US 20070227168A1

(19) United States

(12) **Patent Application Publication** (10) **Pub. No.: US 2007/0227168 A1**

Simmons (43) **Pub. Date: Oct. 4, 2007**

(54) **VARIABLE CAPACITY AIR CONDITIONING SYSTEM**

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(21) Appl. No.: **11/397,260**

(22) Filed: **Apr. 4, 2006**

Publication Classification

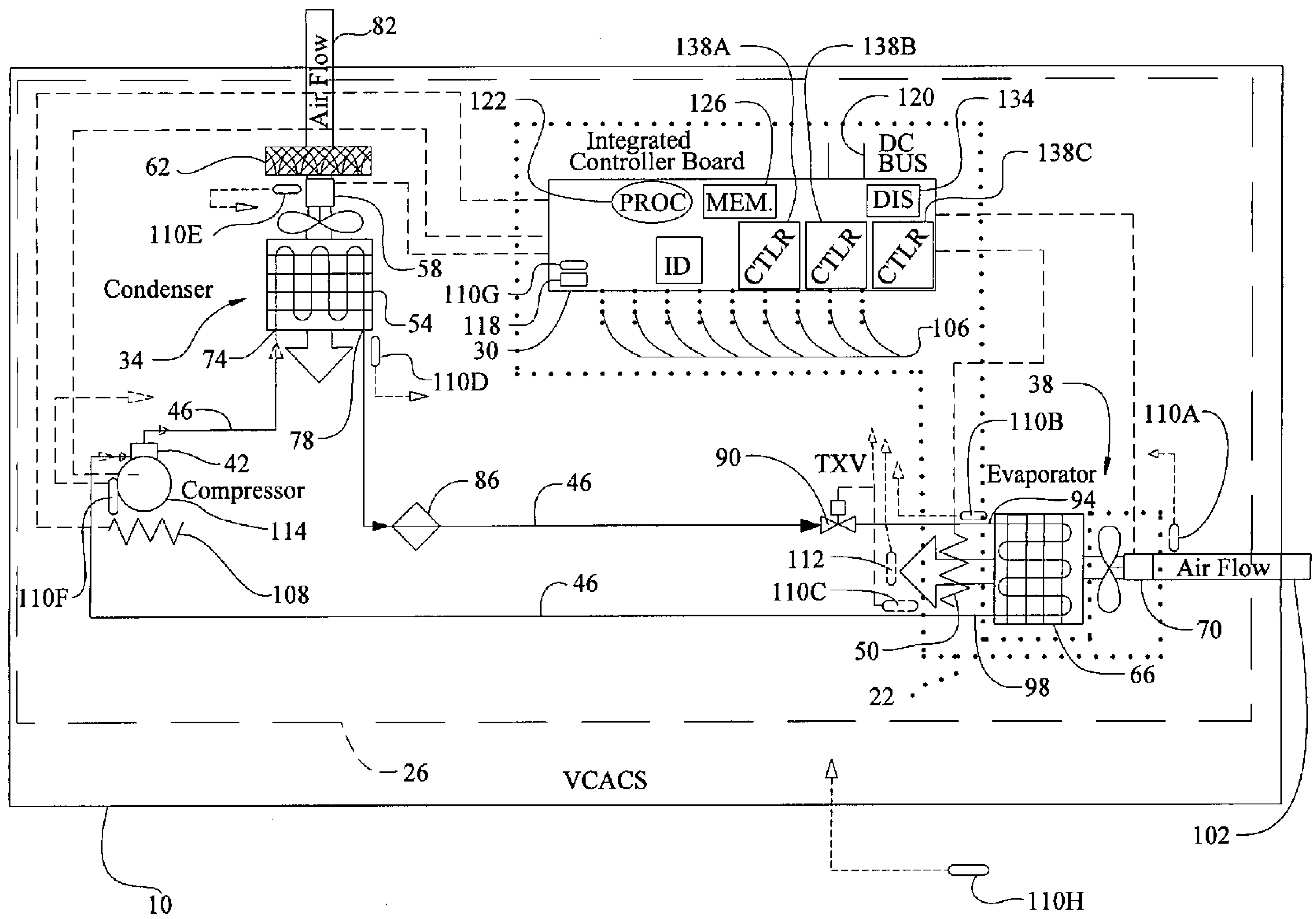
(51) **Int. Cl.**

F25B 39/04	(2006.01)
F25D 17/04	(2006.01)
F25B 1/00	(2006.01)

(52) **U.S. Cl.** **62/229**; 62/186; 62/183

(57) **ABSTRACT**

A direct current (DC) powered variable capacity air conditioning system is provided. The system includes a plurality of temperature sensors for monitoring the temperature of various components, locations and air flows within the system. The system additionally includes an integrated controller board that substantially simultaneously controls a variable speed DC compressor motor, a variable speed condenser air mover and a variable speed evaporator air mover in response to inputs from the sensors. By substantially simultaneously controlling the variable speed DC compressor motor, the variable speed condenser air mover and the variable speed evaporator air mover, the system substantially simultaneously controls at least one of a temperature and a volume of an evaporator output air flow. Thus, the system provides a continuum of evaporator output air flow temperatures and capacities for maintaining an approximately constant temperature within an enclosed environment.



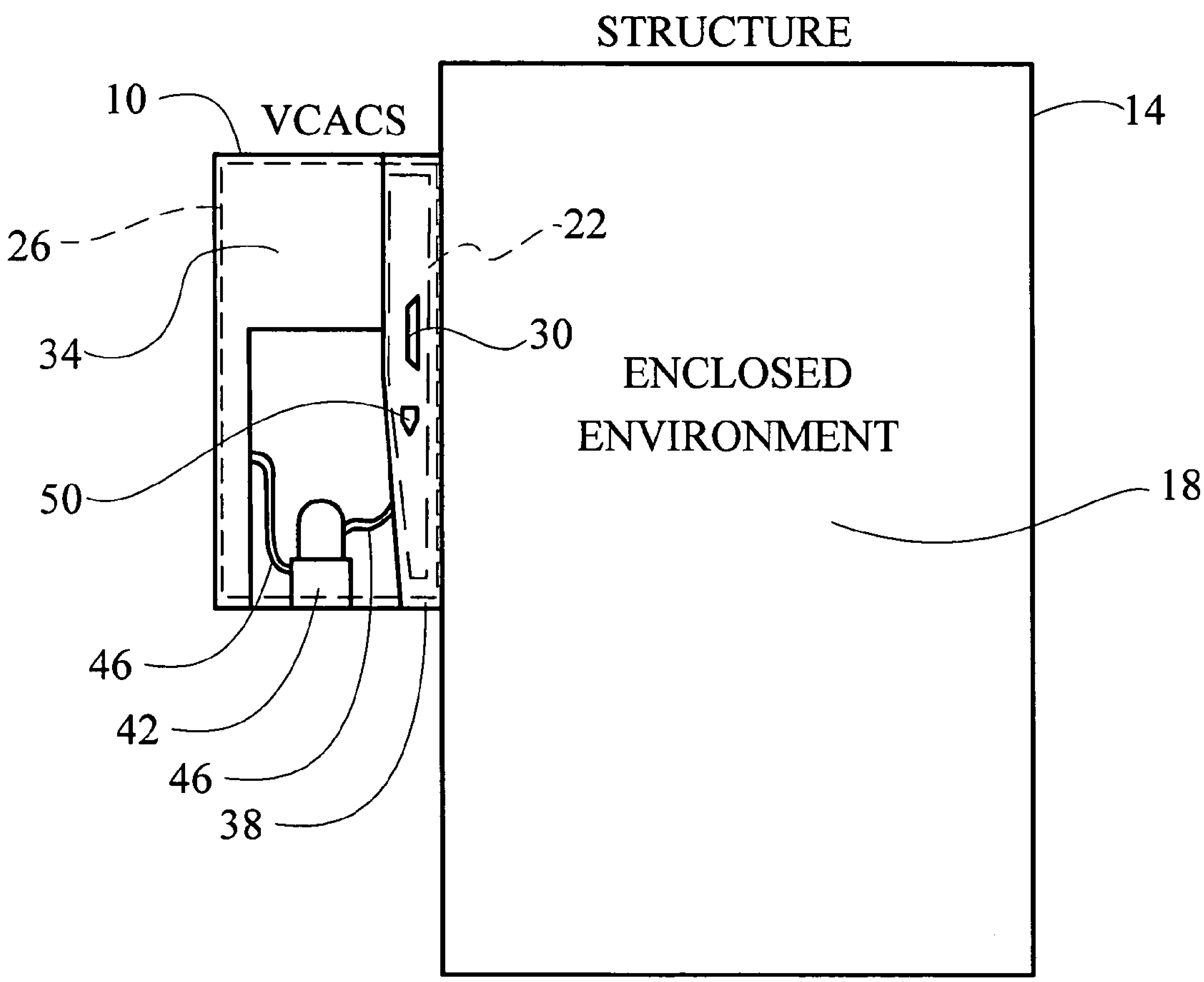

STRUCTURE
10
VCACS
14
26
22
34
30
ENCLOSED
ENVIRONMENT
50
18
46
42
46
38

Fig. 1

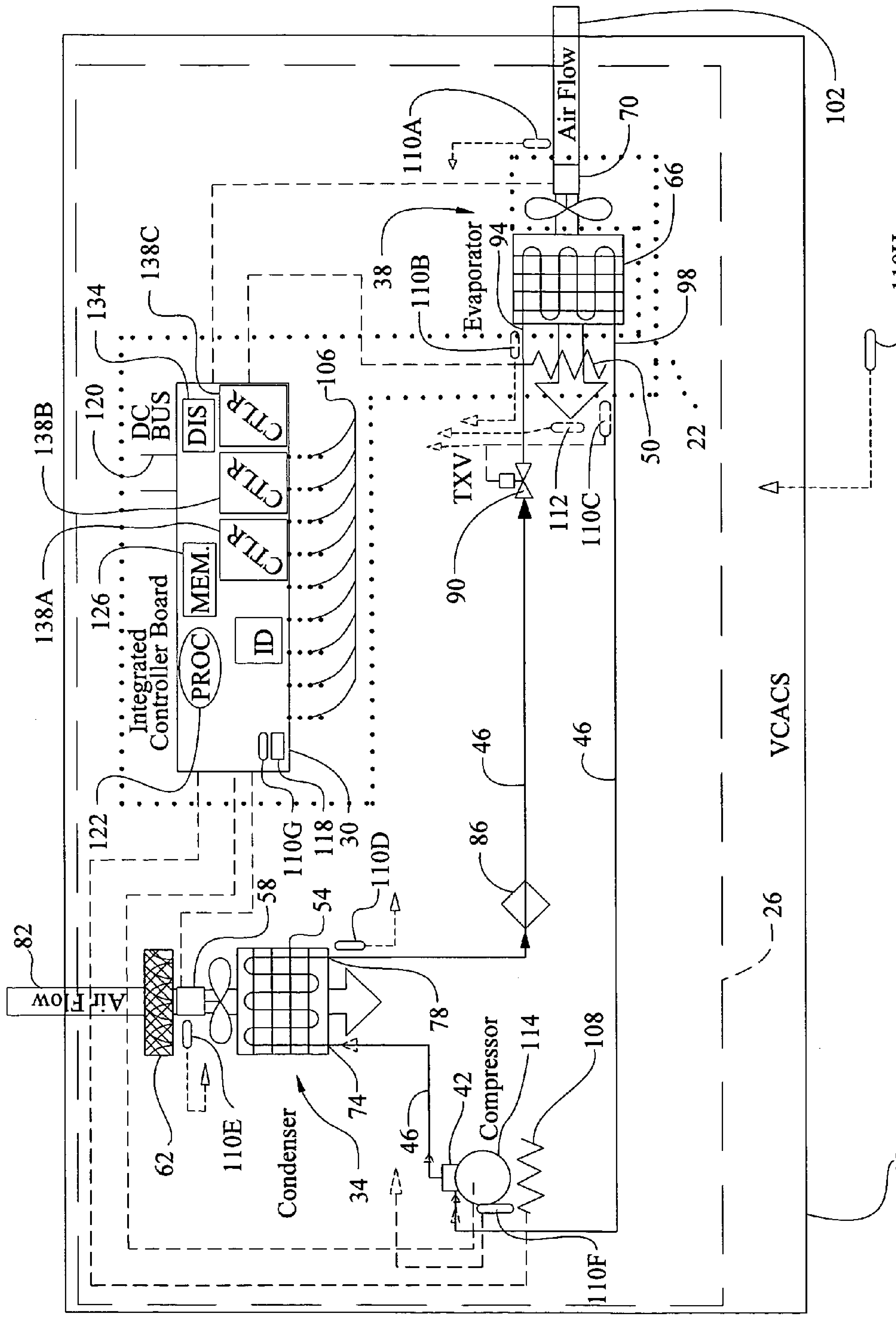
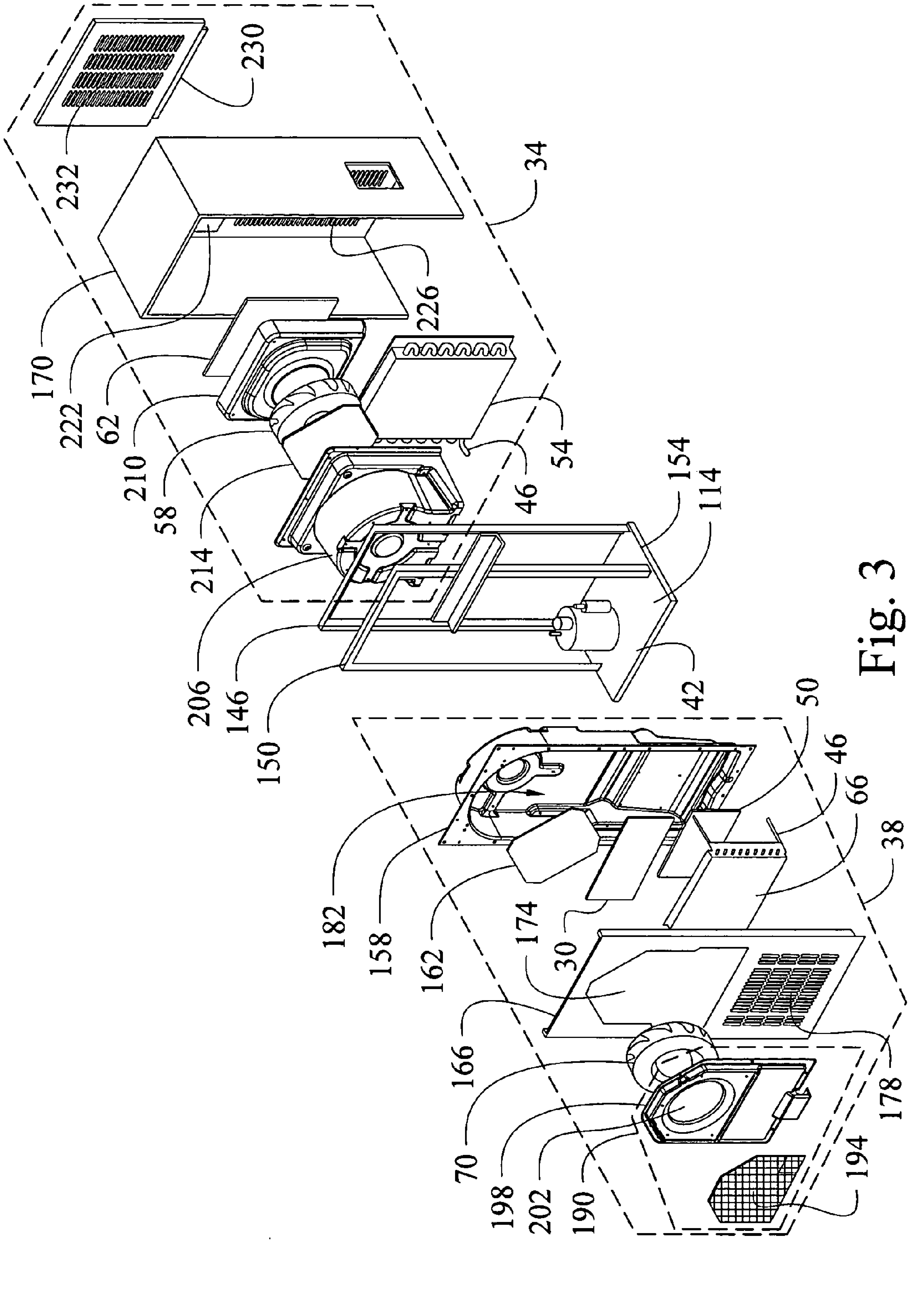

Air Flow
Evaporator
TXV
Integrated
Controller Board
PROC
MEM.
ID
CTLR
CTLR
CTLR
DIS
DC
BUS
Air Flow
Condenser
Compressor
VCACS
10
22
26
30
34
38
42
46
50
54
58
62
66
70
74
78
82
86
90
94
98
102
106
108
110A
110B
110C
110D
110E
110F
110G
110H
112
114
118
120
122
126
134
138A
138B
138C

Fig. 2


230
232
34
170
222
62
210
58
214
206
146
150
226
54
46
154
114
42
50
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66
38
182
158
162
174
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166
70
198
202
190
178
194

Fig. 3

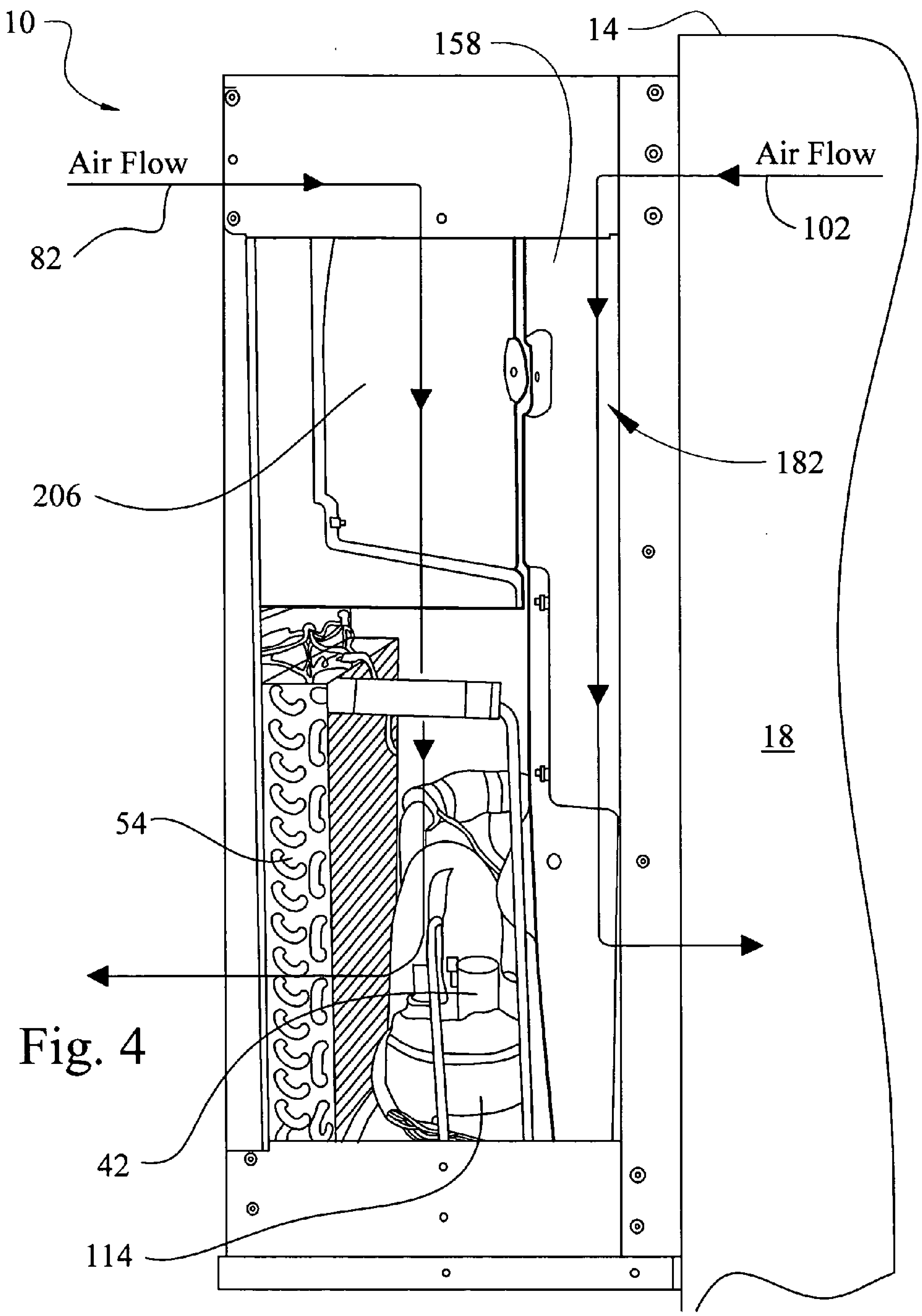

Fig. 4

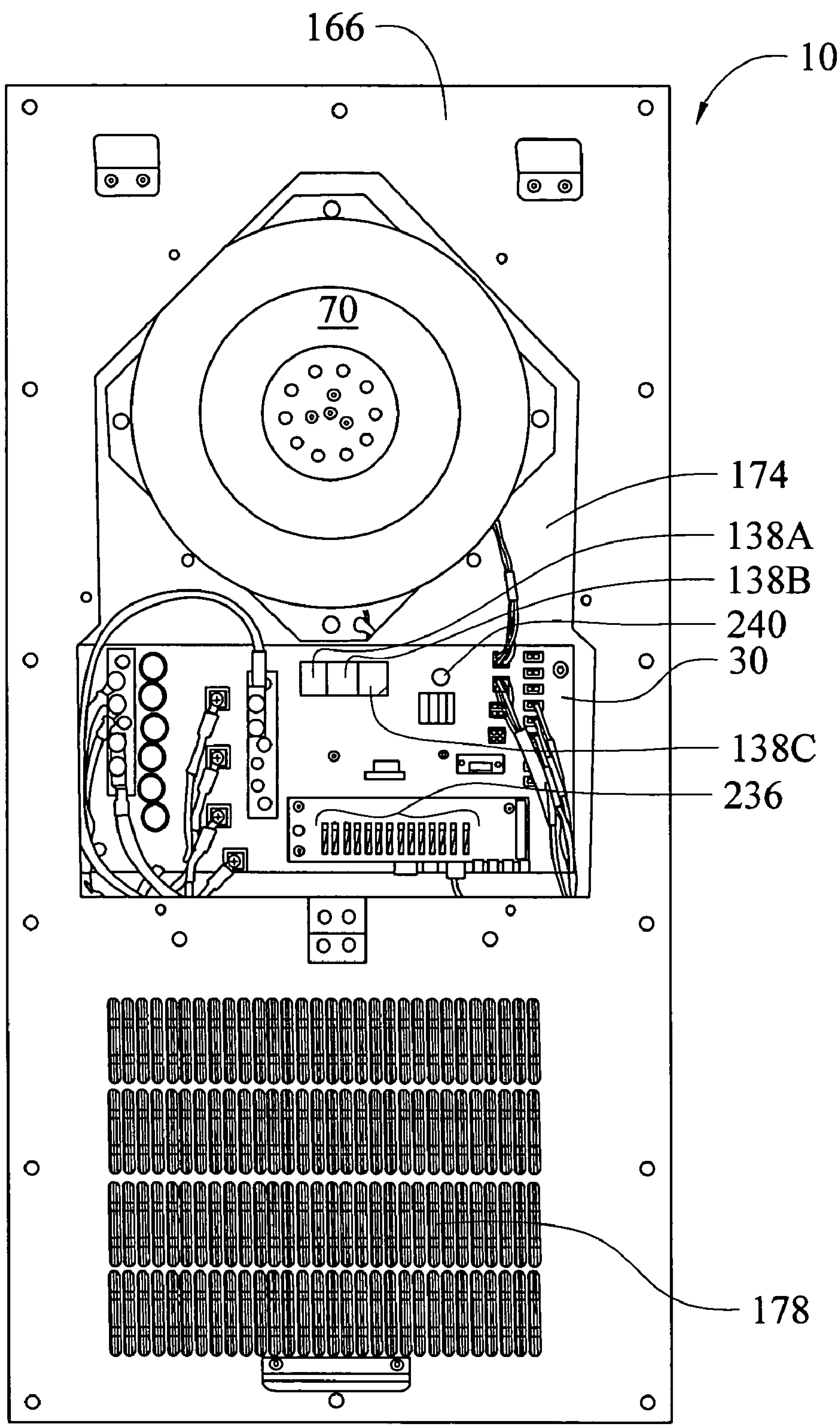

Fig. 5

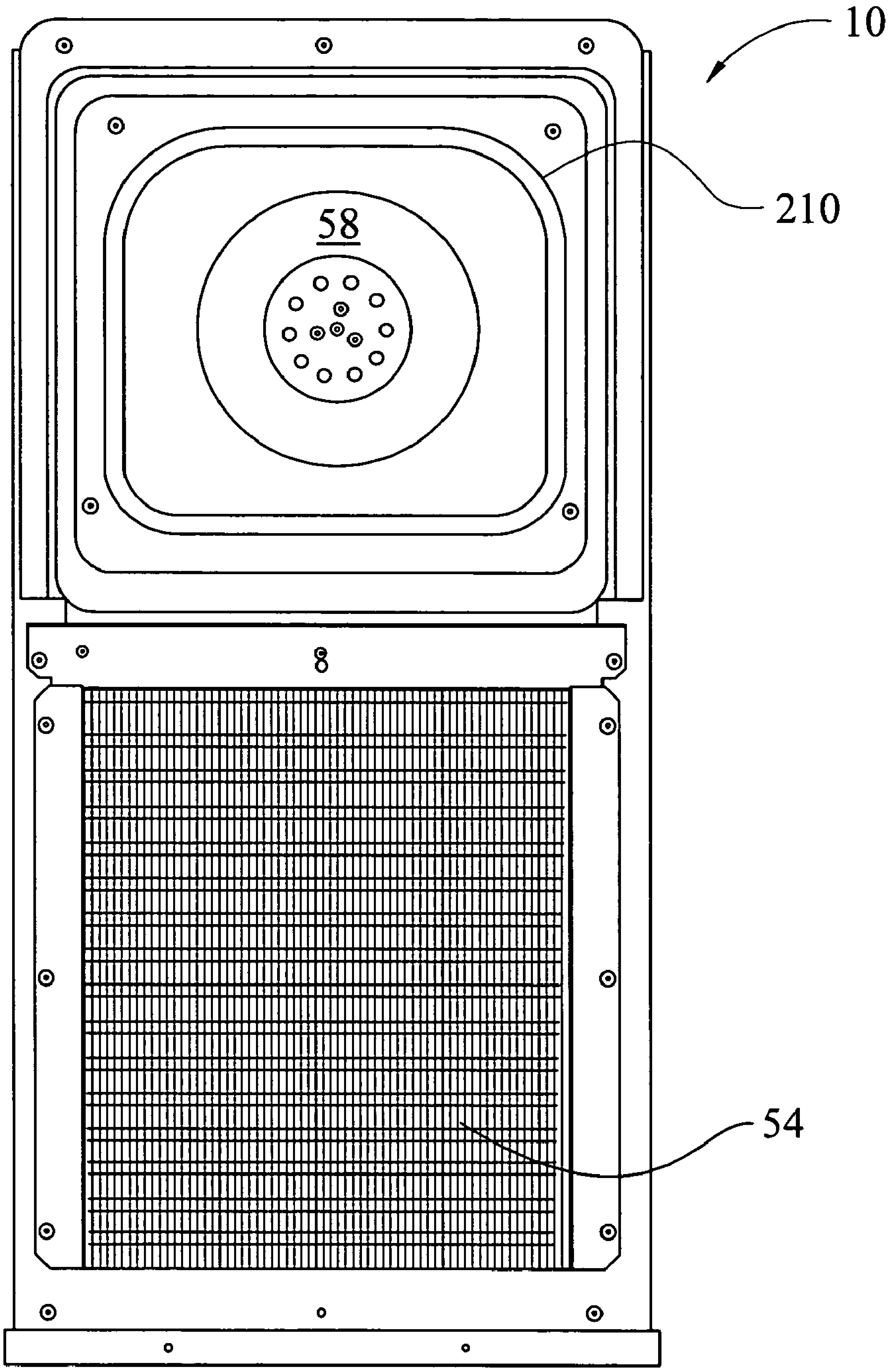

Fig. 6

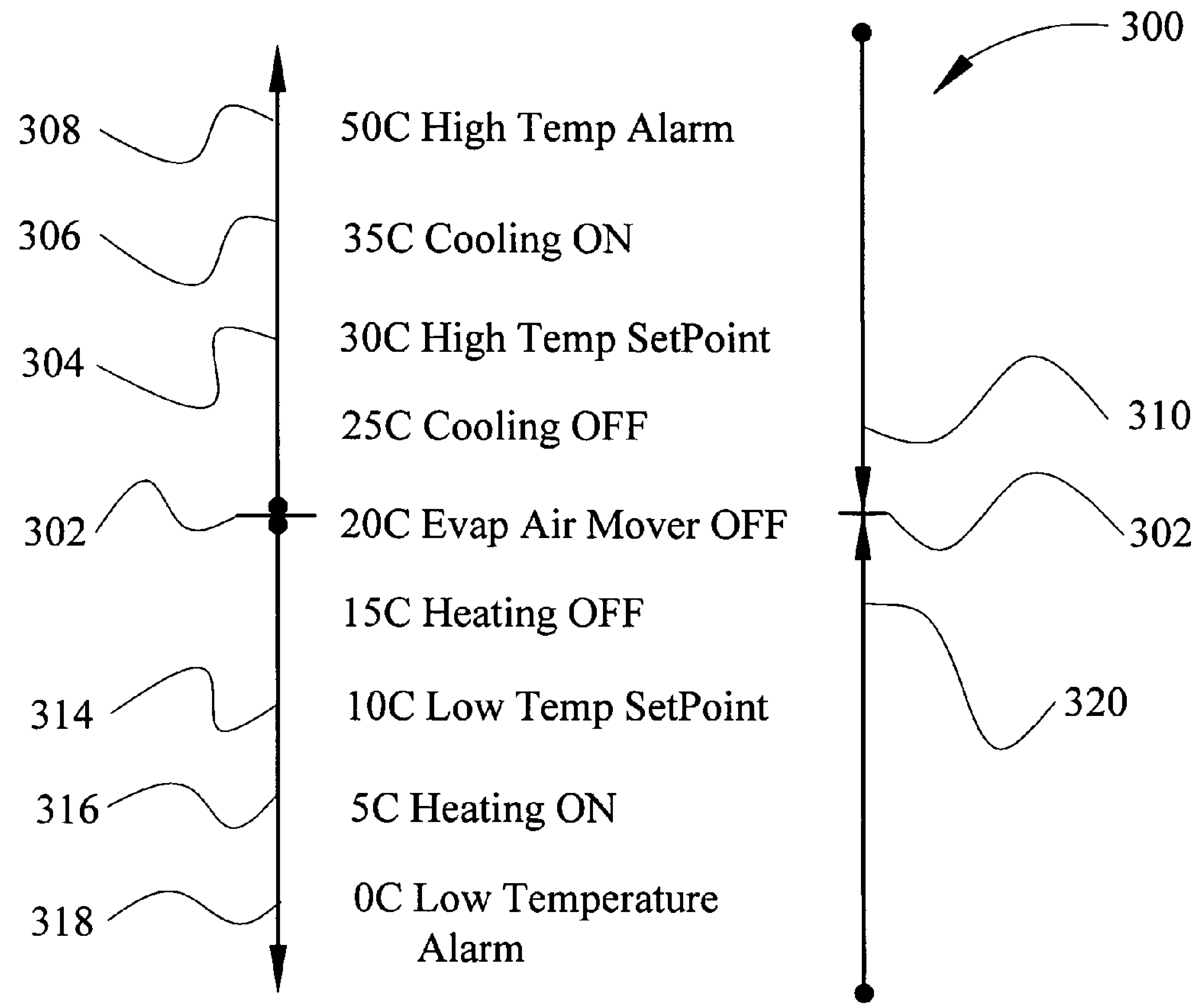
300
308
50C High Temp Alarm
306
35C Cooling ON
304
30C High Temp SetPoint
25C Cooling OFF
310
302
20C Evap Air Mover OFF
302
15C Heating OFF
314
10C Low Temp SetPoint
320
316
5C Heating ON
318
0C Low Temperature Alarm

Fig. 7

VARIABLE CAPACITY AIR CONDITIONING SYSTEM

GOVERNMENT RIGHTS

[0001] This invention was made with Government support under contract DE-FC26-04NT42106, awarded by the United States Department of Energy. The Government may have certain rights in this invention.

FIELD

[0002] The present disclosure relates generally to temperature control systems and methods. More particularly, the present disclosure relates to a variable capacity DC environmental temperature control system and method.

BACKGROUND

[0003] Direct current (DC) environmental temperature control systems (ETCSs), also referred to as air conditioning systems, are often used to control the temperature within enclosed environments where alternating current (AC) ETCSs are not feasible, desirable or reliable. For example, in environments enclosed by structures that are remotely located where AC power is not available or conveniently accessible, or where a backup air conditioning system is necessary in case AC power is interrupted, or where a DC air conditioning system is more desirable than an AC air conditioning system. Generally, DC air conditioning systems have a capacity suitable for efficiently controlling the temperature of environments enclosed by smaller structures or buildings. For example, DC air conditioning systems are very suitable for controlling the temperature within utility sheds, portable or mobile structures, and electronics cabinets and utility or equipment structures such as cellular wireless communication electronic cabinets and battery backup closets.

[0004] Such smaller structures can be located in a wide variety of outdoor locations that present a myriad of rigorous exterior environmental conditions that affect the temperature within the structures. That is, the structures can be exposed to a wide range of external temperatures, e.g., −30° C. to 55° C. (−22° F. to 131° F.), varying solar loads and various forms of precipitation that can all affect the internal environmental temperature. In the case of equipment cabinets, temperature control requirements can be stringent in order to prevent damage to the often expensive and not terribly rugged equipment inside. Thus, employment of DC air conditioning systems is often desirable for actively controlling the temperature enclosed environment of such smaller structures. And in many cases, efficiency, consistency and reliability are critical necessities of the DC air conditioning system.

[0005] In most instances, DC air conditioning systems are designed as typical expansion-compression heating and cooling systems that include a heating mechanism, a compressor, a condenser subsystem and an evaporator subsystem. Generally, operation of the heating mechanism is controlled by a heating mechanism controller, operation of the compressor is controlled by a compressor controller, operation of the condenser sub-system is controlled by a condenser controller and operation of the evaporator subsystem is controlled by an evaporator controller. Each of the controllers turns the respective components/subsystems 'On' or 'Off', based on a set point temperature signal received from a thermostat. Therefore, if the temperature of the enclosed environment rises a predetermined amount above the set point, the compressor controller, condenser subsystem controller and evaporator subsystem controller turn 'On' the respective components/subsystems.

[0006] When the temperature is brought within the set point range, the respective controllers turn the respective components/subsystems 'Off'. Similarly, if the temperature of the enclosed environment drops a predetermined amount below the set point, the heating mechanism controller will turn the heating mechanism 'On' until the temperature rises to be within the set point range, at which point the heating mechanism controller shuts the heating mechanism 'Off'. Additionally, when the respective controllers turn the respective components/subsystems 'On', the components/subsystems operate and full speed or full capacity. Likewise, when the respective controllers turn the respective components/subsystems 'Off', the components/subsystems do not operate. Accordingly, the DC air conditioning system enters a duty cycle turning the components/subsystems 'On' when the enclosed environment temperature is outside the set point range and 'Off' once the temperature is brought back within the set point range.

[0007] Thus, typical DC air conditioning systems include numerous separate, independent controllers, mounted at various locations within the DC air conditioning system, for controlling each of the components/subsystems and have a single capacity, whereby the components/subsystems are either 'On' or 'Off'.

BRIEF SUMMARY

[0008] In various embodiments, a direct current (DC) powered variable capacity air conditioning system is provided. The system includes a plurality of temperature sensors for monitoring the temperature of various components, locations and air flows within the system. The system additionally includes an integrated controller board that substantially simultaneously controls a variable speed DC compressor motor, a variable speed condenser air mover and a variable speed evaporator air mover in response to inputs from the sensors. By substantially simultaneously controlling the variable speed DC compressor motor, the variable speed condenser air mover and the variable speed evaporator air mover, the system substantially simultaneously controls at least one of a temperature and a volume of an evaporator output air flow. Thus, the system provides a continuum of evaporator output air flow temperatures and capacities for maintaining an approximately constant temperature within an enclosed environment.

[0009] Further areas of applicability of the present disclosure will become apparent from the detailed description provided hereinafter. It should be understood that the detailed description and specific examples, while indicating various preferred embodiments, are intended for purposes of illustration only and are not intended to limit the scope of the disclosure. Additionally, the features, functions, and advantages of the present disclosure can be achieved independently in various embodiments or may be combined in yet other embodiments.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] The present disclosure will become more fully understood from the detailed description and accompanying drawings, wherein;

[0011] FIG. **1** is a block diagram of a direct current (DC) powered variable capacity air conditioning system (VCACS) connected to a structure enclosing an environment to be thermally conditioned by the variable capacity air conditioning system, in accordance with various embodiments;

[0012] FIG. **2** is a schematic illustration of the VCACS shown FIG. **1**, in accordance with various embodiments;

[0013] FIG. **3** is an exploded isometric view of the VCACS illustrating various components of the VCACS, in accordance with various embodiments;

[0014] FIG. **4** is a side view of the VCACS shown in FIG. **1** with a side removed to illustrate components within the VCACS, in accordance with various embodiments;

[0015] FIG. **5** is a front view of the VCACS shown in FIG. **1** with an evaporator air mover cover removed, in accordance with various embodiments;

[0016] FIG. **6** is a rear view of the VCACS shown in FIG. **1** with a back removed to illustrate components of a condenser assembly, in accordance with various embodiments; and

[0017] FIG. **7** is a state diagram illustrating a temperature dependent operation of the VCACS shown in FIG. **1**, in accordance with various embodiments.

[0018] Corresponding reference numerals indicate corresponding parts throughout the several views of drawings.

DETAILED DESCRIPTION

[0019] The following descriptions of the preferred embodiments is merely exemplary in nature and is in no way intended to limit the present disclosure, its application or uses. Additionally, the advantages provided by the preferred embodiments, as described below, are exemplary in nature and not all preferred embodiments provide the same advantages or the same degree of advantages.

[0020] FIG. **1** illustrates a direct current (DC) powered variable capacity air conditioning system **10** connected to a wall of a structure **14** enclosing an environment **18** to be thermally conditioned by the variable capacity air conditioning system (VCACS) **10**. The DC VCACS **10** can operate any suitable power rating using any suitable DC power supply (not shown) such as one or more DC batteries or a converted alternating current (AC) supply. In various embodiments the DC VCACS **10** is configured to operate at a power rating of between approximately 1.25 kW and 2.25 kW, e.g., 1.75 kW.

[0021] The structure **14** can be any building, shed, cabinet, closet, portable or mobile structure, or any other structure enclosing an environment desirous of being thermally controlled by the DC variable capacity air conditioning system **10**. For example, the structure **14** can be an electronics and/or equipment cabinet, such as a cellular wireless communication electronics cabinet or battery backup closet, where it is important to maintain the enclosed environment **18** at a desired temperature to prevent damage to the enclosed components and/or systems. The VCACS **10** is configured to provide heating and cooling to maintain a substantially constant temperature of the enclosed environment **18** of the structure **14**. More particularly, in various embodiments, the VCACS **10** provides active variable heating and cooling capacity to the environment **18** enclosed by the structure **14**. As used herein, the phrase 'active variable heating and cooling capacity' means that the temperature of the enclosed temperature controlled environment **18** can be greater than or less than that of the surrounding exterior ambient conditions of the structure **14**. In various exemplary embodiments, the VCACS **10** and the structure **14** can comprise a telecommunication station, e.g., a wireless telecommunication station, wherein the structure **14** is a telecommunication electronics and equipment cabinet.

[0022] The VCACS **10** generally includes a heating subsystem, generally indicated at **22**, a cooling subsystem, generally indicated at **26**, and an integrated controller board **30** that controls the functionality and operation of the heating and cooling subsystems **22** and **26**. The cooling subsystem **26** generally comprises a condenser assembly **34**, an evaporator assembly **38** and a DC variable speed compressor **42** connected to the condenser and evaporator assemblies **34** and **38** via refrigerant lines **46**. As described herein, a system refrigerant flows through the refrigerant lines **46** during operation of the cooling subsystem **26**, changing between various gaseous and liquid states. The heating subsystem **22** generally comprises at least one heating mechanism **50** and various components of the evaporator assembly **38**, as described below. The heating mechanism(s) **50** can be any suitable heat producing mechanism such as an open wire resistive heater, a ceramic resistive heater, radiator type heater, a chemical reaction type heater, or any other heating device, assembly or system. In various embodiments, the heating mechanism(s) **50** is/are variable output positive temperature coefficient heater(s) controlled by the integrated controller board **30** substantially simultaneously with the variable speed evaporator air mover **70**. Particularly, the integrated controller board **30** can vary the heat capacity of the heaters to match the needed load.

[0023] Referring now to FIG. **2**, the condenser assembly **34** generally includes a condenser heat exchanger **54**, a variable speed condenser air mover **58** and a condenser air filter **62**. The evaporator assembly **38** generally includes an evaporator heat exchanger **66** and a variable speed evaporator air mover **70**. The condenser heat exchanger **54** is connected in-line with the refrigerant lines **46** between the compressor **42** and the evaporator heat exchanger **66**. More particularly, the condenser heat exchanger **54** is connected at a condenser refrigerant inlet **74** to a portion of the refrigerant lines **46** from the compressor **42** and at a condenser refrigerant outlet **78** to a portion of the refrigerant lines **46** leading to the evaporator heat exchanger **66**. High pressure superheated refrigerant vapor enters the condenser heat exchanger **54** at the condenser refrigerant inlet **74** and flows through the condenser heat exchanger **54**. As the superheated refrigerant vapor flows through the condenser heat exchanger **54**, it is cooled and converted to a subcooled liquid by a condenser air flow **82** across or through the condenser heat exchanger **54**, as controlled by the integrated controller board **30**, as described below. The condenser air flow **82** comprises air entering the VCACS **10** from the exterior ambient environment of the VCACS **10** and the structure **14**. The high pressure converted liquid refrigerant then exits the condenser heat exchanger **54** at the condenser refrigerant outlet **78**.

[0024] The high pressure liquid refrigerant flows through a standard filter/drier **86** and enters a thermally controlled expansion valve (TXV) **90**. The TXV **90** controls the flow of refrigerant therethrough such that the high pressure liquid refrigerant is converted to a low pressure saturated liquid-gas having a temperature significantly lower than the high pressure liquid refrigerant exiting the condenser refrigerant outlet **78**. In various embodiments, the TXV **90** is a conventional type TXV that is independently controlled. In various other embodiments, the TXV **90** is a stepper-motor style electronically variable expansion valve controlled by the integrated controller board **30** based on a sensed temperature of the refrigerant exiting the evaporator heat exchanger **66** and the sensed temperature of the refrigerant entering the evaporator heat exchanger **66**.

[0025] The evaporator heat exchanger **66** is connected in-line with the refrigerant lines **46** between the TXV **90** and the compressor **42**. More particularly, the evaporator heat exchanger **66** is connected at an evaporator refrigerant inlet **94** to a portion of the refrigerant line **46** from the TXV **90** and at an evaporator refrigerant outlet **98** to a portion of the refrigerant line **46** leading to the compressor **42**. The low pressure refrigerant saturated liquid vapor mixture enters the evaporator heat exchanger **66** at the evaporator refrigerant inlet **94** and flows through the evaporator heat exchanger **66**. As the refrigerant vapor flows through the evaporator heat exchanger **66**, it absorbs heat from an evaporator air flow **102** across or through the evaporator heat exchanger **66** as controlled by the integrated controller board **30**, as described below, and is converted to a low pressure superheated gaseous state. The evaporator air flow **102** comprises air entering the VCACS **10** from the enclosed temperature controlled environment **18**, as described further below. The low pressure superheated gaseous refrigerant exits the evaporator heat exchanger **66** at the evaporator refrigerant outlet **78** and flows to the compressor **42**. The compressor **42** then compresses the low pressure superheated gaseous refrigerant to the high pressure superheated gaseous refrigerant input to the condenser heat exchanger **54**, and the cycle described above is repeated.

[0026] The condenser air mover **58** can be any air mover suitable for moving varying capacities of air, as controlled by the integrated controller board **30**, from the exterior ambient environment, through the condenser assembly **34** and back into the exterior ambient environment. For example, the condenser air mover **58** can be a radial fan, an axial fan or a turbine. In various embodiments, the condenser air mover **58** is a variable speed backward-curved impeller. Similarly, the evaporator air mover **70** can be any air mover suitable for moving varying capacities of air, as controlled by the integrated controller board **30**, from the enclosed environment **18**, through the evaporator assembly **38** and back into the enclosed environment **18**. For example, the evaporator air mover **70** can be a radial fan, an axial fan or a turbine. In various embodiments, the evaporator air mover **70** is a variable speed backward-curved impeller. The condenser air filter **62** can be any air filter suitable for effectively preventing particulate matter such as airborne dust, dirt, leaves, grass, weeds, insects, etc. from infiltrating the condenser assembly **34**.

[0027] As illustrated in FIG. **2**, and described in further detail below, the integrated controller board **30** receives inputs **106** from a plurality of temperature sensors **110** located within the VCACS **10** and the structure **18**. Additionally, in various embodiments, the integrated controller board **30** receives at least one input **106** from at least one relative humidity sensor **112** located within the air flow **102** output by the evaporator assembly **38** for sensing a humidity level of the air flow **102** output to enclosed environment **18**. During a cooling mode of operation of the VCACS **10**, in which the VCACS **10** cools the enclosed environment **18**, the integrated controller board **30** utilizes the inputs **106** from the sensors **110** and **112** to substantially simultaneously control the variable speed condenser air mover **58**, the variable speed evaporator air mover **70**, the variable speed compressor **42** and a compressor heater **108**. Similarly, during a heating mode of operation, in which the VCACS **10** heats the enclosed environment, the integrated controller board **30** utilizes the inputs **106** from the sensors **110** and **112** to substantially simultaneously control the variable speed evaporator air mover **70** and the heating mechanism(s) **50**.

[0028] In various embodiments, the sensors **110** include an evaporator air intake sensor **110**A, an evaporator refrigerant inlet sensor **110**B, an evaporator refrigerant outlet sensor **110**C, a condenser refrigerant outlet sensor **110**D, a condenser air intake sensor **110**E, a compressor housing temperature sensor **110**F, a heat sink temperature sensor **110**G, and at least one remote temperature sensor **110**H. For simplicity and clarity of FIG. **2**, the sensors **110** and **112** are not shown directly connected to the integrated controller board inputs **106**. However, it should be understood that the various temperature signals generated by the various sensors **110** are received by the integrated controller board **30** at the inputs **106**.

[0029] The evaporator air intake sensor **110**A senses the temperature of evaporator air flow **102** taken into the evaporator assembly **38** from the enclosed environment **18**. In various embodiments, the evaporator air intake sensor **110**A is the main sensor **110** used by the integrated controller board **30** for determining the temperature within the enclosed environment **18**. Furthermore, it is the sensed temperature of the enclosed environment **18** that the integrated controller board **30** utilizes to substantially simultaneously control operation of the cooling subsystem **26** components and the heating subsystem **22** components to actively maintain approximately a desired temperature of the enclosed environment **18**. The evaporator refrigerant inlet sensor **110**B senses the temperature of the system refrigerant at the evaporator refrigerant inlet **94** and the evaporator refrigerant outlet sensor **110**C senses the temperature of the system refrigerant at the evaporator refrigerant outlet **98**. The condenser refrigerant outlet sensor **110**D senses the temperature of the system refrigerant at condenser outlet **78**. The condenser air intake sensor **110**E senses the temperature of condenser air flow **82** taken into the condenser assembly **34** from the exterior ambient environment. The compressor housing temperature sensor **110**F senses the temperature of a variable speed DC compressor motor **114** controlled by the integrated controller board **30** to control operation of the compressor **42**. The variable speed DC compressor motor **114** operates using power from the DC power supply and can drive the compressor **42** at significantly varying rates to displace varying rates of the system refrigerant at varying rates of compression.

[0030] In various embodiments, the compressor motor **114** is a brushless sensorless permanent magnet DC motor and the compressor **42** is a scroll compressor in a hermitically sealed enclosure. However, the compressor motor **114** and compressor **42** can be any motor/compressor combination suitable for increasing the system refrigerant pressure within the refrigerant lines **46** in accordance with commands from the integrated controller board **30**. The heat sink temperature sensor **110**G senses the temperature of a heat sink **118** of the integrated controller board **30**. And, the remote temperature sensor(s) **110**H sense(s) the temperature within the enclosed environment at one or more locations other than at the point the evaporator air flow **102** is taken into the evaporator assembly **38** from the enclosed environment, as sensed by intake sensor **110**A. In various embodiments, the remote sensor(s) **110**H are used to input the sensed temperature within the enclosed environment **18** that the integrated controller board **30** utilizes to substantially simultaneously control operation of the cooling subsystem **26** components and the heating subsystem **22** components to actively maintain approximately a desired temperature of the enclosed environment. In various other embodiments, the integrated controller board **30** utilizes a combination of inputs from the evaporator air intake sensor **110**A and the remote sensor(s) **110**H to substantially simultaneously control operation of the cooling subsystem **26** components and the heating subsystem **22** components to actively maintain approximately a desired temperature of the enclosed environment.

[**0031**] Still referring to FIG. **2**, in various embodiments, the integrated controller board **30** includes a DC power supply bus **120**, a processor **122**, e.g., a microprocessor, and at least one electronic storage device **126**. The processor **122** can be any processor suitable to execute all functions of integrated controller board **30**. The electronic storage device(s) **126** can be any computer readable medium suitable for electronically storing such things as data, information, algorithms and/or software programs executable by the processor **122**. For example, in various embodiments, the electronic storage device(s) **126** can be memory device(s) such a hard drive, EEPROM, Flash Memory, OTP memory or any other electronic data storage device or medium. In various other embodiments, the electronic storage device(s) **126** can be remotely located from the controller board **30**. Furthermore, in various embodiments the electronic storage device(s) **126** can be removably connectable to the integrated controller board **30**. For example, the electronic storage device(s) **126** can be a USB hard drive, a Zip drive disk, a CDRW drive disk, a DVDR drive disk, a thumb drive or any other removable electronic storage device.

[**0032**] Further yet, in various embodiments, the integrated controller board **30** includes an input device **130**, such as a keypad, a mouse, a stylus or a joy stick for inputting data and information to the integrated controller board to be stored on the electronic memory device **126**. Still further yet, in various embodiments, the integrated controller board **30** includes a display **134** for illustrating graphical and/or textual/numeric data and various other forms of information. Still even further yet, in various embodiments, the integrated controller board **30** can be wired or wirelessly connected or connectable to a remote computer based system. For example, the integrated controller board **30** can be wired or wirelessly connected or connectable to a remotely located server system (not shown), such that data, information, algorithms, VCACS **10** operational commands, software programs, or any other data can be communicated to and/or from the integrated controller board **30**.

[**0033**] To substantially simultaneously control the operation of the components of the cooling subsystem **26** during the cooling mode and substantially simultaneously control operation of the components of the heating subsystem **22** during the heating mode, the integrated controller board **30** further includes a plurality of VCACS component controllers **138**. For example, in various embodiments, the integrated controller board **30** includes a condenser air mover controller **138**A for controlling operation of the condenser air mover **58**, an evaporator air mover controller **138**B for controlling the operation of the evaporator air mover **70** and a variable speed compressor motor controller **138**C for controlling operation of the variable speed compressor motor **114**. Each of the various controllers **138** are mounted on the integrated controller board **30** and can be substantially simultaneously controlled by the processor **122**. More particularly, the processor **122** executes one or more control software programs and/or algorithms to substantially simultaneously control operation of the various controllers **138** to operate the VCACS **10** in the cooling mode and the heating mode. For example, the processor **122** receives the inputs from the temperature sensor **110** and the relative humidity sensor(s) **112**, then executes one or more control algorithms to substantially simultaneously control operation of the variable speed condenser air mover controller **138**A, the variable speed evaporator air mover controller **138**B and the variable speed DC compressor motor controller **138**C, based on the inputs.

[**0034**] Accordingly, the speed at which the condenser air mover **58**, the evaporator air mover **70** and the compressor motor **114** operate are substantially simultaneously controlled by the processor **122**, based on the various inputs **106**, to dynamically control the output capacity of the VCACS **10**. That is, the temperature and/or volume of the evaporator air flow **102** output by the VCACS **10**, are substantially simultaneously dynamically controlled by the processor **122** substantially simultaneously controlling the speed at which the condenser air mover **58**, the evaporator air mover **70** and the compressor motor **114** operate, based on the various inputs **106**. Thus, a capacity and temperature continuum of evaporator assembly **38** output air flow **102** is provided for maintaining an approximately constant temperature within the enclosed environment **18**. More particularly, the execution of one or more control algorithms seamlessly transitions operation of the VCACS **10** from the cooling mode to the heating mode, if the temperature within the enclosed environment **18** falls below a desired cooling set point, as described below. Similarly, the execution of the single control algorithm can seamlessly transition operation of the VCACS **10** from the heating mode to the cooling mode, if the temperature within the enclosed environment **18** rises above a desired heating set point, as described below.

[**0035**] In various embodiments, the processor **122** executes a single control algorithm to substantially simultaneously control operation of the various controllers **138** to operate the VCACS **10** in the cooling and heating modes based on the inputs from the sensors **110** and **112**.

[**0036**] Referring now to FIGS. **3**, **4**, **5** and **6**, in various embodiments, the VCACS **10** is constructed about a main skeletal support structure **142**. The skeletal support structure **142** generally includes a condenser assembly support frame **146** and an evaporator assembly support frame **150** mounted to, e.g., welded, bolted, or integrally formed with, a base plate **154**. The condenser and evaporator assemblies **34** and **38** are mounted to the respective condenser and evaporator assembly supports **146** and **150**. The variable speed compressor **42**, including the variable speed motor **114**, is mounted to the base plate **154** between the condenser and evaporator assemblies **34** and **38**. The evaporator assembly **38** includes an evaporator shroud **158** coupled to the evaporator assembly support frame **150**. In various embodiments, the evaporator shroud **158** is formed or fabricated as a single piece, seamless structure. For example, the evaporator shroud **158** can be molded, cast, stamped or pressed to form a three-dimensional monolithic structure without folded or bent edges, joint seams or cracks that require sealing with a sealant, e.g., an RTV sealant. The evaporator shroud **158** can be fabricated from any suitable material such as any suitable plastic polymer or composite, any suitable reinforced polyurethane or epoxy resin or any other material suitable for fabricating a three-dimensional monolithic evaporator shroud **158**. Additionally, the evaporator shroud **158** effectively forms a walled enclosure within the VCACS **10** enclosing the remaining evaporator assembly components therewithin and separating the evaporator assembly **38** from the condenser assembly **34**.

[0037] The evaporator heat exchanger **66** and heating mechanism **50** are mounted within a lower portion of the evaporator shroud **158**. The evaporator air mover **70** is mounted within an upper portion of the evaporator shroud **158** and the integrated controller board is mounted within a center portion of the evaporator shroud **158**. In various embodiments, the evaporator air mover **70** is rotationally mounted to an evaporator air mover mounting plate **162** that is mounted to the evaporator shroud **158**. A housing panel **166** is mounted over the evaporator air mover **70**, evaporator heat exchanger **66**, heating mechanism **50** and integrated controller board **30** and coupled to the evaporator shroud **158** and/or a housing hood **170**. The housing panel includes an evaporator air intake opening **174** and a plurality of grated or finned apertures that generally form an evaporator air output opening **178**. The combination of the housing panel **166** mounted over the evaporator shroud **158** form an evaporator air passage **182**, best illustrated in FIG. **4**. Thus, the integrated controller board **30** is mounted within the evaporator air passage **182** such that the evaporator air flow **102** assists in cooling components on the integrated controller board **30**, e.g., power electronics that drive the compressor motor **114**.

[0038] An evaporator air intake cover assembly **190** is mounted to the housing panel **166** over the evaporator air intake opening **174**. In various embodiments, the evaporator air intake cover assembly **190** includes a screen **194** mounted to an evaporator air mover cover **198** over an air mover cover aperture **198**. The screen **194** and aperture **198** allow the air flow **102** from the enclosed environment **18** to be taken or drawn into the evaporator air passage **182** by the evaporator air mover **70**, as described above. When the evaporator air mover **70** is operating, e.g., in the heating mode, the cooling mode and an idle mode, the evaporator air flow **102** is drawn into the evaporator air passage **182** from the enclosed environment **18**, via the evaporator air mover cover aperture **202** and the evaporator air intake opening **174**. As the evaporator air flow **102** flows through the evaporator air passage **182**, the evaporator air flow **102** can be conditioned, i.e., heated or cooled as described herein, and output back into the enclosed environment **18**, via the evaporator air output opening **178**. When the VCACS **10** is operating in the idle mode, the evaporator air flow **102** is circulated through the evaporator air passage **182**, as described above, but is not heated or cooled. Thus, the air within the enclosed environment **18** is circulated but not temperature conditioned by the VCACS **10**.

[0039] The condenser assembly **34** includes a condenser shroud **206** coupled to the condenser assembly support frame **146**. In various embodiments, the condenser shroud **206** is formed or fabricated as a single piece, seamless structure. For example, the condenser shroud **206** can be molded, cast, stamped or pressed to form a three-dimensional monolithic structure without folded edges or joint seams. The condenser shroud **206** can be fabricated from any suitable material such as any suitable plastic polymer or composite, any suitable reinforced polyurethane or epoxy resin or any other material suitable for fabricating a three-dimensional monolithic condenser shroud **206**. The condenser air mover **58** is mounted within the condenser shroud **206** and a condenser shroud cover **210** is mounted to the condenser shroud **206** over the condenser air mover **58**. In various embodiments, the condenser air mover **58** is rotationally mounted to a condenser air mover mounting plate **214** that is mounted to the condenser shroud **206**. The condenser heat exchanger **54** is mounted to the condenser assembly support frame **146** below the condenser shroud **206**. The air intake filter **62** is positioned over, or within, the condenser shroud cover **210** for filtering particulates from the condenser intake air flow **82**.

[0040] The housing hood **170** is mounted over the condenser shroud **206**, the condenser air mover, shroud cover and filter **58**, **210** and **62**, and the condenser heat exchanger **54**, and coupled to the housing panel **166**. It should be understood that although the housing hood **170** is referred to herein as a single structure, the housing hood **170** can be constructed of one or more panels, e.g., side panels, top panel and/or front panel. The housing hood **170** includes a condenser air intake opening **222** and a plurality of grated or finned apertures that generally form a condenser air output opening **226**. A condenser air intake cover **230**, including a plurality of grated or finned apertures that generally form an air intake cover opening **232**, is mounted to the housing hood **170** to cover the condenser air intake opening **222**. When the condenser air mover **58** is operating, e.g., in the heating and cooling modes, the condenser air flow **82** is drawn into the condenser shroud **206** from the exterior ambient environment. The condenser shroud is fabricated to have an open bottom such that the condenser air flow **82** drawn in is circulated through the condenser shroud **206** and down through the VCACS **10** behind the evaporator shroud **158**. The condenser air flow **82** then flows through the condenser heat exchanger **54** and is output back into the exterior ambient environment, via the condenser air output opening **226**. Accordingly, the condenser air flow **82** is circulated through the VCACS **10** and around, or across, the variable speed compressor motor and compressor **114** and **42**, thereby cooling the variable speed compressor motor and compressor **114** and **42**.

[0041] Referring again to FIG. **2**, in the event that the VCACS **10** has been non-operational, i.e., newly installed and not yet turned on, the internal temperature of the enclosed environment **18** can be considerably hotter than the temperature of the external ambient environment. In this scenario, extreme pressures can build within the refrigerant lines **46**, the condenser and evaporator heat exchangers **54** and **66**, and the compressor **42** due to the superheat phases of the refrigerant becoming excessive as the condenser heat exchanger **54** is unable to reject heat to the outdoor ambient as quickly as the evaporator heat exchanger **66** is able to absorb heat from the enclosed environment **18**. To avoid damaging the VCACS **10**, in various embodiments, the processor **122** executes a start-up algorithm, or a start-up subroutine of the control algorithm. The start-up algorithm or subroutine interprets the various inputs **106** from the sensors **110** and **112** and, if necessary, reduces the speed of the evaporator air mover **70** so that less heat is removed from evaporator air flow **102**. This allows the condenser assembly **34** to 'catch up', i.e., the evaporator heat exchanger **66** absorbs less heat while the condenser heat exchanger **54** rejects heat at a maximum capacity, until the superheat phases of the refrigerant are maintained at a desirable level.

[0042] As described above, the air temperature within the enclosed environment **18** is the primary input utilized by the controller board **30** to control the VCACS **10**, that is, to dynamically control the temperature and/or volume of the evaporator air flow **102** output to the enclosed environment **18**. In various exemplary embodiments, the one or more control algorithms executed by the processor **122** utilizes the input **106** from the evaporator air inlet sensor **110**A and/or the input **106** from the remote sensor(s) **110**H to determine the temperature within the enclosed environment **18**. Based on the input(s) **106** from the evaporator air inlet sensor **110**A and/or the remote sensor(s) **110**H, the integrated controller board **30** determines the VCACS **10** should be in the heating mode, cooling mode or idle mode. If the integrated controller board **30** determines the heating mode is required, the integrated controller board **30** turns 'On' the heating mechanism(s) **50** and evaporator air mover **70**. The heat level of the heating mechanism(s) **50** and the speed of the evaporator air mover **70** are then substantially simultaneously controlled by the integrated controller board **30** to dynamically vary the temperature and/or volume of the evaporator air flow **102** output to the enclosed environment **18**.

[0043] If the integrated controller board **30** determines the cooling mode is required, the integrated controller board **30** turns on the compressor motor **114**, the condenser air mover **58** and the evaporator air mover **70**. The integrated controller board **30** then substantially simultaneously controls the speed of the compressor motor **114**, the speed of the condenser air mover **58** and the speed of the evaporator air mover **70** to dynamically vary the temperature and/or volume of the evaporator air flow **102** output to the enclosed environment **18**. If the integrated controller board **30** determines the idle mode is required, the integrated controller board turns 'Off' the heating mechanism(s) **50** or the compressor motor **114** and condenser air mover **58**. Additionally, in the idle mode the integrated controller board **30** either turns the evaporator air mover **70**'off' also, or leaves the evaporator air mover **70** running. If the evaporator air mover **70** remains running, the integrated controller board **30** controls the speed to dynamically vary the volume of the evaporator air flow **102** output to the enclosed environment **18**. Varying temperature and/or volume of the continuum of evaporator air flow **102** output to the enclosed environment **18**, as the VCACS **10** seamlessly transitions between the heating, cooling and idle modes, maintains the enclosed environment **18** at approximately the desired temperature.

[0044] Although the various embodiments are described herein in terms of the integrated controller board **30** having a direct affect on, or direct control of, the VCACS **10**, it should be understood that it is the instructions generated by the execution of the one or more algorithms, via the processor **122** and the subsequent implementation of those instructions by the integrated controller board that have direct effect on, or control of, the VCACS **10**.

[0045] Referring now to FIG. **7**, a state diagram **300** illustrates a temperature dependent operation of the VCACS **10**, in accordance with various embodiments. As described above, upon turning 'On' the VCACS **10** from a non-operational state, the evaporator air mover **70** is turned 'On', and the processor **122** executes the start-up algorithm, or a start-up subroutine of the control algorithm. The start-up algorithm or subroutine interprets the various inputs **106** from the sensors **110** and **112** and, if necessary, adjusts the speed of the evaporator air mover **70** until the condenser assembly **34**'catches up', i.e., the evaporator heat exchanger **66** absorbs less heat while the condenser heat exchanger **54** rejects heat at a maximum capacity, until the superheat phases of the refrigerant are maintained at a desirable level. The exemplary description of the operation of the VCACS **10**, with respect to state diagram **300**, will begin after start-up has been completed and the desired temperature of the enclosed environment has been achieved, as described below. Additionally, for exemplary purposes, the desired temperature of the enclosed environment **18**, with respect to state diagram **300**, is 20° C. (68° F.). However, it should be understood that the desired temperature of the enclosed environment **18** can be set to any desired temperature, via programming of the control algorithm. Furthermore, the various milestone and set point temperatures shown in the state diagram **300** are merely exemplary and can be set to any desired temperature, via programming of the control algorithm.

[0046] Once the desired set point temperature of the enclosed environment **18**, e.g., 20° C. (68° F.), is achieved, the integrated controller board **30**, i.e., execution of the control algorithm, turns the compressor motor **114**, the heating device(s) **50** and the condenser and evaporator air movers **58** and **70**'Off', as illustrated at state **302**. As described above, the temperature of the enclosed environment **18** is monitored using inputs **106** from the evaporator air intake sensor **110**A and/or the remote temperature sensor(s) **110**H. As the temperature of the enclosed environment **18** increases above the desired set point, the integrated controller board **30** turns the evaporator air mover **70** on and begins to 'ramp up' the speed of the evaporator air mover **70** until the temperature of the enclosed environment **18** reaches a high temperature set point, e.g., 30° C. (86° F.), as indicated at state **304**. In various embodiments, at the high temperature set point, the evaporator air mover **70** is 'Full On'. Hysteresis is built into the control algorithm to prevent over-cycling of the VCACS **10**. Therefore, the integrated controller board **30** allows the temperature of the enclosed environment **18** to rise a predetermined amount, e.g., 5° C. (41° F.), above the high temperature set point before activating the cooling mode of operation, as indicated at state **306**.

[0047] Once in the cooling mode, the integrated controller board **30** substantially simultaneously controls the compressor motor **114** and the condenser and evaporator air movers **58** and **70**, as described above, to dynamically vary the temperature and/or volume of the evaporator output air flow **102**. If an error in the operation of the VCACS **10**, and/or the VCACS fails to adequately cool the enclosed environment **18**, the integrated controller board **30** activates a high temperature alarm at a predetermined temperature, e.g., 50° C. (122° F.), as indicated at state **308**. When cooling properly in the cooling mode, hysteresis allows the VCACS **10** to cool the enclosed environment **18** a predetermined amount, e.g., 5° C. (41° F.), below the high temperature set point before deactivating the cooling mode of operation, as indicated at state **310**. Upon deactivation of the cooling mode, the compressor motor **114** and the condenser air mover **58** are turned 'Off' while the evaporator air mover **70** continues to run. If the temperature of the enclosed environment **18** continues to fall after the cooling mode is deactivated, the integrated controller board **30** seamlessly transitions the VCACS **10** from the cooling mode to the idle mode. In the idle mode, the evaporator air mover **70** speed is 'ramped down' until the enclosed environment **18** temperature falls to the desired temperature set point, at which time the integrated controller board turns the evaporator air mover **70**'Off', as indicated at state **302**.

[0048] If the enclosed environment **18** temperature falls below the desired temperature set point, e.g., 20° C. (68° F.), the integrated controller board **30** turns the evaporator air mover **70** on and begins to 'ramp up' the speed of the evaporator air mover **70** until the temperature of the enclosed environment **18** reaches a low temperature set point, e.g., 10° C. (50° F.), as indicated at state **314**. In various embodiments, at the low temperature set point, the evaporator air mover **70** is 'Full On'. Hysteresis built into the control algorithm allows the temperature of the enclosed environment **18** to fall a predetermined amount, e.g., 5° C. (41° F.), below the low temperature set point before activating the heating mode of operation. When the enclosed environment **18** temperature falls the predetermined amount below the low temperature set point, the integrated controller board **30** seamlessly transitions the VCACS **10** from the idle mode to the heating mode, as indicated at state **316**.

[0049] Once in the heating mode, the integrated controller board **30** substantially simultaneously controls the heating mechanism(s) **50** and the evaporator air movers **70**, as described above, to dynamically vary the temperature and/or volume of the evaporator output air flow **102**. If an error in the operation of the VCACS **10**, and/or the VCACS fails to adequately heat the enclosed environment **18**, the integrated controller board **30** activates a low temperature alarm at a predetermined temperature, e.g., 0° C. (32° F.), as indicated at state **308**. When heating properly in the heating mode, hysteresis allows the VCACS **10** to heat the enclosed environment **18** a predetermined amount, e.g., 5° C. (41° F.), above the low temperature set point before deactivating the heating mode of operation, as indicated at state **320**. Upon deactivation of the heating mode, the heating mechanism(s) **50** is/are turned 'Off' while the evaporator air mover **70** continues to run. If the temperature of the enclosed environment **18** continues to rise after the heating mode is deactivated, the integrated controller board seamlessly transitions the VCACS **10** into idle mode. In the idle mode, the evaporator air mover **70** speed is 'ramped down' until the enclosed environment **18** temperature rises to the desired temperature set point, at which time the integrated controller board turns the evaporator air mover **70**'Off', as indicated at state **302**.

[0050] Thus, the integrated controller board **30** seamlessly transitions operation of the VCACS **10** between the cooling, heating and idle modes to dynamically vary the temperature and/or volume of the evaporator air flow **102** output into the enclosed environment **18** to maintain an approximately constant desired temperature of the enclosed environment **18**. More particularly, the integrated controller board **30** seamlessly transitions between substantially simultaneously controlling the compressor motor **114** and the condenser and evaporator air movers **58** and **70** in the cooling mode, controlling the evaporator air mover **70** in the idle mode, and substantially simultaneously controlling the heating mechanism(s) **50** and the evaporator air mover **70** in the cooling mode.

[0051] Referring again to FIG. **2**, in various embodiments, the processor **122** executes one or more system maintenance algorithms that can be independent algorithms or subroutines of the one or more control algorithms. For simplicity, system maintenance algorithm(s), or subroutine(s) will be referred to herein merely as the maintenance algorithm(s). The maintenance algorithm(s) monitor an operational health status of the VCACS **10**, and control the various components to prevent damage to the VCACS **10**. For example, to avoid excessive levels of system refrigerant superheat from occurring within the condenser and/or evaporator assemblies **34** and **38**, the maintenance algorithm(s) monitor the temperature of the evaporator refrigerant inlet **94** and the evaporator refrigerant outlet **98**, via evaporator refrigerant inlet and outlet sensors **110**B and **110**C. A difference between the evaporator refrigerant inlet **94** and outlet **98** temperatures is used by the maintenance algorithm(s) to estimate the superheat level. If the superheat level is above a desired level, the maintenance algorithm(s) slow down the speed of the evaporator air mover **70** and/or adjust the thermal expansion valve **90** so that less heat from the enclosed environment **18** is absorbed.

[0052] In various other exemplary embodiments, the maintenance algorithm(s) is/are executed to monitor a 'float temperature' of the condenser heat exchanger **54**. The 'float temperature' is utilized to insure the pressure of the system refrigerant entering the condenser heat exchanger **54** is not above a desired level. To determine the 'float temperature', the maintenance algorithm(s) monitors the temperature of the condenser air flow **82** taken into the condenser heat exchanger **54** and the condenser refrigerant outlet **78**, via sensors **110**E and **110**D. A temperature difference between the condenser air flow **82** intake and the condenser refrigerant outlet **78** is used by the maintenance algorithm(s) to estimate the "float temperature". If the "float temperature" is above a desired level, the maintenance algorithm(s) reduce the speed of the condenser air mover **58** to maintain the pressure of the system refrigerant entering the condenser heat exchanger **54** approximately at the desired level.

[0053] In other various exemplary embodiments, the maintenance algorithm(s) is/are executed to monitor a state estimate of a rotor (not shown) of the compressor motor **114**. To determine the state estimate of the rotor, the maintenance algorithm(s) monitors the temperature of the evaporator refrigerant inlet **94** and the condenser refrigerant outlet **78**, via sensors **110**B and **110**D. A temperature difference between the evaporator refrigerant inlet **94** and the condenser refrigerant outlet **78** is used by the maintenance algorithm(s) to determine the state estimate, which is indicative of a pressure difference acting on the compressor **42**. Based on the state estimate, the maintenance algorithm(s) can adjust a positional relationship between the compressor motor rotor and a stator of the compressor motor, e.g., a lagging or leading relationship, to maintain optimal function of the compressor **42**.

[0054] In still other various embodiments, the maintenance algorithm(s) is/are executed to monitor conditions of exterior ambient environment of the VCACS **10** that may be detrimental to the VCACS **10**. For example, the maintenance algorithm(s) can monitor the condenser intake air flow **82** temperature, via sensor **110**E. A condenser intake air flow **82** temperature above a predetermined temperature may be indicative of a hazardous exterior ambient environment, e.g., a fire in close proximity to the VCACS **110**. In such cases, the maintenance algorithm(s) may command all components of the VCACS **110**, e.g., the compressor motor **114** and the condenser and evaporator air movers **58** and **70**, to shut down to prevent the induction of hazardous conditions, e.g., flames, into the VCACS **10**.

[0055] In yet other various exemplary embodiments, the maintenance algorithm(s) is/are executed to monitor the temperature of the compressor **42** and/or compressor motor **114** to prevent the compressor **42** and/or compressor motor **114** from overheating. To determine the temperature of compressor **42** and/or compressor motor **114**, the maintenance algorithm(s) monitors the inputs **106** from the compressor housing temperature sensor **110**F. If the compressor housing temperature is above a predetermined threshold, the maintenance algorithm(s) will increase the speed of the condenser air mover **58** to cool the compressor **42** and/or compressor motor **114**.

[0056] In still yet other various exemplary embodiments, the maintenance algorithm(s) is/are executed to monitor a temperature of power electronics portion of the integrated controller board **30**, e.g., power electronics that drive the compressor motor **114**. To prevent overheating of the power electronics portion, the maintenance algorithm(s) monitors the temperature of the heat sink **118**, via sensor **110**G. If the temperature of the heat sink **118** exceeds a predetermined threshold, the maintenance algorithm(s) will command an increase in the speed of the evaporator air mover **70** and/or command the compressor motor **114** to slow down or totally shut 'Off'.

[0057] In various other embodiments, the maintenance algorithm(s) is/are to monitor the relative humidity of the air flow **102** output by the evaporator assembly **38** to the enclosed environment **18**, via the relative humidity sensor **112**. A sensed relative humidity of the output air flow **102** above a predetermined threshold, e.g., 100%, is indicative of water condensing on the evaporator heat exchanger **66**. To prevent condensation from being blown onto the enclosed environment **18**, the maintenance algorithm(s) will decrease speed of the evaporator air mover **70** if the relative humidity of the output air flow **102** is sensed to be above the predetermined threshold.

[0058] In other various embodiments, the processor **122** executes an integrated weighted accumulator error detection algorithm for detecting faulty sensors **110** and/or **112**. The integrated weighted accumulator error detection algorithm can be an independent algorithm or a subroutine of the one or more control algorithms. The integrated weighted accumulator error detection algorithm determines if any of the sensors **110** and/or **112** are outside a predetermined normal operating range. Each time a particular sensor **110** or **112** provides an erroneous reading, i.e., a reading outside of the normal operating range, an accumulator increments to determine a total sum of errors for that particular sensor **110** or **112**. The sum is indicative of a length of time the particular sensor **110** or **112** has been malfunctioning. The larger the total sum in the accumulator, the longer the particular sensor **110** or **112** has been operating outside its normal operating zone. In various embodiments, the integrated weighted accumulator error detection algorithm will reset the accumulator to zero if a predetermined time period elapses between erroneous readings of a particular sensor **110** or **112**. Or, in various other embodiments, the integrated weighted accumulator error detection algorithm decrements the accumulator for each valid reading provided by a particular sensor **110** or **112**. When the total sum in the accumulator exceeds a predetermined value, the integrated weighted accumulator error detection algorithm activates an alarm, for example, lights an LED on the integrated controller board **30**, indicating the particular sensor **110** or **112** need to be repaired of replaced.

[0059] In various embodiments, the integrated controller board **30** includes a plurality of status lights **236**, e.g., LEDs, (shown in FIG. **5**) that can be employed to indicate faulty sensors **110** and/or **112**, as determined by the integrated weighted accumulator error detection algorithm. More particularly, in various embodiments, the integrated weighted accumulator error detection algorithm will illuminate certain status lights based on historical status data of each sensor **110** and **112**. For example, if the integrated weighted accumulator error detection algorithm senses that a particular sensor **110** or **112** has never had an erroneous reading, a green status light **236** corresponding to the particular sensor **110** or **112** can be illuminated, while a corresponding red status light **236** is not illuminated. However, if the integrated weighted accumulator error detection algorithm has sensed that a particular sensor **110** or **112** has provided one or more erroneous readings, but subsequently functioned properly, the integrated weighted accumulator error detection algorithm can illuminate both corresponding red and green status lights **236**. And finally, the total sum in the accumulator for a particular sensor **110** or **112** has exceeded the predetermined value, the integrated weighted accumulator error detection algorithm activates just the corresponding red status light **236**.

[0060] In still yet other embodiments, a self-diagnostics algorithm is stored on the integrated controller board **30** and can be executed by the processor **122** prior to installing the VCACS **10** in the field. During execution of the self-diagnostics algorithm, the integrated controller board **30** communicates with a peripheral device (not shown) removeably connectable to the integrated controller board **30**. Upon execution of the self-diagnostics algorithm the integrated controller board **30** instructs the peripheral device to return various signals simulating various sensor **110** and **112** readings indicating various simulated temperatures of the enclosed environment and/or operation condition of the VCACS **10**. In response to the simulated sensor readings, the self-diagnostics algorithm simulates cooling, idle and heating component control commands to simulate operation of the heating and cooling subsystems **22** and **26**, as described above. The self-diagnostics algorithm then verifies that the various components of the heating and cooling subsystems **22** and **26**, e.g., the compressor motor **114**, the condenser and evaporator air movers **58** and **70**, and the heating mechanism(s) **50**, responded correctly to the commands. Additionally, in various embodiments, the self-diagnostics algorithm tests the system control algorithm to verify the integrity of the system control algorithm.

[**0061**] In yet other embodiments, the VCACS **10** additionally includes a charging dongle **240** (shown in FIG. **5**) that is removably connectable to the integrated controller board **30**. The charging dongle **240** includes a charging mode software program or algorithm readable by the processor **122** upon connection of the charging dongle **240** to the integrated controller board **30**. The charging mode algorithm places the VCACS **10** in a compressor charging mode. More particularly, the charging dongle **240**, i.e., the charging mode algorithm, temporarily disables the various components of the VCACS **10**, e.g., the condenser and evaporator air movers **58** and **70**, while controllably commanding the compressor motor **114** to run, as is needed during the system refrigerant recharging process. Accordingly, if the VCACS **10** requires recharging of the system refrigerant, recharging of the system refrigerant can be performed without having to change temperature set points in the control algorithm in order to cause the compressor motor **114** to operate.

[**0062**] Those skilled in the art can now appreciate from the foregoing description that the broad teachings of the present disclosure can be implemented in a variety of forms. Therefore, while this disclosure has been described in connection with particular examples thereof, the true scope should not be so limited since other modifications will become apparent to the skilled practitioner upon a study of the drawings, specification and following claims.

What is claimed is:

1. A direct current (DC) powered variable capacity air conditioning system, said system comprising an integrated controller board configured to substantially simultaneously control a variable speed DC compressor motor, a variable speed condenser air mover and a variable speed evaporator air mover in response to inputs from a plurality of temperature sensors within the system to substantially simultaneously control at least one of a temperature and a volume of an evaporator output air flow of the system.

2. The system of claim 1, wherein the integrated controller board comprises a compressor motor controller, a condenser air mover controller and an evaporator air mover controller that are controlled by a processor of the integrated controller board.

3. The system of claim 1, wherein the integrated controller board is configured to execute an operation control algorithm to substantially simultaneously control the variable speed DC compressor motor, the variable speed condenser air mover and the variable speed evaporator air mover.

4. The system of claim 1, wherein at least one of the variable speed condenser air mover and the variable speed evaporator air mover comprises a backward-curved impeller.

5. The system of claim 1, wherein the system integrated controller board is located within a path of an evaporator air flow.

6. The system of claim 1, wherein the variable speed DC compressor motor comprises a variable speed brushless DC motor.

7. The system of claim 6, wherein the variable speed brushless DC motor comprises a sensorless variable speed brushless DC motor.

8. The system of claim 1, wherein the system further comprises at least one relative humidity sensor located within an enclosed environment to be air conditioned by the system.

9. The system of claim 1, wherein the plurality of temperature sensors comprise an evaporator intake air flow sensor, an evaporator refrigerant inlet sensor, an evaporator refrigerant outlet sensor, condenser refrigerant outlet sensor and a condenser intake air flow sensor.

10. The system of claim 9, wherein the plurality of temperature sensors further comprise at least one of a compressor housing sensor, a controller board heat sink sensor, and at least one remote sensor located within an enclosed environment to be air conditioned by the system.

11. The system of claim 1, wherein the system further comprises at least one variable output positive temperature coefficient heater controlled by the controller board substantially simultaneously with the variable speed evaporator air mover.

12. The system of claim 1, wherein the system further comprises a charge mode device removably connectable to the integrated controller board for placing the system in a charging mode.

13. The system of claim 1, wherein the system further comprises a stepper-motor type electronically variable expansion valve controlled by the integrated controller board based on a sensed temperature of a system refrigerant exiting an evaporator heat exchanger of the system and a sensed temperature of the system refrigerant entering the evaporator heat exchanger.

14. A method for controlling a temperature within an enclosed environment, said method comprising substantially simultaneously controlling at least one of a temperature and a volume of an evaporator output air flow of a direct current (DC) powered variable capacity air conditioning system utilizing an integrated controller board that uses a plurality of temperature inputs from a plurality of sensors within the system to substantially simultaneously control a variable speed DC compressor motor, a variable speed condenser air mover and a variable speed evaporator air mover, thereby providing a continuum of evaporator output air flow capacities for maintaining an approximately constant temperature within the enclosed environment.

15. The method of claim 14, wherein substantially simultaneously controlling at least one of the temperature and volume of the evaporator output air flow comprises varying at least one of the temperature and the volume of the an evaporator output air flow in response to the sensor inputs.

16. The method of claim 14, wherein monitoring inputs comprises receiving as inputs to the integrated controller board, temperature readings of an evaporator intake air flow, an evaporator refrigerant inlet, an evaporator refrigerant outlet, a condenser refrigerant outlet, a condenser intake air flow, a controller board heat sink, a compressor housing and at least one remote location within an enclosed environment to be air conditioned by the air conditioning system.

17. The method of claim 14, wherein substantially simultaneously controlling at least one of the temperature and the volume of the evaporator output air flow comprises controlling operation of at least one of the variable speed DC compressor motor, the variable speed condenser air mover and the variable speed evaporator air mover when a temperature within the enclosed environment is outside of a desired temperature set point range.

18. The method of claim 17, wherein the set point range is programmable to temporally vary.

19. The method of claim 14, wherein substantially simultaneously controlling at least one of the temperature and the volume of the evaporator output air flow comprises controlling operation of the variable speed DC compressor motor, the variable speed evaporator air mover and at least one variable output positive temperature coefficient heater based on the sensor inputs.

20. The method of claim 14, wherein substantially simultaneously controlling at least one of the temperature and the volume of the evaporator output air flow comprises:

determining a superheat state of a system refrigerant at an evaporator refrigerant outlet based on a temperature difference between an evaporator refrigerant inlet and an evaporator refrigerant inlet; and

controlling the superheat state by controlling operation of at least one of the variable speed evaporator air mover and a thermal expansion valve of the air conditioning system.

21. The method of claim 20, wherein the thermal expansion valve comprises a stepper-motor type electronically variable expansion valve and controlling the operation the thermal expansion valve comprises utilizing the integrated controller board to control the stepper-motor type electronically variable expansion valve based on a sensed temperature of the system refrigerant exiting an evaporator heat exchanger of the air conditioning system and a sensed temperature of the system refrigerant entering the evaporator heat exchanger.

22. The method of claim 14, wherein substantially simultaneously controlling at least one of the temperature and the volume of the evaporator output air flow comprises controlling operation of the variable speed condenser fan to produce a desired float temperature based on a temperature difference between a condenser intake air flow and a temperature of a condenser refrigerant outlet.

23. The method of claim 14, wherein substantially simultaneously controlling at least one of the temperature and the volume of the of the evaporator output air flow comprises:

updating a state estimate of a compressor rotor based on a temperature difference between an evaporator refrigerant inlet and a condenser refrigerant outlet; and

controlling operation of the variable speed DC compressor motor based on the updated state estimate.

24. The method of claim 14, wherein substantially simultaneously controlling at least one of the temperature and the volume of the evaporator output air flow comprises:

monitoring a condenser intake air flow temperature to determine environmental conditions exterior to the air conditioning unit that may be detrimental to the air conditioning system; and

shutting down the air conditioning system if the exterior environmental conditions are determined to be detrimental.

25. The method of claim 14, wherein substantially simultaneously controlling at least one of the temperature and the volume of the evaporator output air flow comprises controlling operation of the variable speed condenser air mover based on a compressor housing temperature to prevent the compressor from overheating.

26. The method of claim 14, wherein substantially simultaneously controlling at least one of the temperature and the volume of the evaporator output air flow comprises:

monitoring a temperature of a heat sink of the integrated controller board to determine; and

controlling operation of at least one of the variable speed evaporator air mover and the variable speed DC compressor motor, based on the heat sink temperature to prevent a power electronics portion of the integrated controller board from overheating.

27. The method of claim 14, wherein substantially simultaneously controlling at least one of the temperature and the volume of the evaporator output air flow comprises executing an operation control algorithm, via a processor of the integrated controller board, to substantially simultaneously control the variable speed DC compressor motor, the variable speed condenser air mover and the variable speed evaporator air mover.

28. The method of claim 14, wherein the method further comprises executing a self-test mode algorithm, via a processor of the integrated controller board, to test functionality of the variable capacity air conditioning system.

29. A telecommunications station comprising:

a direct current (DC) powered variable capacity air conditioning system coupled to a structure enclosing an environment to be thermally conditioned by the DC powered variable capacity air conditioning system, said system comprising:

a plurality of temperature sensors;

a variable speed DC compressor motor;

a variable speed condenser air mover;

a variable speed evaporator air mover; and

an integrated controller board configured to substantially simultaneously control the variable speed DC compressor motor, the variable speed condenser air mover and the variable speed evaporator air mover in response to inputs from the temperature sensors to substantially simultaneously control at least one of a temperature and a volume of an evaporator output air flow of the system to the enclosed environment.

30. The station of claim 29, wherein the integrated controller board is configured to execute an operation control algorithm to substantially simultaneously control a compressor motor controller, a condenser air mover controller and an evaporator air mover controller to substantially simultaneously control the variable speed DC compressor motor, the variable speed condenser air mover and the variable speed evaporator air mover.

31. The station of claim 29, wherein the variable speed DC compressor motor comprises a sensorless variable speed brushless DC motor.

32. The station of claim 29, wherein the plurality of temperature sensors comprise an evaporator intake air flow sensor, an evaporator refrigerant inlet sensor, an evaporator refrigerant outlet sensor, condenser refrigerant outlet sensor and a condenser intake air flow sensor.

33. The station of claim 29, wherein the system further comprises at least one variable output positive temperature coefficient heater controlled by the controller board substantially simultaneously with the variable speed evaporator air mover.

34. The station of claim 29, wherein the system further comprises a charge mode device removably connectable to the integrated controller board for placing the system in a charging mode.

35. A direct current (DC) powered variable capacity air conditioning system, said system comprising:

a variable speed DC compressor; and

a controller board configured to operate the variable speed DC compressor at varying speeds during operation of the variable capacity air conditioning system.

36. The system of claim 35, wherein the variable speed DC compressor comprises a sensorless variable speed brushless DC motor.

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