For example, the replacement of an HVAC system might mean the replacement of existing and fully functional equipment that is already on the vehicle, such as replacing the evaporator, circulation fans, or ducting. Thus, there is a need to provide an HVAC system that can be easily installed and does not necessarily involve the replacement of all the existing components of a vehicle's HVAC system.

SUMMARY

[0008] According to one embodiment of the present invention, an HVAC system to be installed in a vehicle may comprise: at least one power source; a plurality of heating devices; and a component controller. The component controller is configured to operate a selected portion of the plurality of heating devices based on user preferences stored in the component controller, available power from the at least one power source, and a desired set point temperature.

[0009] According to another embodiment of the present invention, a heating system to be installed in a vehicle may comprise a temperature control system and a component controller. The temperature control system includes a radiant heat panel configured to be installed in a cabin of the vehicle. The component controller is configured to operate the radiant heat panel based on a desired set point temperature.

[0010] It is to be understood that both the foregoing general description and the following detailed description are exemplary and explanatory only, and are not restrictive of the invention as claimed.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] The features, aspects and advantages of the present invention will become apparent from the following description, appended claims, and the accompanying exemplary embodiments shown in the drawings, which are briefly described below.

[0012] FIG. **1** is a schematic diagram of an HVAC system to be installed in a vehicle according to an embodiment of the present invention.

[0013] FIG. **2** is a schematic diagram of an HVAC system according to another embodiment of the present invention.

[0014] FIG. **3** is a schematic diagram of an alternative configuration of the HVAC system of FIG. **2** according to an embodiment of the present invention.

[0015] FIG. **4** is a schematic diagram of an HVAC system according to another embodiment of the present invention.

[0016] FIGS. **5**(*a*) and **5**(*b*) are schematic diagrams of the battery management controller and the HVAC component controller, respectively, according to an embodiment of the present invention.

[0017] FIGS. **6**(*a*) and **6**(*b*) are flow charts showing the operation of the battery management controller during the discharging and recharging of the power sources, respectively, according to an embodiment of the present invention.

[0018] FIG. **7** is a flow chart showing the operation of the HVAC component controller according to an embodiment of the present invention.

[0019] FIG. **8** is a schematic diagram of an HVAC system to be installed in a vehicle according to an embodiment of the present invention.

[0020] FIGS. **9**(*a*) through **9**(*c*) are perspective, front, and side view, respectively, of an assembled radiant heat panel according to an embodiment of the present invention.

[0021] FIGS. **10**(*a*) and **10**(*b*) are exploded perspective and side views, respectively, of a radiant heat panel according to an embodiment of the present invention.

[0022] FIGS. **11**(*a*) and **11**(*b*) are views showing the mounting and emissive sides of the radiant heat panel of FIG. **10**(*a*), respectively.

[0023] FIGS. **12**(*a*) through **12**(*c*) are perspective, side, and partial cross-sectional views of a heated mattress pad, respectively, according to an embodiment of the present invention.

[0024] FIGS. **13**(*a*) through **13**(*d*) are front views of a user interface according to an embodiment of the present invention in which the steps of inputting desired environment and operating conditions are shown.

[0025] FIG. **14** is a front view of a user interface according to an alternative embodiment of FIG. **13**(*d*) in which power levels of different heating devices are displayed.

DETAILED DESCRIPTION

[0026] Hereinafter, various embodiments of the present invention will be described in detail with reference to the drawings.

[0027] FIG. **1** is a schematic diagram of an HVAC system to be installed in a vehicle according to an embodiment of the present invention. The HVAC system **10** may comprise a motor **12**, a compressor **14**, circulation blowers **210** and **212**, an HVAC component controller **50**, a battery management controller **60**, and a plurality of heating devices **800**. The motor can be operatively coupled to the compressor **14**. The compressor **14** is a stepless continuously variable speed compressor, which is driven by the motor **12**. The compressor **14** circulates refrigerant through the condenser **16** to an optional refrigerant receiver and dryer **18**. From the refrigerant receiver and dryer **18**, the refrigerant then passes to either a first cooling path **21** that cools the driving compartment **23** or a second cooling path **25** that cools the sleeping compartment **27** of the vehicle. As to the first cooling path **21**, the refrigerant passes through a refrigerant metering device **20** and an evaporator **22**. The refrigerant metering device **20** may or may not be an expansion device, such as a thermostatic expansion valve, a pressure control expansion valve, a capillary tube, or the like, used in the conventional way. In one arrangement, the refrigerant metering device **20** is a metering device feeding refrigerant into the flooded evaporator **22** with no expansion taking place at or near the valve **20**, and thus merely meters in liquid refrigerant at a rate sufficient to maintain the correct liquid level in the evaporator. Air is blown over the evaporator **22** by the circulation blower **210**. After the air is cooled by the evaporator **22**, the air proceeds through an air duct **272** towards the driving compartment **23** of the vehicle.

[0028] A second cooling path **25** runs parallel to the first cooling path **21** in which the refrigerant is provided through a refrigerant metering device **24** and an evaporator **26**. Air is blown over the evaporator **26** by a circulation blower **212**. After the air is cooled by the evaporator **26**, the air proceeds through an air duct **276** towards the sleeping compartment **27** of the vehicle. The evaporator **26** of the second cooling path **25** can be smaller than the evaporator **22** of the first cooling path **21** because the sleeping compartment **27** is typically smaller than the driving compartment **23**.

[0029] The two coolant loops may be selectable through the use of valves **28** and **29**. The inclusion of such valves permits the driving compartment **23**, the sleeping compartment **27**, or both compartments to be air conditioned at a particular time. The valves **28** and **29** can be controlled through the HVAC component controller **50** (to be discussed below). Once the refrigerant passes through the evaporator **22** and/or **26**, the refrigerant then passes through an optional refrigerant accumulator **30** before being returned to the compressor **14** to restart the process.

[0030] The motor **12** can be any suitable motor. For example, the motor **12** can be a brushless DC motor that is commutated by a square or trapezoidal wave form. In another example, the motor **12** can be a synchronous permanent magnet motor that is commutated with a sine wave. When the motor is driven by a sine wave, additional benefits can be obtained, such as better drive efficiency, better cooling and quieter operation.

[0031] By using a variable speed compressor **14** driven by a brushless DC or a synchronous permanent magnet motor **12**, the vehicle's HVAC system may be operated when the engine is turned on or when the engine is turned off. The variable speed compressor **14** also can permit the HVAC system **10** to operate at a lower capacity during the engine off operation to conserve the amount of stored energy available for usage by the system **10**. The control for this operation is provided by an HVAC component controller **50** that monitors various system parameters while the battery management controller **60** monitors the availability and status of the power sources on the vehicle. The available power sources can include a first power source **40**, a second power source **42**, and/or the vehicle's main electrical power generation system **44**.

[0032] In a similar manner, the circulation blowers **210** and **212** can also have stepless continuously variable speeds such that the circulation blowers can operate at a lower capacity during the engine off operation to conserve the amount of stored energy available for usage by the HVAC system **10**. The control for this operation is also provided by the HVAC component controller **50**.

[0033] The battery management controller **60** is configured such that the vehicle's HVAC system **10** is capable of being powered by the vehicle's main electrical power generation system **44**, which is available while the vehicle's engine is operating. When the vehicle's engine is off, the HVAC system **10** can be powered with a first power source **40** and/or a second power source **42** depending on the power levels of the power sources (as will be described later). In one embodiment, the first power source **40** can be one or more auxiliary deep-cycle batteries and the second power source **42** can be the vehicle's one or more starter batteries. In another embodiment, one of the first and second power sources may be an external source of AC power connected to the system through an external connection.

[0034] In the HVAC system **10**, the motor driven compressor **14** can have the ability to modulate its output from full capacity to low capacity. This ability to modulate allows the use of a single HVAC system that can be used for both high output for the time periods that the engine is operating, and low output during the time periods when the engine is turned off so as to continue to cool or heat the driving and/or sleeping compartments. The coordination of this modulation is provided by the HVAC component controller **50**, which reduces the speed of the compressor when the engine is turned off. This modulation extends the duration of the heating and cooling operations because the charge of the available power sources is expended more slowly. That is, with a reduced speed of the compressor, the electric power demand is reduced as well.

[0035] Another aspect of FIG. **1** is a heating mode of operation in which there is a plurality of heating devices **800** that may be used. The plurality of heating devices may include an air heater in each air duct that leads to the vehicle compartments. For example, the air heater **270** is disposed in the air duct **272** which leads to the driving compartment **23**. The air heater **274** is disposed in the air duct **276** which leads to the sleeping compartment **27**. The air heaters **270** and **274** may be any heater known in the art, such as an electric resistance-type heater. The advantage of using an electric resistance-type heater is that such a heater allows the heating function to be completed without relying on the engine or additional fuel by merely relying on the circulation blowers and the heaters, which are powered by the first and/or second power sources or the vehicle electrical power generation system. In a preferred embodiment, instead of the air ducts **272** and **276**, the air heaters **270** and **274** can be placed within the same enclosures as the circulation blowers **210** and **212** but still in the path of the gas stream which enters the vehicle and/or sleeping compartments. If the air heaters are in the same enclosures as the circulation blowers, there can be a reduction in the complexity of the installation.

[0036] The plurality of heating devices **800** may include a radiant heat panel **810**, a heated mattress pad **812**, a heating blanket **814**, or any combination thereof, either in addition to or alternative to the air heaters **270** and **274**. A plurality of radiant heat panels **810**, a plurality of heated mattress pads **812**, a plurality of heating blankets **814**, and/or any combination thereof may also be used, for example, in the case of a double bunk sleeping compartment.

[0037] The radiant heat panel **810** provides heating through radiant heat transfer. The radiant heat panel may be used to warm the vehicle occupant(s) directly. The use of radiant heat panels may allow for maintaining a lower vehicle cabin temperature for the same comfort level achieved by a corresponding conventional HVAC system. The radiant heat panel will heat quickly and, thus, providing for less energy usage. Many different panel designs would be acceptable for use. A suitable panel may include fiberglass insulation board, a solid state heating element and a textured surface coating mounted in a frame, as to be described below. The panel may operate in the range of 150 to 170° F., although other suitable temperature ranges could be employed. One suitable panel may be similar to one of the radiant heat panels produced by Marley Engineered Products.

[0038] An example of an assembled radiant heat panel **810** is shown in FIGS. **9**(*a*) through **9**(*c*). The radiant heat panel **810** may be mounted in the sleeping compartment of the vehicle cabin. The heat panel **810** emits long-wave infrared radiation **916** onto a sleeping vehicle occupant, which heats the occupant without the need to heat the air between the occupant and the panel. In FIGS. **9**(*a*) through **9**(*c*), a sleeping compartment may have a top bunk **912** and a bottom bunk **910**. The radiant heat panel **810** may be mounted on or installed in, for example, the ceiling of the sleeping compartment and/or vehicle cabin to warm a sleeping occupant sleeping in the top bunk **912**; the bottom surface of the top bunk **912** so as to warm a sleeping occupant **914** resting on the top surface of the bottom bunk **910**; or the wall of the sleeping compartment. If the sleeping compartment of the vehicle only has a single bunk, the radiant heat panel may be mounting on or installed in the ceiling or wall of the sleeping compartment. In any case, the radiant heat panel may be installed in the vehicle cabin so that the radiation heat may be directed to the vehicle occupant **914** lying in the target bed.

[0039] FIG. **10**(*a*) shows the various components of the radiant heat panel in an exploded perspective view. FIG. **10**(*b*) shows the various components in an exploded side view. FIGS. **11**(*a*) and **11**(*b*) show the emissive side and the mounting side, respectively, of a radiant heat panel according to another embodiment of the present invention.

[0040] The heat panel **810** may comprise: a substrate backing **1002**; an internal reinforcement structure **1004**; an insulation layer **1006**; a heating element **1008**; and an emissive panel **1010**. The substrate backing **1002** may be any suitable material, preferably a powder coated steel material. On the mounting surface **1028** of the substrate backing, there is one or more mounting brackets **1014** with one or more mounting points **1012** on each bracket. For example, in FIG. **11**(*a*) there are two mounting brackets **1014** with two mounting points **1012** on each bracket. The mounting points may be, for example, apertures to accommodate screws, nails, rivets, or the like for mounting the heat panel onto a bunk, a ceiling, or a wall of a vehicle cabin, such as in a sleeper compartment.

[0041] A power and sensor receptacle **1016** is also provided on the mounting side **1028** of the substrate backing **1002**. This receptacle is used as electrical connections to the heating element **1008**, which provides the radiation for the panel, and to thermal sensors, such as thermistors or the like, for monitoring the temperature of the heat panel.

[0042] Mounted on the substrate backing **1002** may be the internal reinforcement structure **1004** and the insulation layer **1006**. The internal reinforcement structure **1004** may be of any suitable configuration to stiffen the overall structure of the panel **810** such that bending of the panel **810** is inhibited or prevented. The reinforcement structure **1004** may be plates, slats, brackets, or the like made from steel or other suitable materials, such as other metals. The reinforcement structure **1004** may be held in place by fixing it to the substrate backing using screws, nails, rivets, or the like.

[0043] The insulation layer may be fiberglass insulation, such as non-woven unfaced fiberglass, which is similar to building fiberglass. The insulation layer may have a nominal thickness of **2** inches, but may be compressed upon assembly of the heat panel. Other suitable insulation materials and thicknesses (such as ½, 1, 3, 4 inches) may be used. According to one embodiment of the present invention, the internal reinforcement structure **1004** and/or the insulation layer **1006** may be omitted, if desired. For example, if substrate backing **1002** is of a suitable thickness, the internal reinforcement structure **1004** may be omitted. If the substrate backing **1002** comprises an insulative material, the insulation layer **1006** may be omitted.

[0044] The heating element **1008** is mounted on the substrate backing **1002**, along with the internal reinforcement structure **1004** and the insulation layer **1006**. The heating element may be a resistance wire, such as a Teflon-coated 26 awg Nichrome 80 or other suitable resistive material. The heating element **1008** may be arranged in any suitable patterned formation, such as one or more rows of wire in which each rows is in a straight line, in a square wave pattern, in a sine wave pattern, in a triangular pattern, or the like. The heating element may be one or more resistance wires, and be configured to emit approximately 500 W of heat when operated at approximately 350V. In one embodiment, 70 to 90 feet of resistance wire may be used. The heating element may be mounted on the insulation layer **1006** so as to fix it in place relative to the insulation layer. For example, the insulation layer may have groove(s) in which the heating element is inserted or the heating element may be soldered, brazed, bolted, riveted or the like to the emissive panel **1010**.

[0045] The emissive panel **1010** covers the heating element **1008**, the insulation wire **1006**, the internal reinforcement structure **1004**, and the substrate backing **1002**. The emissive panel has a emissive side **1022** that faces the vehicle occupant, and may be a textured powder coat on steel. Other possible materials may be used as long as it permits the transmission of the radiation therethrough. According to one embodiment, long-wave infrared radiation is transmitted to the vehicle occupant, but other forms of radiation may be used as well, such as mid-wave or short-wave infrared radiation.

[0046] To assemble the heat panel **810**, the substrate backing **1002**; the internal reinforcement structure **1004**; the insulation layer **1006**; the heating element **1008**; and the emissive panel **1010** are stack upon each other. As previously mentioned, the internal reinforcement structure **1004** may be fixedly mounted on the substrate backing and the heating element may be fixedly mounted on the insulation layer **1006** and/or the emissive panel **1010**. The internal reinforcement structure **1004**, the insulation layer **1006** and the heating element **1008** are substantially encased between the substrate backing **1002** and the emissive panel **1010**. The emissive panel includes at least two sidewalls **1018** projecting upwards from the planar surface of the emissive panel, which abut against at least two sidewalls **1030** of the substrate backing that project downward from the planar surface of the substrate backing. The sidewalls **1018** and the sidewalls **1030** have apertures **1024** and **1026**, respectively, that align with each other. The apertures **1024** may be through holes that accommodate screws that engage with the apertures **1026**, which may be threaded. Of course, other methods of fastening the substrate backing and emissive panel together may be used, such as rivets, nails, welding, brazing, or the like. Also, the substrate backing **1002** has end walls **1020** that cover the remaining edges of the heat panel, and are attached to the emissive panel **1010** by screws, nails, rivets, welding, brazing, or the like.

[0047] The radiant heat panel may be any suitable shape and size. For example, the overall heat panel may be oval, as shown in FIG. **9**(*a*) or may be rectangular, as shown in FIG. **10**(*a*). A plurality of smaller radiant heat panels may be disposed in the sleeper compartment of the vehicle cabin along the ceiling, floor, walls, the bottom surfaces of bunks, etc.

[0048] Another heating device that may be used in conjunction with the radiant heat panel **810**, the air heater **270**, and/or the air heater **274** is a heated mattress pad **812**, as shown in FIGS. **12**(*a*) through **12**(*c*). FIG. **12**(*a*) is a perspective view, FIG. **12**(*b*) is a side view, and FIG. **12**(*c*) is a partial cross-sectional view taken along line **12C-12C** in FIG. **12**(*a*). The heated mattress pad may comprise a mattress **1110** and a mattress cover **1102**. The mattress cover **1102** may comprise a carrier fabric **1106**, a heater wire **1104**, and a cover fabric **1112**. The carrier fabric may be any suitable lightweight material, and abuts the mattress **1110**. According to one embodiment, the mattress **1110** may be a twin mattress with the mattress cover **1102** being a fitted sheet that fits about the mattress **1110**.

[0049] The heater wire **1104** may be insulated copper wire of a small gauge creating between 10 and 70 watts of heat. For example, the heater wire **1104** may be 50 feet of 26 awg of copper wire. The heater wire is operated by a power supply providing between 10V and 12V in which the heater wire is connected to the power supply by an electrical connector **1108** that protrudes out from the cover fabric **1102**. The heater wire **1104** may be arranged in any suitable patterned formation, such as one or more rows of wire in which each rows is in a straight line, in a square wave pattern, in a sine wave pattern, in a triangular pattern, or the like. The heater wire may be one or more wires.

[0050] The cover fabric **1112** may be any suitable non-woven comfortable material, which has a visible face **1114** on which the vehicle occupant rests. The heater wire is captured between the carrier and cover fabrics, and may be attached to one or both fabrics by any suitable mechanism, such as adhesive, stitching, staples, or the like.

[0051] Another possible heating device to be used with the radiant heat panel, the heated mattress pad, and/or the air heaters may be a heating blanket **814**. Any suitable heating blanket may be used, such as those found in U.S. Pat. No. 6,770,853 or U.S. Pat. No. 6,563,090, both of which are incorporated by reference in their entireties. The heating blanket may be configured to accept the vehicle's standard power supply of 12V.

[0052] To operate in the heating mode using the air heaters, the HVAC component controller **50** does not operate the compressor **14** but merely operates the circulation blower **210** and the air heater **270** to provide the necessary heating to the driving compartment and/or the circulation blower **212** and the air heater **274** to provide the necessary heating to the sleeping compartment. This configuration provides additional power consumption savings and allows for a longer operating duration in the heating mode. In the cooling mode of operation, the air heaters **270** and **274** are simply not activated. If temperature control is desired, the HVAC component controller **50** can preferably provide pulse width modulation control (PWM) of power to the air heaters **270** and **274**. Alternatively, temperature control can be performed by a control door known in the art (not shown) placed in each duct (if provided) to control the flow of air (which may or may not be cooled by the evaporators **22** and/or **26**) passing over the air heaters **270** and/or **274** to regulate the temperature of the air flowing into their respective vehicle compartments.

[0053] The embodiment of FIG. **1** can include alternative configurations. For example, the first or second cooling path can be eliminated such that there is only one expansion device, one evaporator, one blower, and no accumulator **30**. With this configuration only one vehicle compartment can be temperature controlled. Alternatively, ducting can be used to channel the temperature controlled air into separate channels in which a first channel goes to the driving compartment and a second channel goes to the sleeping compartment. In this embodiment, a control door or the like can be used to channel the temperature controlled air to one compartment to the exclusion of the other.

[0054] FIG. 2 is a schematic diagram of another embodiment of the HVAC system **10** according to another embodiment of the present invention. The HVAC system **10** of this embodiment includes a primary coolant loop **170** that includes a first refrigerant and a secondary coolant loop **172** that includes a second refrigerant. The first refrigerant in the primary coolant loop **170** is driven by the compressor **14** which passes through the condenser **16**, the receiver and dryer **18**, the refrigerant metering device **20**, the first refrigerant-to-second refrigerant heat exchanger **174**, and back to the compressor **14**.

[0055] In contrast, the second refrigerant in the secondary coolant loop **172** is driven by a low pressure liquid pump **176**. The fluid passes through a second refrigerant-to-air heat exchanger **178**, a heater **180**, and the first refrigerant-to-second refrigerant heat exchanger **174**. The first refrigerant-to-second refrigerant heat exchanger **174** serves as the heat exchange medium between the primary coolant loop **170** and the secondary coolant loop **172**. The second refrigerant-to-air heat exchanger **178** cools the air supplied by the circulation blower **210**, which then flows to the vehicle compartment with or without ducting. To provide heating of the vehicle compartment, the HVAC component controller **50** need only operate the low pressure liquid pump **176** and the heater **180** in the secondary coolant loop **172** and the circulation blower

210. That is, no power is delivered to the compressor 14, and as a result the amount of power consumption is further reduced, which extends the time duration that heating can take place.

[0056] FIG. 3 shows an alternative configuration of FIG. 2 in which there are two second refrigerant-to-air heat exchangers 178 and 182 in the secondary coolant loop 172. One second refrigerant-to-air heat exchanger 178 can be used to provide cooling/heating to the driving compartment 23 while the other heat exchanger 180 can be used to provide cooling/heating to the sleeping compartment 27 with or without ducting. The passage of the liquid through either or both of the heat exchangers 178 and 182 can be selected by the HVAC component controller 50, which, in turn, controls the valve 184 that leads to the heat exchanger 180 and the valve 186 that leads to the heat exchanger 178. Thus, the control of the valves 184 and 186 permits the driving compartment 23, the sleeping compartment 25, or both compartments to be air conditioned or heated at a particular time.

[0057] FIG. 4 shows another embodiment of the present invention in which the HVAC system uses a reverse cycle heating system. The reverse cycle heating system also allows the heating function to be completed without relying on the engine or additional fuel by merely relying on the compressor and the circulation blowers, which are powered by the first and/or second power sources or the vehicle electrical power generation system. As with the embodiment shown in FIG. 1, the HVAC system 10 of FIG. 4 may comprise a motor 12, a compressor 14, circulation blowers 210 and 212, an HVAC component system 50, and a battery management system 60. The motor can be a brushless DC or a synchronous permanent magnet motor, which is operatively coupled to the compressor 14. The compressor 14 is a continuously variable speed compressor, which is driven by the motor 12. Connected to the compressor is a reversing valve 502, which allows the compressor to pump refrigerant in a cooling direction indicated by single arrows 520 or a heating direction indicated by double arrows 522.

[0058] As to the cooling direction, the compressor 14 circulates refrigerant through a heat exchanger 504 (which functions as a condenser in the cooling mode as the hot compressed gas from the compressor condenses to a liquid as heat is given off) to a first flow path 510 that thermally treats air going to the driving compartment 23 and/or a second flow path 512 that thermally treats air going to the sleeping compartment 27 of the vehicle. As to the first flow path 510, the refrigerant passes through a refrigerant metering device 20 and a heat exchanger 506 (which functions as an evaporator in the cooling mode as the liquid refrigerant boils and forms a gas as heat is absorbed by the refrigerant liquid). Air is blown over the heat exchanger 506 by the circulation blower 210. After the air is cooled by the heat exchanger 506, the air proceeds towards the driving compartment 23 of the vehicle.

[0059] A second flow path 512 runs parallel to the first flow path 510 in which the refrigerant is provided through a refrigerant metering device 24 and a heat exchanger 508 (which functions as an evaporator during the cooling mode as the liquid refrigerant boils and forms a gas as heat is absorbed by the refrigerant liquid). Air is blown over the heat exchanger 508 by a circulation blower 212. After the air is cooled by the heat exchanger 508, the air proceeds towards the sleeping compartment 27 of the vehicle. The heat exchanger 508 of the second flow path 512 can be smaller than the heat exchanger 506 of the first flow path 510 because the sleeping compartment 27 is typically smaller than the driving compartment 23.

[0060] The two coolant loops may be selectable through the use of valves 28, 29, 514, and 516. The inclusion of such valves permits the driving compartment 23, the sleeping compartment 25, or both compartments to be air conditioned at a particular time. The valves 28 and 514 are opened and the valves 29 and 516 are closed when only the driving compartment is being temperature controlled. By a similar token the valves 29 and 516 are opened and the valves 28 and 514 are closed when only the sleeping compartment is being temperature controlled. The valves 28, 29, 514, and 516 can be controlled through the HVAC component controller 50. Once the refrigerant passes through the heat exchanger 506 and/or 508, the refrigerant then returns to the reversing valve 502 and the compressor 14 to restart the process.

[0061] As to the heating direction, the reversing valve 502 is switched such that the refrigerant pumped by the compressor flows in the reverse direction as indicated by double arrows 522. Thus, the compressor causes the refrigerant to flow through the first flow path 510 and/or the second flow path 512 depending if the valves 28 and 514 and the valves 29 and 516 are opened or closed. If the valves 28 and 514 are opened, the refrigerant flows through the heat exchanger 506 (which functions as a condenser in the heating mode as the hot gas is condensed to a liquid as it gives up heat). Air is blown over the heat exchanger 506 by the circulation blower 210. After the air is heated by the heat exchanger 506, the air proceeds towards the driving compartment 23 of the vehicle. Meanwhile, the refrigerant continues from the heat exchanger 506 through the refrigerant metering device 20 to the heat exchanger 504 (which functions as an evaporator in the heating mode). After flowing through the heat exchanger 504, the refrigerant returns to the reversing valve 502 and the compressor 14.

[0062] If the valves 29 and 516 are opened, the refrigerant flows through the heat exchanger 508 (which functions as a condenser in the heating mode). Air is blown over the heat exchanger 508 by a circulation blower 212. After the air is heated by the heat exchanger 508, the air proceeds towards the sleeping compartment 27 of the vehicle. Meanwhile, the refrigerant continues from the heat exchanger 506 through the refrigerant metering device 24 to the heat exchanger 504 (which functions as an evaporator in the heating mode). After flowing through the heat exchanger 504, the refrigerant returns to the reversing valve 502 and the compressor 14 to restart the process.

[0063] Similar to the embodiment shown in FIG. 1, the embodiment of FIG. 4 can include a variable speed compressor 14 driven by a brushless DC or a synchronous permanent magnet motor 12; the control for the heating and cooling operations being provided by the HVAC component controller 50; the available power sources can include a first power source 40, a second power source 42, and/or the vehicle's main electrical power generation system 44; the circulation blowers 210 and 212 can also have continuously variable speed which can be controlled by the HVAC component controller 50; and the battery management controller 60 can monitor and control the available power sources when the engine is turned off.

[0064] Also as with the embodiment of FIG. 1, FIG. 4 can include alternative configurations. For example, the first or the second cooling path can be eliminated such that there is only one refrigerant metering device, one heat exchanger in which air passes over, and one blower. With this configuration only one vehicle compartment can be temperature controlled. Alternatively, ducting can be used in which the duct channeling the temperature controlled air can be spit into multiple channels such that a first channel goes to the driving compartment and a second channel goes to the sleeping compartment. In this embodiment, a control door or the like can be used to channel the temperature controlled air to one compartment to the exclusion of the other.

[0065] The power requirements and operation of the HVAC system **10** are handled by the battery management controller **60** and the HVAC component controller **50**, respectively. The two controllers **50** and **60** can be software control loops with associated hardware or circuitry, and they may be physically housed in separate devices or the same device. Suitable memories (such as RAM, ROM, or the like) may be used to store all programs, sensed and calculated variable and values, and all other necessary data to help carry out their respective functions. One or more memories may be stored in only the controller **50**, only the controller **60**, or both controllers.

[0066] The battery management controller **60** will now be discussed with reference to FIG. **5**(*a*). The battery management controller **60** can fulfill a variety of different purposes including: (1) maximizing the electrical power available for use by the HVAC system; (2) ensuring that sufficient electrical reserve power is available to start the engine; (3) tracking historical use (charge and discharge) of all connected batteries; (4) determining the current state of charge of all connected batteries; (5) determining the current end-of life status of all connected batteries irrespective of their respective charge level; (6) ensuring that the charge and discharge cycles of all connected batteries are consistent with the user's preferred compromise between battery longevity and available stored energy; and (7) prevent overloading of the battery charging system.

[0067] The battery management controller **60** carries out its function by being connected to a plurality of power sources **40** and **42**, a combination/separation device **61**, and a charging device **61**. In one exemplary embodiment, a truck can have seven batteries in which four batteries are connected in parallel to provide a high capacity first battery bank as the first power source **40** and the three remaining batteries are connected in parallel to provide a second, somewhat smaller battery bank as the second power source **42**.

[0068] The first power source **40** and/or the second power source **42** are connected to a separation device **61**, temperature and voltage sensors **63**, and an engine starter **64**. The first and second power sources (e.g., the first and second battery banks) are connected to the combination/separation device **61** so as to allow the first and second power sources to be electrically combined or separated.

[0069] The combination/separation device **61** can be electrically connected to supply power to the individual components of the HVAC system **10** and can optionally be connected to other electrical power accessories, such as microwave ovens, televisions, stereos, refrigerators, etc. These additional electrical power accessories could include, for example, other or alternative heating components such as radiant heat panels, electric heating blankets or mattress pads. The combination/separation device **61** is configured to electrically split and combine multiple power sources so as to maximize the availability of power to the components of the HVAC system **10** and the engine starter **64**. Furthermore, the combination/separation device **61** can electrically split and combine multiple batteries to prevent overloading of a charging device **62**, such as an alternator, by selectively combining the discharged power sources into a partially charged pack.

[0070] The temperature and voltage sensors **63** can monitor the voltage and temperatures of the first and second power sources **40** and **42**. These sensors can be used to monitor the state of charge of the power sources so as to prevent the power sources from being overly discharged.

[0071] The engine starter is connected to one of the power sources so as to provide enough power to start the engine of the vehicle. The engine starter **64** can be electrically connected to the first power source or the second power sources but not to both. Also, the engine starter **64** may have an optional connection **65** that leads directly to the combination/separation device **61**.

[0072] The charging device **62** can be connected to the combination/separation device **61** so that the electrical power output from the charging device **62** can be selectively routed to any individual or combination of connected power sources. The charging device can comprise one or more of the following: the engine alternator, an accessory generator, a show power connection, and other charging devices.

[0073] The battery management controller **60** can include a control logic circuit **66** and a memory **67**, and can be connected to the voltage and temperature sensors **63**, a user interface **51** (which can comprise one or more displays **310** and one or more input devices **312**), the combination/separation device **61**, and the HVAC component controller **50**. Thus, the battery management controller **60** can receive measurements from the voltage and temperature sensors **63** and user preferences from the user interface **51**. Additionally the battery management controller **60** can receive and transmit information in a bi-direction manner to and from the HVAC component controller **50**. The battery management controller **60** is used to regulate the degree of discharge among the power sources so as to conform to the user preferred compromise between the daily battery performance and the ultimate life of the power sources. In addition, the memory **67** of the battery management controller can be used to log historical data obtained during previous charge and discharge cycles, such as voltage and temperature levels, and use the historical data to modify the permitted depth of discharge to ensure the completeness of future charge cycles.

[0074] In a more conventional HVAC system, the measurement of the battery voltage under load is used to determine the state-of-charge. While this method is low in cost and easy to implement, it is also highly inaccurate. The voltage can be used to accurately determine the state-of-charge but only when such measurements are taken in conjunction with temperature and only after the battery has been "at rest" (i.e., unloaded) for a period or time (typically over one hour). In contrast, the battery management controller **60** of FIG. **5**(*a*) can use multiple sources of historical and real-time data to more accurately determine the amount of stored energy available for use. Additionally, the battery management controller **60** allows a highly accurate "resting voltage" measurement of the state of charge to be made of the power reserve even when portions of the battery power supply are still in use. Below is a discussion of the processes that occur during the discharging of the power sources when in the engine is turned off, the starting up of the engine, and the charging of the power sources when the engine is turned on. In the discussion below, the first and second power sources are battery banks but is should be recognized that any type of power source can be used. For example, one of the first and second power sources may be an external AC connection.

[0075] The process that the battery management control circuit undergoes during discharge is provided in FIG. **6**(*a*). The discharging of the first and/or second battery banks occurs when the engine is turned off as shown in step **402**, and a command is issued from the HVAC component controller **50** ("HCC") to the battery management controller **60** ("BMC") to supply power to the components of the HVAC system **10** as shown in step **404**. In step **406**, upon receiving the command from the HVAC component controller **50**, the battery management controller **60** through its control circuit **66** would determine the state of charge of the combination of the first and second battery banks by comparing the current voltage and temperature of the combined banks from data received by the voltage and temperature sensors **63** with the historical data stored in the memory **67** of the controller **60**. If there is sufficient charge with both power sources, the process proceeds to step **408**. If there is not sufficient charge, the process proceeds to step **430**.

[0076] At step **408**, upon determining that sufficient stored energy was available for use, the first and second battery banks **40** and **42** would be electrically combined through the combination/separation device **61** so as to supply power to the components of the HVAC system **10**. The power draw (current) from the HVAC system **10** is monitored and the rate of decline in the combined battery banks **40** and **42** is noted. The power draw and rate of decline is compared to historical data to determine the approximate state of sulfation of the battery plates and from this comparison, the approximate condition of the batteries is deduced. Under a given load, the voltage of batteries in poor condition will decline faster than batteries in good condition. Consequently, it can be predicted that batteries in poor condition will have less total stored energy even though the actual voltage at any given time may be the same. In one example, data can be collected related to the maximum battery discharge and/or the average battery discharge during an operation cycle of the power sources when the power sources are batteries. This data can be compiled over time such that a history of the maximum and/or average battery discharge is stored in the memory **67** in the battery management controller **60**.

[0077] As the voltage of the combined batteries falls, the battery management controller logic circuit **66** will use the temperature, the load, the rate of voltage change, the estimated battery condition, the stored historical data and the user preference inputted from the user interface **51** to determine the preferred voltage point at which to separate the first and second battery bank **40** and **44** using the combination/separation device **61**. The user interface can comprise one or more displays **310** and one or more input devices **312**, such as a keyboard, a control panel, or the like, so that the vehicle occupant can input user preferences for the operation of the HVAC system **10**. According to one embodiment of the present invention, the user interface **51** can be a touch screen pad in which the display and input devices are provided on the same screen as seen in FIG. **13**(*a*). The user preferences can include the operating mode of the HVAC system such as off, heating, and cooling modes of operation.

[0078] The user preferences which are inputted using the user interface **51** are also those factors that influence the extent to which the battery banks **40** and **42** will be allowed to be discharged. One example is the battery replacement life. Battery replacement life is related to the depth of the discharge of the power source as well as the rate of discharge, i.e., a function of the minimum battery voltage adjusted by the load. For example, a lightly loaded battery which is consistently discharged to 11.8 V may only last through 100 charge/recharge cycles while a heavily loaded battery that was consistently discharged to 11.8 V might last 200 charge/recharge cycles. If a user preference is set for a long battery life, the batteries will be less deeply discharged and will last longer. However, because less stored energy will be available for use, more batteries will need to be carried to supply a given amount of cooling or heating than would be the case if a shorter battery life (and more deeply discharged batteries) were selected.

[0079] In addition, the display **310** of the user interface **51** can provide a user, such as a vehicle occupant, information related to the status of the HVAC system **10**. The display can include one or more of an alphanumerical display, a graph, or the like. For example, the display can include the vehicle's interior ambient temperature, the exterior ambient temperature, the circulation blower speeds, the usage of the power source or sources supplied to the HVAC system **10**, and warning messages, etc. In one example, if the first power source and the second power source are batteries, the display can show the current approximate battery charges for each power source to the vehicle occupant.

[0080] As the HVAC operation continues, the combined battery bank voltage can be continually monitored. The preferred voltage point is determined based on the temperature, the load, the rate of voltage change, the estimated battery condition, the stored historical data and user preferences such that the preferred voltage point becomes a predetermined amount of voltage that is dynamically determined based on ambient operating conditions in which the first and second power sources separate if the combined voltage drops below the predetermined amount. If the voltage does not drop below the preferred voltage point, the monitoring of the power draw and rate of decline is continued. If the combined bank voltage eventually falls to the preferred voltage point, the battery management controller logic circuit **66** commands the combination/separation device **61** to electrically separate the first and second battery banks **40** and **42** at step **410**. Once separated, the HVAC power is supplied solely by the first battery bank **40** while the second bank (i.e., the battery bank connected to the engine starter **64**) is isolated and the voltage of the second battery bank partially recovers to an unloaded resting state. In time it will be possible to use this "resting" voltage to accurately determine the state of charge of the isolated bank. Then, a determination will then be made by the control logic circuit **66** about whether additional power can be safely drawn from the isolated bank.

[0081] With continued operation of the HVAC system **10**, the voltage of first battery bank **40** continues to decline. The battery management controller logic circuit re-analyzes the battery bank **40** by comparing real time data on the power draw, the temperature and the rate of voltage decline with the stored historical data and the user input preferences to determine the amount of stored energy available. A determination is made of the minimum system disconnect voltage, i.e., the battery cut-out voltage. From this determination, a calculation is made of the estimated time to battery depletion for the first battery and this estimated time information is communicated to the HVAC component controller **50**. Because the estimated time information is based on both static data (such as historical and user input) and real-time data (such as current voltage levels and temperatures), a change in the performance, the system load or the ambient conditions during the operation of the HVAC system **10** can change the estimated time information which may increase or decrease the calculation of the available system run time.

[0082] As the HVAC system **10** continues to run, the voltage level of the first battery is monitored in step **410**. As long as there is sufficient voltage, the battery management controller will continue to have the first battery bank power the HVAC components and monitor the first battery bank's voltage level. However, the power can eventually be depleted from the first battery bank **40** to the point where the voltage falls to the level calculated by the control logic circuit to be the minimum allowed, i.e., the battery cut-out voltage, and disconnect the first battery bank **40** as shown in step **412**. If continued operation of the HVAC system **10** is desired, the battery management controller logic circuit **66** will use the resting voltage measurement of the second battery bank **42** (which has been isolated) to determine how much, if any, additional power can safely be drawn from that bank at step **414**. If power is available from the second battery bank (the "YES" path), the control logic circuit **66** will set a second lower voltage level at step **416** and command the combination/separation device **61** to re-route power from the second battery bank **42**. As the HVAC system **10** continues to run, the voltage level of the second battery is monitored. If the voltage level remains above the second voltage, the process remains at step **416**. Power will then continue to be supplied by the second bank **42** until such time as the voltage of the second bank **42** falls below the second lower voltage. At that time, the battery management controller logic circuit will command the combination/separation device **61** to cut off all power to the HVAC system **10** at step **420**. However, if no additional power is available from the second bank **42**, the battery management controller logic circuit will just command the combination/separation device **61** to cut off all power to the HVAC system **10** at step **420**.

[0083] In contrast, if there is insufficient charge in both battery banks at step **406**, the battery management controller determines if there is sufficient charge in one of the battery banks at step **430**. If there is not sufficient charge in either battery bank (the "NO" path), the battery management controller logic circuit will command the combination/separation device **61** to cut off all power to the HVAC system **10** at step **430**. If there is sufficient charge in one of the battery banks (the "YES" path), the particular battery bank with sufficient charge would supply power to the components of the HVAC system **10** at step **432**. The battery management controller logic circuit analyzes the selected battery bank by comparing real time data on the power draw, the temperature and the rate of voltage decline with the stored historical data and the user i n p u t preferences to determine the amount of stored energy available. A determination is made of the minimum system disconnect voltage, i.e., the battery cut-out voltage. From this determination, a calculation is made of the estimated time to battery depletion for the selected battery and this estimated time information is communicated to the HVAC component controller **50**. Because the estimated time information is based on both static data (such as historical and user input) and real-time data (such as current voltage levels and temperatures), a change in the performance, the system load or the ambient conditions during operation of the HVAC system **10** can change the estimated time information which may increase or decrease the calculation of the available system run time.

[0084] As the HVAC system **10** continues to run, the voltage level of the selected battery bank is monitored. If there is sufficient voltage, the battery management controller will continue the monitoring process. However, the power can eventually be depleted from the selected battery bank to the point where the voltage falls to the level calculated by the control logic circuit to be the minimum allowed, i.e., the battery cut-out voltage. Once the voltage level falls below this minimum, the battery management controller logic circuit will command the combination/separation device **61** to disconnect the selected battery bank at step **434**; thus cutting off all power to the HVAC system **10** at step **420**.

[0085] At the end of the discharge cycle, the battery management controller **60** has regulated the battery banks **40** and **42** so that the first battery bank **40** is more deeply discharged than the second bank **42**. Additional power has been reserved in the second battery bank **42**, which is the bank to which the engine starter **64** is connected, thus ensuring that sufficient energy is available to start the engine. Because the charge level of the two banks is different, the voltage level is also different. Therefore, the battery management controller logic circuit **66** commands the combination/separation device **61** to keep the two battery banks electrically separated and can monitor the voltage of each bank individually.

[0086] At the start up of the engine, a heavy electrical load is applied to the second bank **42** causing the voltage of the second bank **42** to drop. The amount of drop depends on the condition, the state of charge, and the temperature of the second bank **42** as well as the engine itself. Thus, there is a chance that under certain adverse conditions, the voltage drop will be so severe as to prevent the engine from starting unless additional electrical power is made available.

[0087] By monitoring the voltage of the first bank **40** separately from the second bank **42**, and by monitoring the rate of charge of the voltage in the second bank **42** at the time the electrical load is applied at the engine start up cycle, the battery management controller logic circuit **66** can determine if additional electrical power is available in the first battery bank **40** to provide a starting boost. If the control algorithm in the battery management controller logic circuit **66** determines that such power is available, the logic circuit **66** will command the combination/separation device **61** to electrically combine the first battery bank **40** with the second battery bank **42** during the engine start up cycle. In this case, the engine starter **64** is connected to the combination of the first and second battery banks **40** and **42** through the combination/separation device **61** via the optional connection **65**; thus allowing the engine to be started. After the engine is started, the battery management controller logic circuit switches to its charge mode algorithm as will be described next.

[0088] According to another embodiment of the present invention, a starter assist system may be used to assist the first battery bank, the second battery bank, or a combination thereof in the starting of the engine. Such a starter assist system is disclosed in co-pending U.S. patent application Ser. No. 12/149,095, entitled "Power Generation and Battery Management Systems", which is hereby incorporated by reference in its entirety.

[0089] FIG. **6**(*b*) is a flow chart showing the process for charging the batteries after the engine has been turned on. After the engine has started up at step **450**, one or more power sources can be used to recharge the first and second battery banks **40** and **42**. When the charging device **62** (such as the alternator) is activated at step **452**, the battery management controller logic circuit **66** reviews the historical data from the last discharge cycle to estimate the amount of load that the recharging operation will be put on the charging device **62** at step **454**. Previously entered user input from the user interface **51** will be used to determine if this estimated load is "high" or "low." A deeply discharged battery bank and/or large battery banks that contain a great deal of storage capacity are more likely to cause a "high" load than smaller or more lightly discharged batteries. Therefore, if the estimated load is determined to be "high," the battery management controller logic circuit commands the combination/separation device at step **456** to route the electrical power from the charging device **62** to only to the second battery bank **42** (i.e., the bank connected to the engine starter **64**). Once the second bank has reach a state of charge sufficient to significantly reduce the load on the charging device **62**, the control logic circuit commands the combination/separation device **61** at step **458** to electrically combine the first and second battery banks **40** and **42** so that all batteries get recharged. If, at the beginning of the recharge cycle, the battery management controller logic circuit determines that the load will be "low" then all batteries from both the first and second battery banks **40** and **41** are combined via the combination/separation device **61** and charged together at step **460**. From either step **458** or step **460**, the charging of both battery banks is continued until both are fully charged or the engine is turned off at step **462**.

[0090] According to one embodiment of the present invention, so as to ensure that the batteries are fully recharged between cycles to prevent premature sulfation and destruction of the batteries, the battery management controller can also monitor and store the time and power levels of the batteries during the discharge and recharge cycles. This historical data can verify that, in a typical discharge and re-charge cycle, sufficient time and power is available to fully recharge the batteries. If there is not sufficient time and power to fully recharge, the control logic circuit **66** can respond by raising the minimum battery cut-off voltages thereby reducing the total amount of power which can be drawn from the battery banks. In other words, the battery management controller **60** can be configured to be self-learning which allows the controller to maximize the battery replacement life by monitoring the first and/or second power sources such that they are not excessively discharged (i.e., drained) and such that they are not discharged to a level that does not allow the power source to be fully recharged during the typical engine run time. For example, consider that a power source might be a battery in which the battery can be safely discharged to a level X. Thus, the level X can be the predetermined amount value during the determination of whether the power source should be connected to the HVAC system. However, if the run cycle of the engine was too short to allow the battery to fully recharge during the engine run after the battery had been partially discharged, the battery would still be prematurely destroyed because failure to fully recharge a battery is just as harmful as discharging it too deeply (or draining the charge too much). To prevent the premature destruction of a battery due to it not being fully recharged, the battery management controller **60** can monitor the battery charge in the power source to determine if the battery was fully recharged. If the battery was not, then the controller **50** can be configured to "learn" during the next operation where the power source is connected and the engine is turned off that the battery should be less deeply discharged, i.e., the battery should be discharged to a level Y, which is greater than the level X. Then, the level Y can be the predetermined amount value during the determination of whether the power source should be connected to the HVAC system.

[0091] Next, the HVAC component controller **50** will be described. The HVAC component controller **50** controls the components of the HVAC system **10**, and works in conjunction with the battery management controller **60**. The purpose of the HVAC component controller **50** is to: (1) communicate to the user via the user interface; (2) monitor safety functions and initiate appropriate responses; (3) maximize the operational efficiency of the HVAC system by optimizing the speed of the condenser and evaporator fans and the speed of the compressor motor according to ambient conditions and user preferences; (4) regulate the speed of the condenser fans to control the condenser temperature thereby obtaining the best compromise between increased fan motor power consumption and increased compressor motor power; (5) regulate the speed of the evaporator fan proportionate to the temperature differential between the user temperature set point and the actual interior ambient temperature; (6) regulate the speed of the compressor motor to maintain the desired evaporator temperature; and (7) regulate the power to the heating devices **800** proportionate to the temperature differential between the user temperature set point and the actual interior ambient temperature. In the manner described herein with regard to the HVAC components, in the alternative embodiment described further below, the HVAC component controller **50** also manages the power being supplied to other heating devices such as the radiant heat panel **810**, the heated mattress pad **812**, and/or the electric heating blankets **814**.

[0092] The HVAC component controller **50** carries out its function by being operationally connected to the battery management controller **60**, the user interface **51** (which includes one or more displays **310** and one or more inputs **312**), a plurality of sensors, and the operational components of the HVAC system as show in FIG. **5**(*b*). The plurality of sensor detects a variety of parameters including: the vehicle's interior ambient temperature detected by a temperature sensor **304**, the humidity of the vehicle's compartments by using a humidity sensor **307**, noise and/or vibration from one or more noise or vibration sensors **308**, and/or thermal sensors associate with any or all the of the heating devices **800**. Examples include: a thermal sensor **303** for measuring the temperature of the radiant heat panel T_{RP}, thermal sensor **305** for measuring the temperature of the heated mattress pad T_{MP}, and/or a thermal sensor **309** for measuring the temperature of electric heating blanket T_{HB}.

[0093] As to the operational components of the HVAC system, the HVAC component controller **50** can run the motor **12** that drives the compressor **14**; the circulation blowers that blow the temperature-controlled air into one or more designated compartments (such as the vehicle compartment **23** and/or the sleeping compartment **27**); the plurality of heating devices for the heating system (such as the air heaters **272** and **274** from FIG. **1**, the heater **180** from FIG. **2**, the radiant heat panel **810**, the heated mattress pad **812**, and/or the electric heating blankets **814**); and the control doors (if applicable) for the regulation of the temperature. Additionally the HVAC component controller **50** can also switch any control valves to control the flow of refrigerants (such as the valves **28** and **29** from FIG. **1** or the valves **184** and **184** from FIG. **2**). In one embodiment, the motor **12** of the compressor **14** can be controlled by the HVAC component controller **50** using a closed loop proportional, integral, derivative (PID) control. Similarly, the HVAC component controller **50** can also control the fan speed of the circulation blowers **210** and **212** via a pulse width modulated (PWM) PID control loop that is independent of the control for the compressor.

[0094] In one embodiment, the HVAC component controller **50** can modulate the speed of the motor **12**, and thus can modulate the capacity of the compressor **14** driven by the motor **12**. The modulation of the compressor can range between an upper compressor capacity and a lower compressor capacity. The compressor capacity can vary depending on the compressor capacity required to maintain the evaporator **22** or **26** at the evaporator temperature T_E as commanded by the HVAC component logic circuit **66**.

[0095] In one exemplary embodiment of the present invention, the HVAC component controller **50** ("HCC") can work as described below with reference to FIG. **7**. The HVAC component controller **50** receives a signal from the user interface **51** to begin operation at step **702**. Commands are sent to the battery management controller **60** ("BMC") from tile power supply management controller **50** to supply power to the HVAC system **10** at step **704**. At step **706**, the user interface **51** is polled for the user preference settings, such as the mode of operation, the location of temperature control, and the desired set point temperature Tsp. Also the interior ambient temperature T_a is read from the temperature sensor **304** at step **706**.

[0096] FIGS. **13**(*a*)-**13**(*d*) provide an example of inputting user preferences in relation to environmental conditions. These user preferences can be stored in a suitable memory in the HVAC component controller. FIG. **13**(*a*) shows a user interface **51** with a touch screen **1202** and an On/Off toggle switch **1203** for activating the interface **51** (or this particular interface if there is more than one interface). The default touch screen displays the interior ambient temperature T*a* and the possible modes of operation, i.e., the cooling mode, the heating mode, a fans only mode (in which the circulation blowers are operated without further heating or cooling operations in the HVAC system), and an off mode. If a vehicle occupant wishes to set the desired set point temperature T_{SP}, he or she would merely touch the "Set" field box **1204** on the screen **1202**.

[0097] After touching the "Set" field box **1204**, a key pad **1206** is activated, as seen in FIG. **13**(*b*). The vehicle occupant would enter the desired set point temperature, which would be displayed in the "Set" field box **1204**. In FIG. **13**(*b*), the occupant has set the set point temperature to 65° F. After pressing the "Enter" key **1208**, the default touch screen is displayed, as seen in FIG. **13**(*c*).

[0098] To initiate a cooling mode, the "Cool" field box **1210** is touched. To initiate a heating mode, the "Heat" field box **1212** is touched. To initiate only the circulation blowers, the "Fan Only" field box **1214** is touched. To turn off the HVAC system, the "Off" field box is touched. In the case of initiating the heating mode, once the "Heat" field box is touched, the heat preference display in FIG. **13**(*d*) is activated.

[0099] In FIG. **13**(*d*), the heat preference display discloses available power preferences of the available heating devices. In the embodiment of FIG. **13**(*d*), these heating device include a air heater **274**, a radiant heat panel **810**, and an electric heating blanket **814**. The air heater has a power indicator **1120**, the heat panel has a power indicator **1222**, and the heating blanket has a power indicator **1224**. Each power indicator indicates the preference of power to the respective heating device. For example, FIG. **13**(*d*) shows that power is most preferably channeled to the heating blanket because the power bar **1230** inside the heating blanket power indicator **1224** is the highest of the three indicators. Power channeled to the radiant heat panel is preferred over the power to the air heater but not preferred over the heating blanket because the power bar **1230** in the radiant heat panel power indicator **1222** is below the power bar **1230** in the heating blanket power indicator **1224**. Thus, if there-is insufficient power to run both the radiant heat panel and the heating blanket, the radiant heat panel will be shut-off first. There is no power to be channeled to the air heater because the air heater power indicator **1220** has no power bar. The respective levels of the power bars may be raised and lower by touching the increasing arrows **1226** or the decreasing arrows **1228** located above and below each power indicator. For example, if the vehicle occupant touches the increasing arrow **1226** above the radiant heat panel power indicator **1222**, the power bar **1230** in this indicator will increase. If the power bar **1230** in the radiant heat panel power indicator is raised above the level of the power bar **1230** in the heating blanket power indicator **1224**, then when there is insufficient power to run both the radiant heat panel and the heating blanket, the heating blanket will be shut-off first. After the power bars are set, the display may automatically revert back to the default display shown in FIG. **13**(*a*) after a predetermined amount of time has elapsed with no input by a user.

[0100] FIG. **14** shows an alternative embodiment to FIG. **13**(*d*) in which the display indicates power indicators for a plurality of heating devices that include a fuel heater ("Fuel"), an air heater ("Air"), a radiant heat panel ("Radiant"), and a heated mattress pad ("Bed"). A fuel heater is a heater that comprises a dedicated burner which pulls fuel from the tank (when the engine is not running) and burns it to heat air directly or through circulated water. The display in FIG. **14** shows that all heating devices are equally preferred.

[0101] Referring back to FIG. **7**, if the user preference is for the "cooling" mode, the process is sent to step **708** where a command is issued to start all fans of the circulation blowers **210**, **212** and the motor **12** of the compressor **14** to a minimum speed. At step **710**, the compressor speed is then commanded to bring and hold the evaporator **22** to a predetermined evaporator temperature T_E if the vehicle compartment is being cooled or to bring and hold the evaporator **26** to a predetermined evaporator temperature T_E if the sleeping compartment is being cooled. At step **712**, the fans of the condenser **16** are commanded to bring and hold the condenser **16** to a predetermined condenser temperature T_C.

[0102] If the user preference is for the "heating" mode, a command from the HVAC component controller **50** is issued at step **714** to start the selected heating devices that are read in at step **706**. For example, if one or both air heaters are selected, the fan(s) of the circulation blower(s) of the evaporator(s) **22**, **26** are started, and the electric heating element(s) **270**, **274** are commanded to a power level (via PWM control) proportionate to the fan speed of the circulation blower(s) of the evaporator(s) **22**, **26**. If the radiant heat panel, the heated mattress pad, and/or the heating blanket are selected, these elements have power supplied to their respective heating elements.

[0103] With the HVAC system **10** now running in either the heating or cooling mode, the battery management controller **60** is polled for an estimate of the run time based on the present power draw and stored energy available for use in step **718**. As step **720**, the estimated run time is compared to the desired run time which was programmed into the user settings by the user using the user interface **51**. The HVAC component controller **50** factors the difference between the estimated and desired run times into planning the output of the HVAC system **10** to ensure that sufficient power is available for the duration of the heating or cooling period (also called the "run time plan"). Based on the run time plan, the HVAC component controller **50** may increase or decrease the average capacity of the HVAC system periodically throughout the cycle. In particular, if the amount of heating (step **736**) or the amount of cooling (steps **726**, **728**, and **730**) would require too much power to be drawn from the power source(s), the highest capacity of the HVAC system **10** possible would be employed which would still allow the battery management controller to supply power through the entire operational period. The highest capacity possible can be obtained through a combination of settings which would offer the best efficiency for the prevailing conditions.

[0104] At step **722**, a variety of measurements are taken at step **722** so as to ensure that the HVAC system runs efficiently with its limited power supply. These measurements include the actual interior ambient temperature of the vehicle's interior T_a, the evaporator temperature T_E, the condenser temperature T_C, the radiant heat panel temperature T_{RP}, the mattress pad temperature T_{MP}, and the heating blanket temperature T_{HB}. At step **722**, temperature sensors on the evaporator measure the evaporator temperature T_E, temperature sensors on the condenser measure the condenser temperature T_C, sensors in the vehicle and/or sleeping compartments measure the interior ambient temperature T_a, a thermal sensor **303** measures the radiant heat panel temperature T_{RP}, a thermal sensor **305** measures the heated mattress pad temperature T_{MP}, and a thermal sensor **309** measures the electric heating blanket temperature T_{HB}. The user inputs the desired interior ambient temperature or the set point temperature T_{SP} via the user interface **51**.

[0105] For efficient operation of the HVAC components in the cooling mode, a calculation is made at step **724** in which a difference Δ between the interior ambient temperature Ta and the set point temperature T_{SP} is determined. Then, the circulation blowers at the evaporator **22** or **26** are commanded to a speed proportionate to the difference Δ at step **726**. The determination of an appropriate fan speed for the blowers at the evaporator based on a given Δ can be based on any one of a number of methods known in the art such as tabular formulations or computer models.

[0106] The air blown into the vehicle and/or sleeping compartments affects the interior ambient temperature of the compartment; thus with continued operation of the HVAC system, the difference (Δ) between the interior ambient temperature Ta and the set point temperature T_{SP} begins to decrease. As the interior ambient temperature T_a nears the set point temperature T_{SP}, the HVAC component controller **50** reduces the fan speed of the circulation blowers at the evaporator **22** or **26** proportionately based on Δ, as seen in step **726**. In the cooling mode, the reduced air flow over the evaporator **22** or **26** causes the evaporator temperature T_E to fall. In response, the HVAC component controller **50** adjusts the speed of the motor **12** that drives the compressor **14** to maintain the desired evaporator temperature T_E at step **728**. Similarly, the changing capacity of the evaporator **22** or **26** also changes the temperature of the condenser T_C. Again, the HVAC component controller **50** adjusts the fan speed of the condenser **16** so as to maintain the desired condensing temperature T_C at step **730**. However, the settings for the circulation blowers, the compressor, and the condenser (which are set in steps **726**, **728**, and **730** respectively) are subject to the highest possible capacity of the HVAC system based on the run time plan. Thus, if too much power would be drawn by these components while running at the most efficient operation, the settings of these components would be adjusted so as to allow the system to run for the desired run time while operating as close as possible to the most efficient operation determined by Δ.

[0107] The process continues to step **732** where the HVAC component controller receives data from the battery management controller **60** about whether there is sufficient power being supplied. If there is sufficient power (the "YES" path), the process returns to step **718** and the process is repeated. If there is insufficient power (the "NO" path), the operation of the HVAC system is terminated at step **734**.

[0108] For efficient operation of the HVAC components in the heating mode, an evaluation is made of which heating devices are being utilized (performed in step **706**), what order the operations of these heating devices are preferred (performed in step **706**), and how the most efficient operation of each heating device is achieved based on user input, operational conditions (such as state of charge of batteries, power consumption of HVAC components, set point temperature T_{SP}, etc.), and environmental conditions (interior and exterior ambient temperatures, etc.) (performed in step **736**). For example, if one or both air heaters are selected, a calculation is made in which a difference Δ between the interior ambient temperature Ta and the set point temperature T_{SP} is determined at step **724**. Then, the circulation blowers at the evaporator **22** or **26** are commanded to a speed proportionate to the difference Δ (similar to step **726** of the cooling mode). The determination of an appropriate fan speed for the blowers at the evaporator based on a given Δ can be based on any one of a number of methods known in the art such as tabular formulations or computer models.

[0109] The air blown into the vehicle and/or sleeping compartments affects the interior ambient temperature of the compartment; thus with continued operation of the HVAC system, the difference (Δ) between the interior ambient temperature Ta and the set point temperature T_{SP} begins to decrease. As the interior ambient temperature T_a nears the set point temperature T_{SP}, the HVAC component controller **50** reduces the fan speed of the circulation blowers at the evaporator **22** or **26** proportionately based on Δ. The HVAC component controller **50** alters the PWM cycle of the resistive heating elements **270** or **274** to match the changing fan speed of the circulation blower at the evaporator **22** or **26**. In this way, the temperature of the discharged air remains constant. Similar with the cooling operation, the settings for the circulation blowers and the heater are subject to the highest possible capacity of the HVAC system based on the run time plan. Thus, if too much power is being drawn by these components while running at the most efficient operation, the settings of these components can be adjusted so as to allow the system to run for the desired run time while operating as close as possible to the most efficient operation determined by Δ. For example, the settings of the circulation blowers may be lowered to a level that permits operation during the entire desired run time while still operating as close as possible to the settings for the most efficient operation based on Δ.

[0110] If the radiant heat panel, the heated mattress pad, or the heating blanket are selected, a calculation is made in which a difference Δ between the interior ambient temperature Ta and the set point temperature T_{SP} is determined at step **724** along with the determination of the radiant heat panel temperature T_{RP}, the mattress pad temperature T_{MP}, or the heating blanket temperature T_{HB} in step **722**. The HVAC component controller **50** alters the PWM cycle of the resistive heating element in the selected device such that the temperature of the respective heating device that would be needed to achieve the desired set point temperature is set. The settings for the respective heating device are subject to the highest possible capacity of the HVAC system based on the run time plan. Thus, if too much power is being drawn by the resistive heating element of the heating device while running at the most efficient operation, the settings of the heating device can be adjusted so as to allow the system to run for the desired run time while operating as close as possible to the most efficient operation determined by Δ. For example, the power settings to the resistive heating element of the respective heating device may be lowered to a level that permits operation during the entire desired run time while still operating as close as possible to the settings for the most efficient operation based on Δ.

[0111] In the example of only the radiant heat panel being selected, if the interior ambient temperature is 30° F., the necessary current to the heating element **1008** of the radiant heat panel may be **60**A to achieve the desired set point temperature of 65° F. If the interior ambient temperature is at 20° F., the necessary current to the heating element **1008** may be raised to **80**A to achieve the desired set point temperature of 65° F. If, to maximize battery life, the battery can only be discharged to a predetermined level (for example, 40% of the total capacity of the battery) and this predetermined level will be surpassed if **80**A is supplied to the heating element **1008** for the projected length of time of the HVAC system's run, the controller **50** will lower the necessary current to the heating element **1008** to a lower level (for example, to **50**A) which will allow the battery to be discharged only to the predetermined level of 40% even if the interior ambient temperature is 20° F. The operations of the heated mattress pad and the heating blanket are similar.

[0112] If the heat panel, the heated mattress pad, the electric heating blanket, the air heaters, or any combination thereof are being operated at the same time, the HVAC component controller **50** will balance all activated heating devices so as to provide the most efficient operation for each of these devices at step **736** so as to achieve the desired set point temperature T_{SP}. For example, if the radiant heat panel **810** and the heated mattress pad **812** are the only selected heating devices, the desired set point temperature T_{SP} is 65° F. and the interior ambient temperature is 40° F., the HVAC component controller **50** will evaluate which settings of the radiant heat panel and the heated mattress pad will achieve the desired set point temperature of 65° F. The initial selection of the settings of these heating devices to achieve the desired set point temperature may be determined based on a predetermined combination of settings determined by previous runs or by the manufacturer, which can be stored in tabular form or in a computer model. For example, the HVAC component controller **50** may determine that **50**A supplied to the radiant heat panel and **10**A supplied to the mattress pad will provide the necessary desired set point temperature T_{SP}.

[0113] The initial selection then may be adjusted by the HVAC component controller **50** based on various sensor readings. For example, if the thermal sensors indicate that the interior ambient temperature is 70° F. after running the heating devices, the HVAC component controller **50** may lower the amount of power supplied to either or both of the heating devices, depending upon if the operation of one device is preferred over the other, until the interior ambient temperature reaches the desired set point temperature. In one embodiment, if one heating device is preferred over another, the amount of power to each device may be lowered in an amount proportional to the amount of preference given to the heating devices as reflected by the power indicators on the user interface **51** (see FIGS. **13**(*d*) and **14**).

[0114] On the other hand, if the thermal sensors indicate that the interior ambient temperature becomes 55° F. after running the heating devices, the HVAC component controller **50** may raise the amount of power supplied to either or both of the heating devices, depending upon if the operation of one device is preferred over the other, until the interior ambient temperature reaches the desired set point temperature. In one embodiment, if one heating device is preferred over another, the amount of power to each device may be raised in an amount proportional to the amount of preference given to the heating devices as reflected by the power indicators on the user interface **51** (see FIGS. **13**(*d*) and **14**). The process proceeds to step **732**, back to steps **718**, **720**, **722**, **724**, and **736** if there is sufficient power to operate the selected heating devices, and continues in this cycle as long as there is sufficient power.

[0115] If too much power would be drawn by using all the selected heating devices even at their most efficient operation as determined at step **732**, the least preferred heating device would be shut off, and the remaining activated devices would be reevaluated for their most efficient operations so as to achieve the desired set point temperature T_{SP}. If the power draw is still too great the next least preferred heating device would be shut off, and the remaining activated devices would be reevaluated for their most efficient operations so as to achieve the desired set point temperature T_{SP}. This process continues until the battery management controller at step **732** has determined that there is insufficient power to run any heating device. At which point, the process terminates at step **734**.

[0116] According to another embodiment of the present invention, the HVAC system may have at least two heating devices in which one heating device is the radiant heat panel **810** and the other heating device is another additional heating device, such as a fuel-fired heater, an electrical heater (such as air heaters, resistance heaters, or the like), or any other heating system. Under the conditions in which only the radiant heat panel **810** is being used to warm a driver while in a bed of the sleeping compartment, the additional heating device may be powered for a short period of time to "warm up" the cab after the driver gets out of the bed and is away from the radiant heat panel. For example, a position sensor may be used to indicate the position of the driver in the bed of the sleeping compartment. If only the radiant heat panel is used to provide warmth to the driver in this instance (even though there may be a variety of other heating devices available) and the position sensor indicates that the driver has moved from the bed to another location in the cab out of the reach of the radiant heat panel **810**, a controller (such as component controller **50**) initiates the additional heating device to warm up the cab. The controller may be configured to run the additional heating device for a predetermined time limit, until a predetermined temperature is reached, or until some other condition is satisfied. The radiant heat panel **810** may be kept on while the additional heating device is operating, or may be turned off while the additional heating device is operating to conserve power. According to other embodiments, the heated mattress pad **812** and/or the heating blanket **814** may function the same way as the radiant heating panel **810**. In other words, if the heated mattress pad **812** and/or the heating blanket **814** is used to provide warmth to the driver in this instance (even though there may be a variety of other heating devices available) and the position sensor indicates that the driver has moved from the bed to another location in the cab out of the reach of the heated mattress pad **812** and/or the heating blanket **814**, a controller (such as component controller **50**) initiates the additional heating device to warm up the cab for a predetermined time limit, until a predetermined temperature is reached, or until some other condition is satisfied.

[0117] Other system parameters can be used to control the motor-driven compressor **14** and the circulation blowers **210** and **212**. For example, the HVAC component controller **50** can also monitor humidity of the vehicle's compartments by using a humidity sensor **307**. If the humidity of the compartments is above a predetermined threshold (which can be set by the vehicle occupant), the HVAC component controller **50** can control the compressor **14** to speed up (up to but not exceeding the upper compressor capacity) and the circulation blowers **210** and **210** to slow down.

[0118] Furthermore, one or more noise or vibration sensors **308** can be used to determine the level of noise or vibration of the HVAC system **10**. Once the signal is sent to the HVAC component controller **50**, the controller **50** determines whether there is a need to speed up or slow down the compressor and/or blower, and to control the compressor and/or blower accordingly.

[0119] The use of one or more system parameters, such as the evaporator temperature, the humidity, the exterior ambient temperature, the vehicle's interior temperature, etc. to control the compressor and blower capacities can be accomplished by monitoring the one or more system parameters and using a program in the HVAC component controller **50** that was compiled using, for example, a multivariate model known in the art.

[0120] Other system parameters can also be provided to the HVAC component controller **5**, which may allow the HVAC component controller **50** to detect faults within the HVAC system. For example, performance and safety functions are monitored and an appropriate response by the HVAC component controller **50** can be initiated, such as shutting down the system in the event of the overheating of the motor **12** of the compressor **14**.

[0121] FIG. **8** shows another embodiment of the HVAC system according to the present invention. The embodiment in FIG. **8** is similar to the embodiment of FIG. **1**; however, FIG. **8** shows how the HVAC system can be divided up into a split system **600** in which there is an exterior subsystem **602** and an interior subsystem **604**. The exterior subsystem **602** can comprise components that are located on the exterior of the vehicle's cab. The interior subsystem **604** can comprise components that are located in the interior of the vehicle's cab. For example, FIG. **8** shows an exterior subsystem **602** that comprises a motor **12**, a compressor **14**, a condenser **16**, and a first power source, which are located outside the cab of a large vehicle, such as a truck. In addition, the second power source and the electrical power generation system **44** can also be located on the exterior of the vehicle's cab as is conventional with large vehicles.

[0122] The interior subsystem **604** can comprise the circulation blower **610**, the evaporator **622**, the HVAC component controller **50**, the battery management controller **60**, the display **310**, the input device **312**, the radiant heat panel **810**, the heated mattress pad **812**, and the heating blanket **814**, which are all located inside the cab of the vehicle. The temperature controlled air can be optionally channeled into ducts **672**, which may split into two or more ducts that may lead to different compartments or areas of the interior of the vehicle's cab. In one embodiment, the ducts **672** can be the vehicle's own ducting which is already installed in the vehicle cab. Additionally, the interior subsystem **604** can comprise the vehicle's already existing evaporator **622** and circulation blower **610**. In such a situation, the exterior subsystem **602** may be configured to be able to connect to a plurality of different evaporators, such as the vehicle's own evaporator. In addition, the exterior subsystem **602** may be configured to connect to a plurality of evaporators at one time, such as one evaporator for cooling/heating the driving compartment and one evaporator for cooling/heating the sleeping compartment.

[0123] In FIG. **8**, the refrigerant metering device is located exterior to the vehicle's cab as part of the exterior subsystem **602**, which allows the servicing of the metering device to be easier if it should fail. Alternatively, the refrigerant metering device **20** can be located in the interior of the cab as part of the interior subsystem **604**.

[0124] The split system **600** has several advantages. First, less interior space is taken up by the system because a substantial portion of the components are located exterior to the vehicle's cab. Additionally, the vehicle's existing ducts can be used so that no additional ducting is needed. Thus, the system can have an easier installation process, improved efficiency, and quieter operation.

[0125] The disclosed battery management controller and HVAC system can provide temperature control to a vehicle occupant for extended periods of time when the vehicle's engine is not running. In addition, the system ensures sufficient battery power to start the vehicle even when the HVAC system has been running for a period of time when the engine has been turned off. The battery management and HVAC systems can be used in large trucks, such as **18** wheelers, as well as any other type of vehicle.

[0126] During operation, the HVAC component controller **50** processes the user inputs to determine the operational mode of the HVAC system **10**. When either the heating or cooling mode of operation is selected and when the engine is turned on, the vehicle electrical power generation system is used to power the necessary components. For example, the heater and circulation blowers are turned on during the heating mode of operation while the compressor, circulation blowers, and pumps are turned on during the cooling mode of operation.

[0127] When the heating mode is operating when the engine is turned off, the HVAC component controller **50** commands a heater (such as the coolant heater **180** in FIG. **2**; the air heaters **270** and **274** in FIG. **1**; the radiant heat panel heater **810**; the mattress pad **812**; and/or the electric blanket

814) and the circulation blowers **210** and **212** (if applicable) to turn on. The HVAC component controller **50** also controls the speed of the circulation blowers **210** and **212** via a pulse width modulated (PWM) PID control loop in order to maintain the temperature of the driving and/or sleeping compartment at the interior set point temperature. With the various disclosed embodiments, the heating of the interior of the cab can be performed without relying on diesel fuel but can be run purely by battery power. Thus, the heating can be performed without relying on the vehicle's engine being turned on.

[0128] When the cooling mode of operation is used when the engine is turned off, the circulation blowers **210** and **212**, the compressor **14** and/or the pump **176** are turned on. The HVAC component controller **50** modulates the capacity of the compressor **14** and the circulation blowers **210** and **212** to maintain the temperature of the driving and/or sleeping compartments at the interior set point temperature via PID control.

[0129] In either the heating or cooling mode when the engine is turned off, if the voltage of the combination of the first and second power sources drops below a predetermined amount, the first and/or second power source is disconnected and the HVAC system is only powered by the remaining power source. Once the voltage of the remaining power source drops below another predetermined level, the battery management controller **60** can be configured to disconnect the remaining power source, thus shutting down the HVAC system **10**.

[0130] Upon start up of the vehicle, the alternator or other charging device can be used to charge up the first and second power sources (if they are batteries) so that they are fully charged. In one embodiment of the present invention, the battery management controller **60** can also be used to connect the first power source (such as an auxiliary battery or bank of auxiliary batteries) during the start up of the vehicle in the situation where the second power source (such as the starter battery or bank of batteries) is too weak to start the vehicle, such as in the case where the starter battery is weakened because of very low exterior ambient temperatures.

[0131] Furthermore, the HVAC system can be a split system with a substantial portion of the components exterior to the vehicle's cab such that less interior space is taken up by the HVAC system. Also, the vehicle's existing evaporator and/or ducting can be used with the HVAC system for an easier installation process, improved efficiency, and quieter operation.

[0132] The above discussion also describes embodiments of an HVAC system that may include a plurality of devices or system for providing heating or cooling. When the system is installed in a vehicle, alternative heating systems or components may be provided. For example, a radiant heat panel and/or a heated mattress pad or heating blanket may be provided.

[0133] The plurality of heating devices may be used with all of the embodiments and systems described above and shown in FIGS. **1-8**. The exemplary system includes one or more of a radiant heat panel **810**, a heated mattress pad **812**, and a heating blanket **814**. The heated mattress and heating blanket would preferably be configured to accept the vehicles standard power supply of 12V.

[0134] The radiant heat panel **810** provides heating through radiant heat transfer. The radiant heat panel may be used to warm the vehicle occupant(s) directly. The use of radiant heat panels may allow for the maintenance of a lower vehicle cabin temperature for the same comfort level achieved by a corresponding conventional HVAC system. The radiant heat panel will heat quickly and, thus, providing for less energy usage. Many different panel designs would be acceptable for use.

[0135] The system may also include a heated mattress pad **812**. The heated mattress pad may be connected to the vehicle electrical system via a conventional method and placed on a bed located in the vehicle cabin. Alternatively, an electric heating blanket **814** may be employed instead of, or in addition to, the heated mattress pad **812**.

[0136] The HVAC component controller **50** can control the operation of the heating devices (**810**, **812**, **814**). For example, if two heating devices (for example, the radiant heat panel and the heating blanket; the radiant heat panel and the heated mattress pad; or the heating blanket and the heated mattress pad) are being used for heating, the management controller can adjust system operational characteristics to account for user preferences, battery state-of charge, etc. Thus, the system including the radiant heat panel **810** or the heating blanket **814** or the heated mattress pad **812** would operate and function in the same general manner as the embodiments described above. For example, both the battery management controller **60** and HVAC component controller **50** would function as described above.

[0137] Given the disclosure of the present invention, one versed in the art would appreciate that there may be other embodiments and modifications within the scope and spirit of the invention. Accordingly, all modifications attainable by one versed in the art from the present disclosure within the scope and spirit of the present invention are to be included as further embodiments of the present invention. The scope of the present invention is to be defined as set forth in the following claims.

What is claimed is:

1. An HVAC system to be installed in a vehicle comprising:
at least one power source;
a plurality of heating devices; and
a component controller configured to operate a selected portion of the plurality of heating devices based on user preferences stored in the component controller, available power from the at least one power source, and a desired set point temperature.

2. The HVAC system of claim **1**, wherein the component controller evaluates, based on the user preferences, which heating devices are selected for operation and what order are operations of these heating devices preferred.

3. The HVAC system of claim **2**, where the component controller is configured to shut-off one of the selected heating devices that is least preferred when the available power is insufficient to operate all the selected heating devices.

4. The HVAC system of claim **3**, wherein the component controller is configured to shut-off as many heating devices of the selected heating devices as needed, in an order from least preferred to most preferred, for the available power to be sufficient to operate those selected heating devices that have not been shut-off.

5. The HVAC system of claim **1**, wherein the component controller provides enough power to each heating device in the selected portion of heating devices such that the desired set point temperature is achieved when sufficient power is available from the at least one power source.

6. The HVAC system of claim **1**, wherein the component controller determines settings of each heating device in the selected portion of heating devices such that the desired set point temperature is achieved when sufficient power is available from the at least one power source.

7. The HVAC system of claim **1**, wherein the component controller adjusts settings of each heating device in the selected portion of heating devices during operation such that interior ambient temperature reaches as close as possible to the desired set point temperature while maintaining user preferences related to power source conditions.

8. The HVAC system of claim **7**, wherein the power source conditions are maximization of battery life, operation time of the HVAC system, state of charge or voltage of at least one power source, or any combination thereof.

9. The HVAC system of claim **1**, wherein the plurality of heating devices comprise a radiant heat panel.

10. The HVAC system of claim **9**, wherein the radiant heat panel is configured to be mounted in a sleeper compartment of the vehicle.

11. The HVAC system of claim **9**, wherein the radiant heat panel comprises a heating element mounted on a substrate backing.

12. The HVAC system of claim **11**, wherein the radiant heat panel comprises an emissive panel covering the heating element and substrate backing.

13. The HVAC system of claim **9**, wherein the plurality of heating devices further comprises a heating blanket, a heated mattress pad, a resistance heater mounted in a duct in front of a blower, or any combination thereof.

14. The HVAC system of claim **1**, further comprising a second power source and a battery management controller to supply power to the plurality of heating devices from a combination of the first and second power sources with a combined voltage, wherein the second power source is disconnected when the combined voltage drops below a predetermined amount.

15. The HVAC system according to claim **14**, wherein the second power source is at least one battery connected to an engine starter of the vehicle.

16. The HVAC system of claim **15**, wherein the first power source is at least one auxiliary battery.

17. The HVAC system of claim **16**, wherein the battery management controller is configured to gather historical data for any one of the at least one auxiliary battery and the at least one battery connected to the engine starter.

18. The HVAC system of claim **14**, wherein the predetermined amount is an amount dynamically determined based on ambient operating conditions.

19. A heating system to be installed in a vehicle comprising:

a temperature control system including a radiant heat panel configured to be installed in a cabin of the vehicle; and

a component controller configured to operate the radiant heat panel based on a desired set point temperature.

20. The heating system of claim **19**, wherein the radiant heat panel comprises a heating element mounted on a substrate backing.

21. The heating system of claim **20**, wherein the radiant heat panel comprises an emissive panel covering the heating element and substrate backing.

22. The heating system of claim **20**, wherein the radiant heat panel further comprises an insulative layer mounted between the heating element and the substrate backing.

23. The heating system of claim **19**, further comprising a heating blanket, a heated mattress pad, a resistance heater mounting mounted in a duct in front of a blower, or any combination thereof.

24. The heating system of claim **19**, wherein the component controller is configured to operate the radiant heat panel based on user preferences stored in the component controller and available power from at least one power source.

25. The heating system of claim **19**, further comprising an additional heating device, wherein the component controller evaluates, based on the user preferences, if the radiant heat panel, the additional heating device, or a combination thereof are selected for operation and what order are operations of the radiant heat panel and the additional heating device preferred.

26. The heating system of claim **25**, wherein the component controller determines settings of the radiant heat panel and the additional heating device such that the desired set point temperature is achieved when sufficient power is available from at least one power source.

27. The heating system of claim **25**, wherein the component controller adjusts settings of the radiant heat panel and the additional heating device such that interior ambient temperature reaches as close as possible to the desired set point temperature while maintaining user preferences related to power source conditions.

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