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(54) **AIR PROCESSOR AND SYSTEM FOR HEATING AND COOLING**

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(57) **ABSTRACT**

A heating and cooling system including an air processor, a compression subsystem, a heat box, a recuperator, and an operating system. The air processor includes a pre-conditioner, a drenched coil and a post conditioner. The heat box includes a refrigerant line in fluid communication with the compression subsystem, a heat exchange line, and a series of motorized shutters. The recuperator includes a thermal storage means, a supply pump and at least two heat exchange lines.

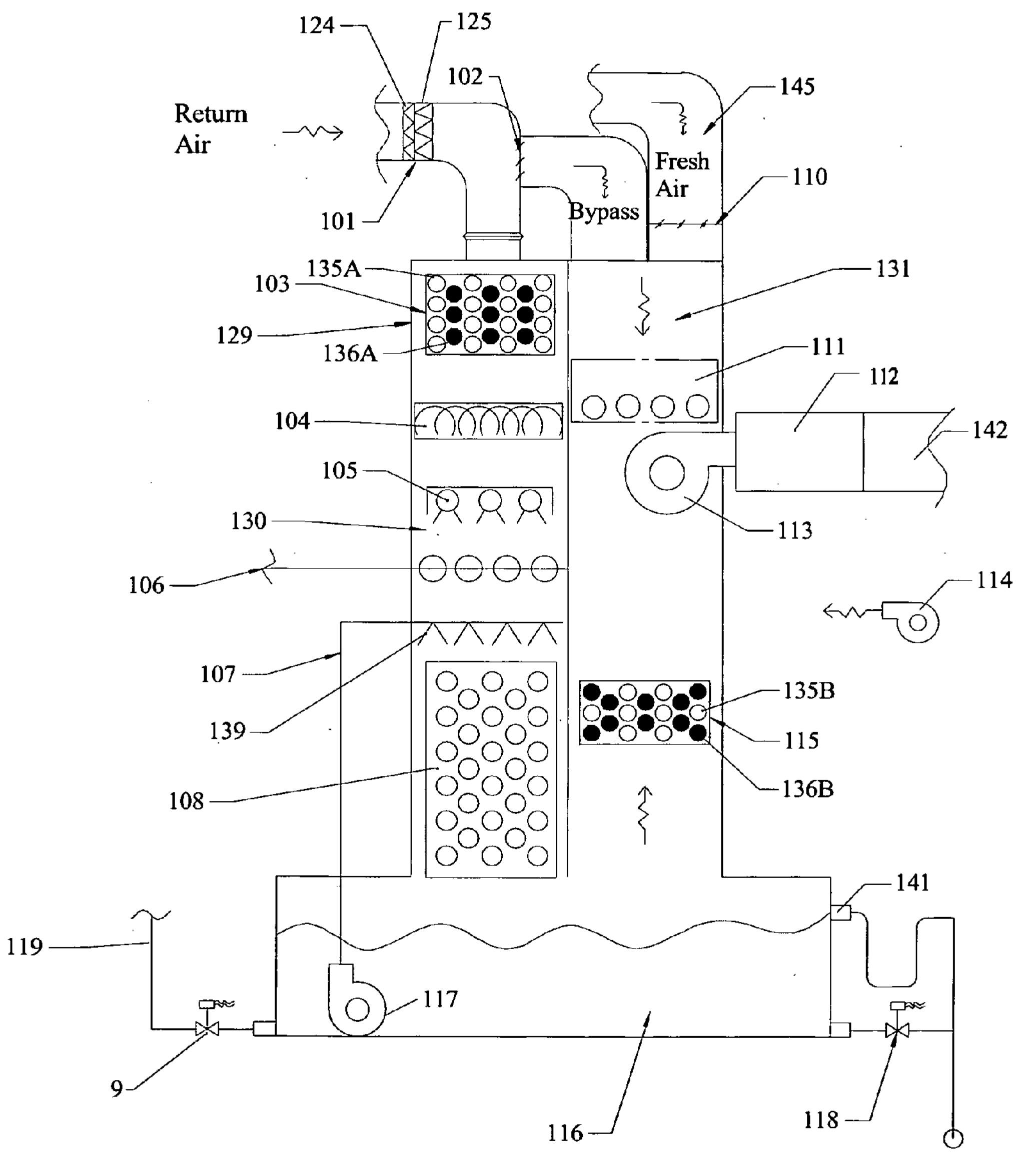


FIG. 1

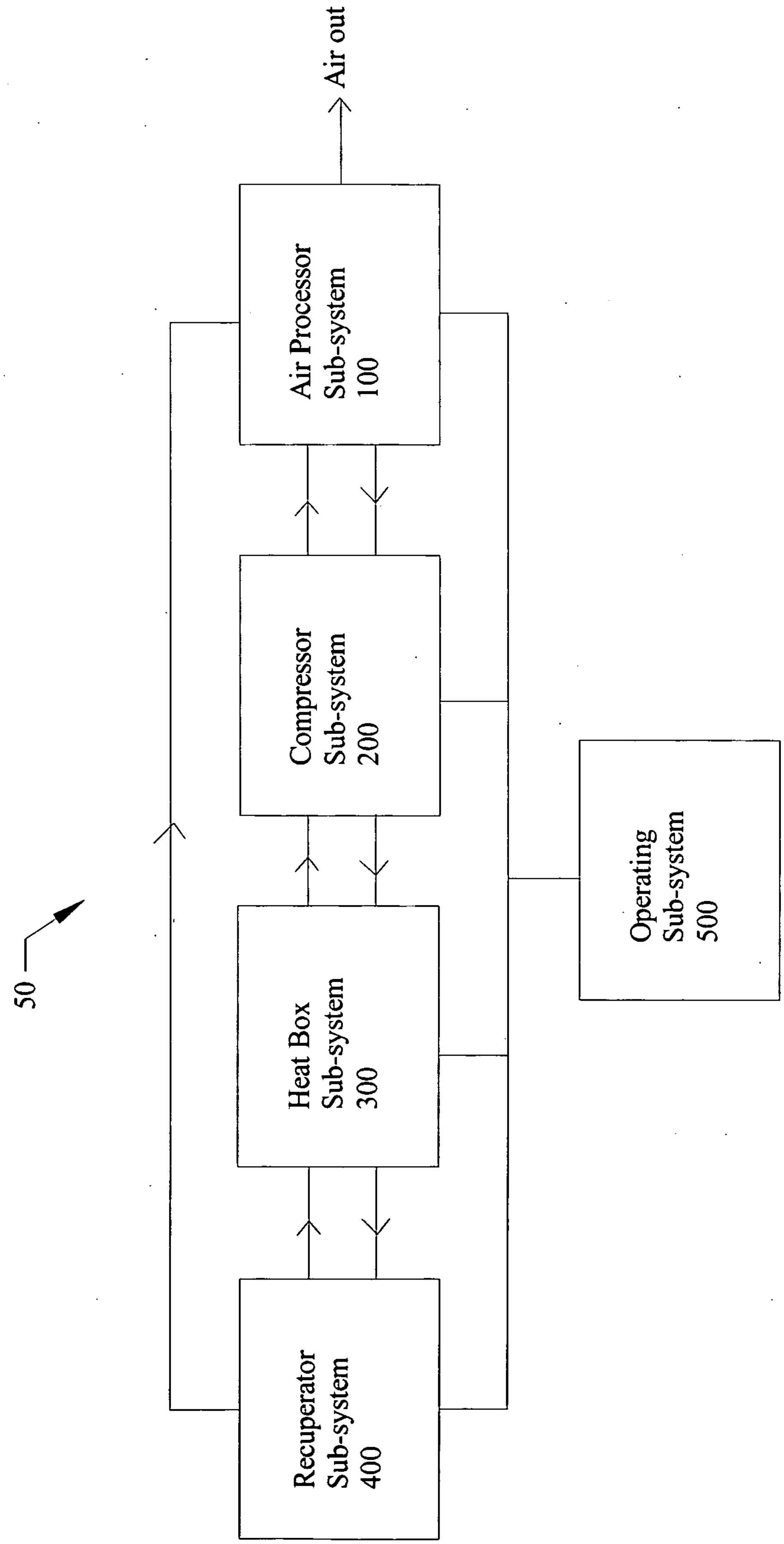

50
Air out
Air Processor
Sub-system
100
Compressor
Sub-system
200
Heat Box
Sub-system
300
Recuperator
Sub-system
400
Operating
Sub-system
500

FIG. 2

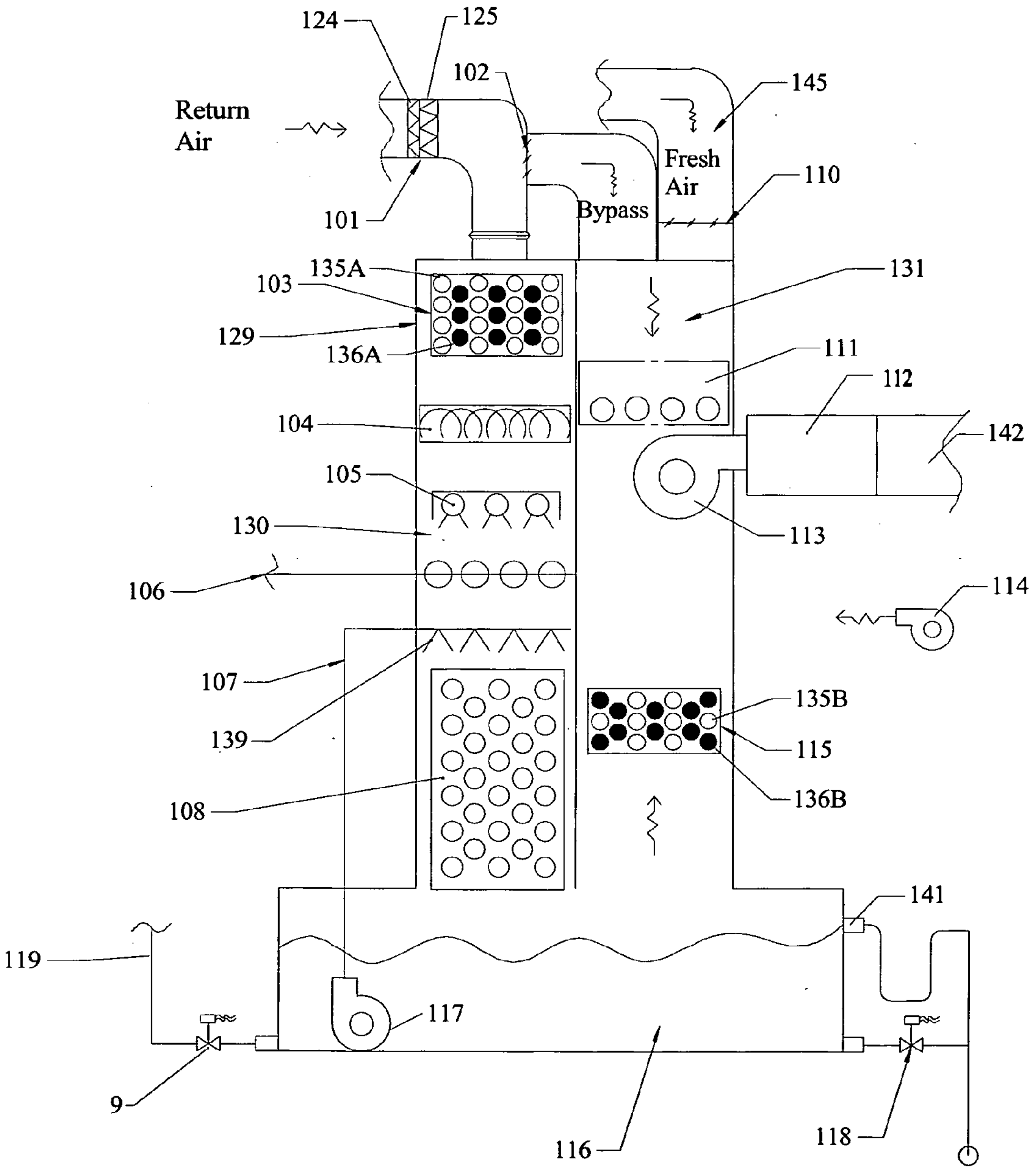
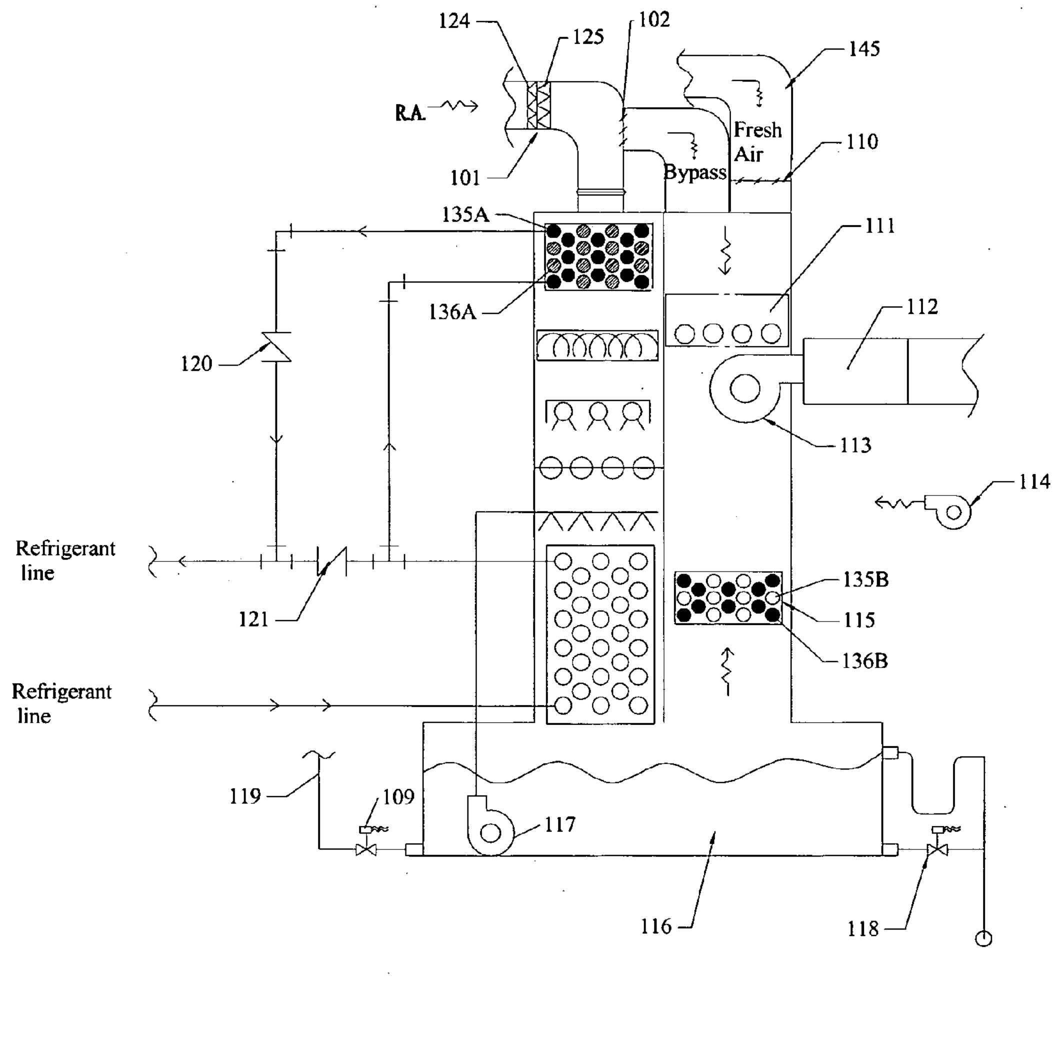

124
125
102
145
Return
Air
Fresh
Air
110
101
Bypass
135A
131
103
129
136A
111
112
104
142
105
113
130
106
114
107
135B
139
115
108
136B
141
119
117
9
116
118

FIG. 3



124
125
102
145
R.A.
Fresh
Air
Bypass
110
101
135A
111
136A
112
120
113
114
Refrigerant
line
135B
115
121
136B
Refrigerant
line
119
109
117
116
118

FIG. 4

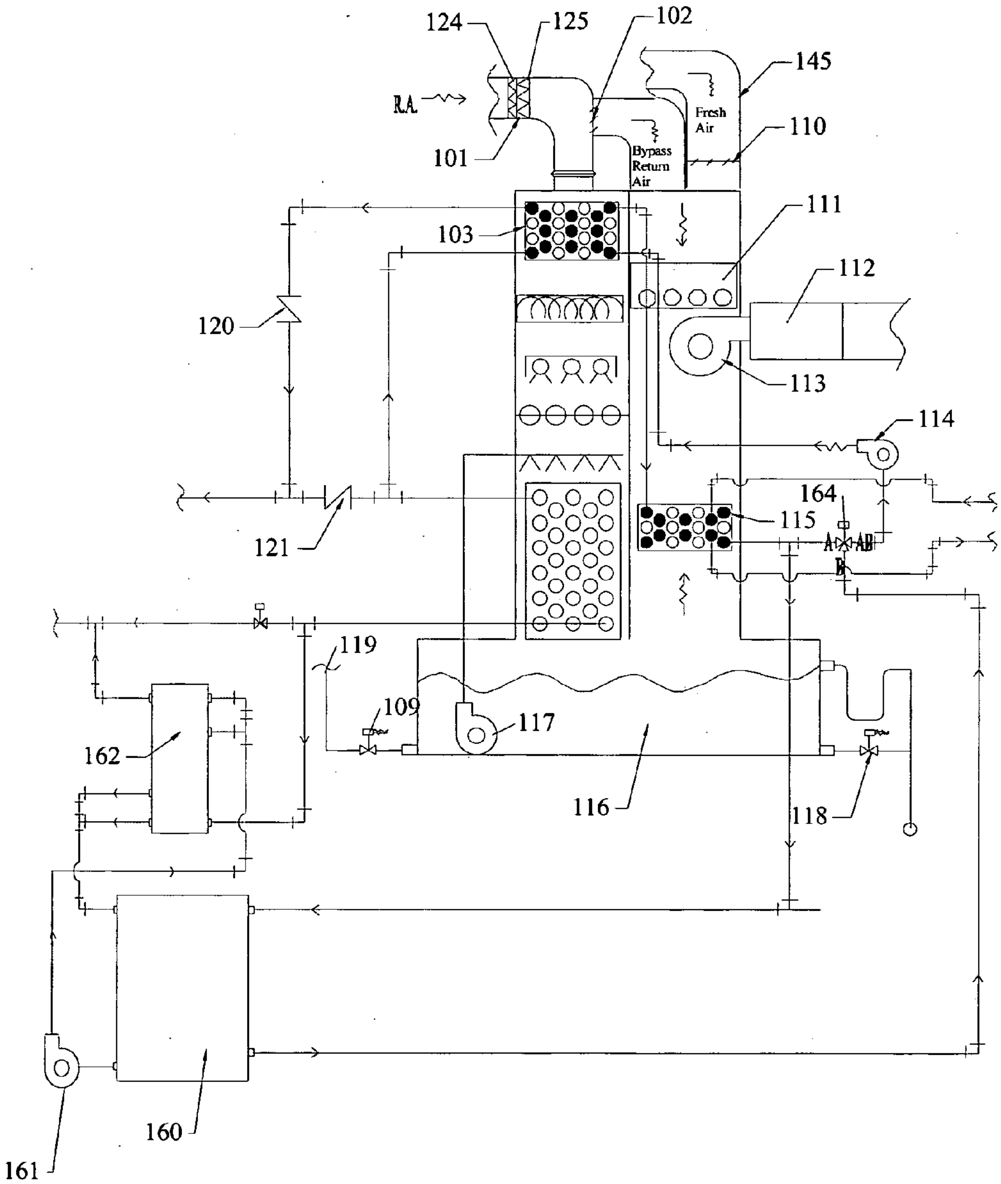

124
125
102
145
R.A.
Fresh Air
110
101
Bypass Return Air
103
111
112
120
113
114
164
115
A
AB
B
121
119
109
117
162
116
118
160
161

FIG. 5

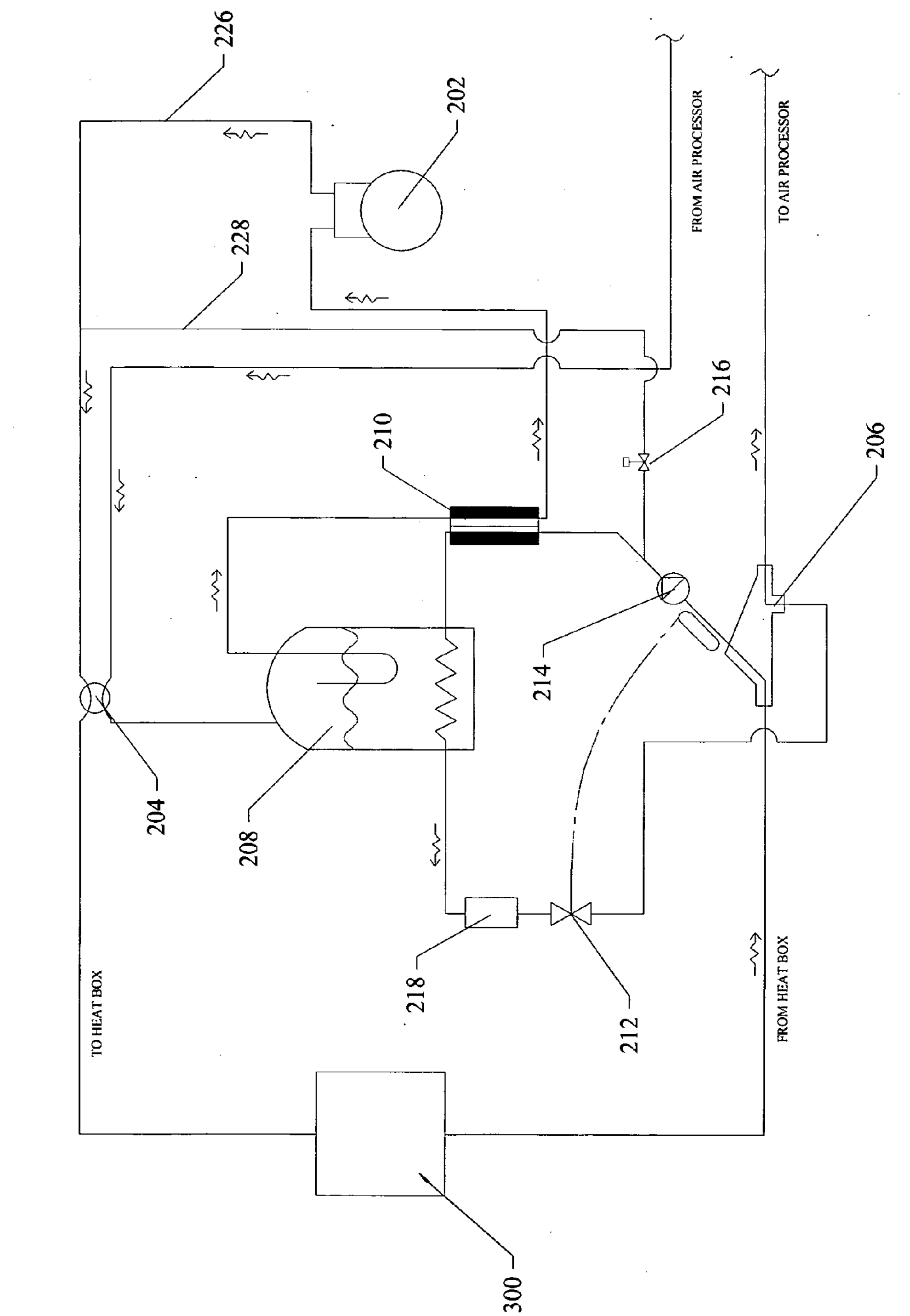

226
202
228
FROM AIR PROCESSOR
TO AIR PROCESSOR
216
210
206
214
204
208
218
212
TO HEAT BOX
FROM HEAT BOX
300

FIG. 6

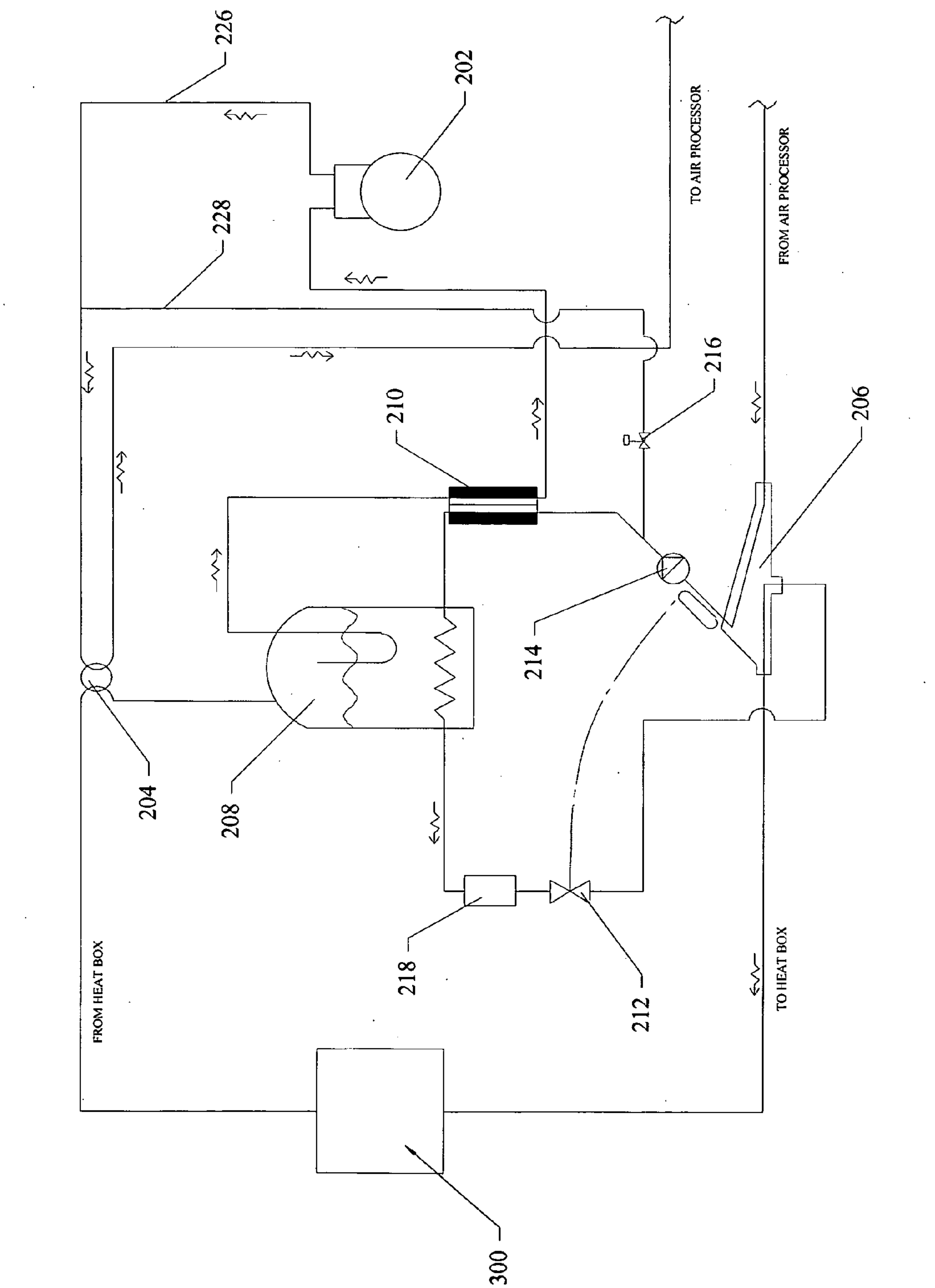
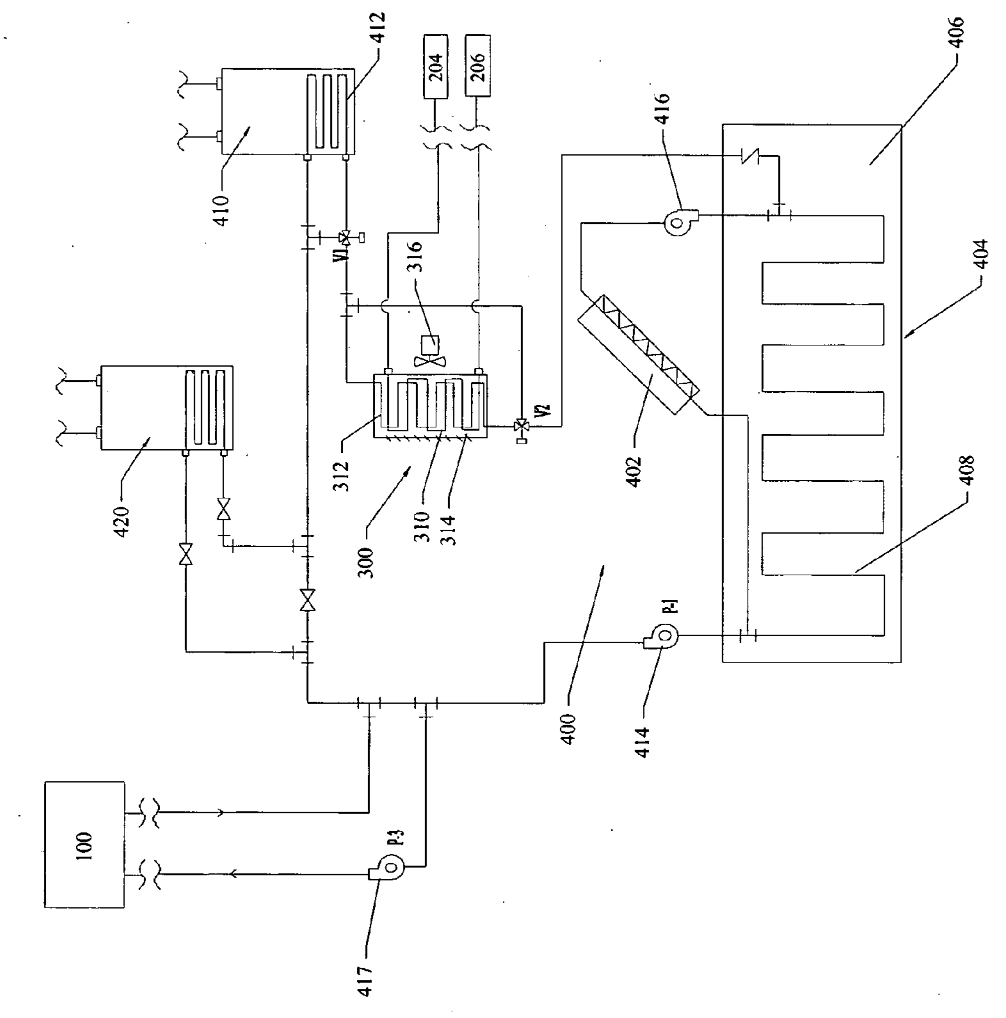

226
202
228
TO AIR PROCESSOR
FROM AIR PROCESSOR
216
210
206
214
204
208
218
212
FROM HEAT BOX
TO HEAT BOX
300

FIG. 7


412
410
204
206
416
406
404
316
V1
V2
312
300
310
314
402
408
420
400
414
P-1
100
P-3
417

AIR PROCESSOR AND SYSTEM FOR HEATING AND COOLING

FIELD OF THE INVENTION

[0001] The present invention relates to systems for heating and cooling and, in particular, to air processors and forced air systems for heating and cooling an enclosed space.

BACKGROUND OF THE INVENTION

[0002] Systems for heating and cooling air in an enclosed spaced, such as a home or office building, have been used for many years. Traditionally, separate systems had been used for heating and for cooling. However, a number of systems have been developed to perform both functions. One such system is a heat pump.

[0003] A heat pump is a machine or device that moves heat from one location to another location using work. Many heat pumps move heat from a low temperature heat source to a higher temperature heat sink. One common type of heat pump works by exploiting the physical properties of an evaporating and condensing fluid known as a refrigerant. In heating, ventilation, and cooling (HVAC) applications, a heat pump normally refers to a vapor-compression refrigeration device that includes a reversing valve and optimized heat exchangers so that the direction of heat flow may be reversed.

[0004] According to the second law of thermodynamics heat cannot spontaneously flow from a colder location to a hotter area; work is required to achieve this. Heat pumps differ in how they apply this work to move heat, but they can essentially be thought of as heat engines operating in reverse. A heat engine allows energy to flow from a hot 'source' to a cold heat 'sink', extracting a fraction of it as work in the process. Conversely, a heat pump requires work to move thermal energy from a cold source to a warmer heat sink. Since a heat pump uses a certain amount of work to move the heat, the amount of energy deposited at the hot side is greater than the energy taken from the cold side by an amount equal to the work required.

[0005] One common type of heat pump works by exploiting the physical properties of an evaporating and condensing fluid known as a refrigerant. In such systems, the working fluid, in its gaseous state, is pressurized and circulated through the system by a compressor. On the discharge side of the compressor, the now hot and highly pressurized gas is cooled in a heat exchanger called a condenser until it condenses into a high pressure, moderate temperature liquid. The condensed refrigerant then passes through a pressure-lowering device, such as an expansion valve, capillary tube or a restrictor. This device then passes the low-pressure refrigerant in a saturated vapor state to the evaporator, where the refrigerant evaporates into a gas via heat absorption. The refrigerant then returns to the compressor and the cycle is repeated.

[0006] In HVAC applications, a heat pump normally refers to a vapor-compression refrigeration device that includes a reversing valve and optimized heat exchangers so that the direction of heat flow may be reversed. The reversing valve switches the direction of refrigerant through the cycle and therefore the heat pump may deliver either heating or cooling to a building. In the cooler climates the default setting of the reversing valve is heating. The default setting in warmer climates is cooling. Because the condenser and evaporator must swap functions, they are optimized to perform adequately in both modes. As such, the efficiency of a reversible heat pump is typically slightly less than two separately-optimized machines. Therefore, there is a need for a system for heating and cooling that operates at higher efficiencies than conventional reversible heat pump systems.

[0007] Conventional air-source heat pumps are relatively easy and inexpensive to install and, therefore, have historically been the most widely used heat pump type. Further, when the outside air is at sufficient temperature, air source heat pumps can typically produce three times the heating per kilowatt then electric heat systems. However, they suffer limitations due to their use of the outside air as a heat source or sink, as the higher temperature differential during periods of extreme cold or heat leads to a lower efficiency. Therefore, there is a need for a system for heating and cooling that operates at higher efficiencies than conventional heat pump systems at high temperature differentials.

[0008] Conventional air-source heat pumps also typically rely upon dry bulb temperature control for both heating and cooling. The dry bulb temperature refers to the ambient air temperature without regard to the moisture in the air. Conversely, wet-bulb temperature takes the amount of moisture in the air into account. As the amount of heat that can be absorbed the air is greatly impacted by its humidity, and as the humidity of air is greatly variable from day to day, the use of the dry bulb temperature for control of conventional systems during the cooling cycle leads to further inefficiency. Therefore, there is a need for a system for heating and cooling that controls the cooling mode based upon the wet-bulb temperature of the air and the heating mode based upon the dry bulb temperature of the air.

[0009] When used for cooling, the overall efficiency of conventional heat pumps is also reduced due to their failure to use the waste heat for useful purposes. Typically, waste heat is discharged to the atmosphere and not used for other purposes, such as heating residential water. Therefore, there is a need for a system for heating and cooling that will use this waste heat productively.

[0010] Another problem with any air conditioning processes is the need to add sensible heat back into the air after it has been de-humidified. The reason for this that lower temperature air has higher relative humidity and the failure to add sensible heat can result in excessively high relative humidity levels. Accordingly, most air conditioning process include a separate reheat process during the dehumidification cycle. This process is typically performed by an electric heater, or a hot refrigerant, which further reduces the efficiency of the system. Therefore, there is a need for a system for heating and cooling that has a more efficient reheat process than conventional systems.

[0011] There are a number of industrial cooling systems that utilize a flow of water over heated coils as the primary means of cooling in industrial processes. Such systems are often referred to as drenched coil or wet surface air coolers. These systems utilize banks of coils through which water or a refrigerant are pumped and a fluid, typically water, is sprayed over the coils and cools the fluid passing through the coils. Drenched coil cooling has a number of advantages. For example, the use of sprays acts to clean the process air being blown over the coils and also acts to clean the coils of dirt, scale and other buildup. However, as these systems are limited to cooling and operate most efficiently under certain ambient conditions, they have heretofore not been readily adapted for use in applications that require both heating and cooling. Therefore, there is a need for a system for heating and cooling that utilizes drenched coil cooling but that is adapted to automatically switch off the drenched coil cooling when conditions require it to do so.

[0012] Finally, evaporative cooling has been used to cool air in outdoor applications, such as livestock barns and along the sidelines at sporting events, as well as in industrial applications where hot gasses must be quickly cooled. Evaporative cooling works by spraying a fine mist of a liquid into a flow of gas, which causes the liquid to evaporate and remove heat from the gas. As was the case with the drenched coil systems above, these systems are limited to cooling, operate most efficiently under certain ambient conditions, and have not heretofore been adapted for use in applications that require both heating and cooling. Therefore, there is a need for a system for heating and cooling that utilizes evaporative cooling but that is adapted to automatically switch to compression heating or cooling when conditions require it to do so.

SUMMARY OF THE INVENTION

[0013] The present invention is a unique heating and cooling system and a unique air processor for use in a heating and cooling system.

[0014] The air processor of the present invention includes a housing including a top, a bottom, a coil section and an air output section. An air inlet is in communication with the top of the housing and a bypass damper is in communication with the air inlet and the air output section of the housing.

[0015] A preconditioning coil chamber is disposed within the coil section of the housing and proximate to the air inlet. The preconditioning coil chamber includes a first portion of a refrigerant coil and a first portion of a thermal return coil.

[0016] A coil drenching spray system is disposed within the coil section of the housing between the humidification nozzles and the bottom of the housing. The coil drenching spray system includes a spray sump dimensioned to hold a volume of water, a recirculatory spray pump in fluid communication with the spray sump, a drenched coil including a refrigerant inlet and outlet, and at least one spray nozzle in communication with the recirculatory spray pump. The nozzles are disposed over the drenched coil such that water sprayed from the nozzles contacts the drenched coil.

[0017] A post-conditioning chamber is disposed within the air output section between the bottom of the housing and the bypass damper. The post-conditioning chamber includes a second portion of the thermal return coil and a first stage heating coil in communication with a source of heating medium.

[0018] Finally, a processed air outlet is disposed within the air output section of the housing between the bypass damper and the post-conditioning chamber and allows processed, or conditioned, air to pass into the room to be heated or cooled.

[0019] The preferred air processor includes at least one ultraviolet emitter disposed within the coil section of the housing between the preconditioning coil chamber and the bottom or the housing. The preferred air processor also includes at least one humidification nozzle, connected to a supply of high purity water, which is disposed within the coil section of the housing between the ultraviolet emitter and the bottom of the housing.

[0020] The preferred air processor includes a filter section having a pre-filter and a final filter, an economizer damper disposed between the air inlet and the air output section of the housing. The preferred air processor also includes at least one evaporative cooling nozzle disposed within the air output section between the bypass damper and the processed air outlet. The evaporative cooling nozzle includes a connector for connection to a supply of high purity water.

[0021] The preferred air processor includes a supply fan in fluid communication with the processed air outlet and at least one electric heater. The air processor preferably includes two electric heaters. A first electric heater disposed within the coil section of the housing between the recirculatory spray system and the top of the housing and a second electric heater disposed within the processed air outlet.

[0022] Finally, the spray sump of the preferred air processor also includes an inlet control valve for attachment to a potable water line and a drain control valve for attachment to a drain line.

[0023] The heating and cooling system includes an air processor, such as the air processor of the present invention, and a compression subsystem in communication with the air processor. The compression subsystem includes and accumulator, a compressor, a reversing valve and at least one refrigerant line. A heat box including a refrigerant line, which is in fluid communication with a refrigerant line of the compression subsystem, a heat exchange line, and a series of motorized shutters. A recuperator is provided, which includes a thermal storage means, a supply pump and at least two heat exchange lines. A first heat exchange line is in fluid communication with the heat exchange line of the heat box and the second heat exchange line is in communication with the air processor. Finally, an operating system is in electrical communication with the air processor, the compression subsystem, the heat box and the recuperator. The operating system includes at least one input from at least one user control, an internal temperature sensor and an external temperature sensor, a processor that includes a computer program product for processing user and temperature information and determining an appropriate system operating condition based upon the user and temperature information, and at least one output to each of the air processor, the compression subsystem, the heat box and the recuperator.

[0024] In the preferred heating and cooling system, the heat box also includes a fan disposed such that air may be blown over the refrigerant line and the heat exchange line and where the output from the computer program product of the operating system controls an operation of the motorized shutters and the fan. The preferred heat box also includes a plurality of conductive plates attached to, and in heat conducting relation to, aid refrigerant line and the heat exchange line. The preferred recuperator includes at least one solar collector array in fluid communication with the thermal storage means. The use of a solar collector array is unique and is preferred due to its ability act as a thermal flywheel for the system.

[0025] In some embodiments of the heating and cooling system, a potable water heater and/or a radiant heat water heater is in communication with the heat exchange line of the heat box. In such embodiments, the output from the computer program product of the operating system control a flow of heat transfer fluid from the heat box to the potable water heater and/or the radiant heat water heater when the system is in a cooling mode of operation.

[0026] Some embodiments of the heating and cooling system also include an ice storage unit through which a heat transfer fluid line is disposed. In some such embodiments, a coaxial chiller is also provided and the heat transfer fluid line is disposed through the coxial chiller and the ice storage unit.

It is preferred that the coaxial chiller be disposed relative to the ice storage unit such that a heat transfer fluid passing through the heat transfer fluid line passes through the coxial chiller before passing through the ice storage unit.

[0027] The preferred heating and cooling system also includes a first check valve and a second check valve. The first check valve is in communication with a refrigerant line from the compression subsystem and the refrigerant coil of the preconditioning coil chamber and is disposed so as to control a flow of refrigerant to the refrigerant coil of the preconditioning coil chamber. The second check valve is in communication with the refrigerant coil of the preconditioning coil chamber and the refrigerant inlet of the drenched coil of the coil drenching spray system. In such embodiments, the output from the computer program product of the operating system controls a position of the first check valve and the second check valve. During the heating cycle, the check valves direct the refrigerant flow through the refrigerant coil of the preconditioning coil chamber for increased heating efficiency. During the cooling cycle, the check valves direct the flow around the preconditioning coil chamber, providing increased efficiency of the drenched coil.

[0028] In the preferred heating and cooling system, the spray sump of the coil drenching spray system includes an inlet control valve in communication with a potable water supply line and a drain control valve in fluid communication with an overflow drain. The inlet control valve and the drain control valve are preferably computer controlled valves and the output from the computer program product of the operating system preferably controls a position of the inlet control valve and the drain control valve based upon a signal from the external temperature sensor such that the spray sump is filled when an external temperature is at least 55° Fahrenheit and such that the spray sump is drained when the external temperature is below 50° Fahrenheit. Therefore, it is an aspect of the invention to provide a system for heating and cooling that operates at higher efficiencies than conventional reversible heat pump systems.

[0029] It is a further aspect of the invention to provide a system for heating and cooling that operates at higher efficiencies than conventional heat pump systems at higher temperature differentials.

[0030] It is a further aspect of the invention to provide a system for heating and cooling that is controlled based upon the wet-bulb temperature of the air.

[0031] It is a further aspect of the invention to provide a system for heating and cooling that will use waste heat productively.

[0032] It is a further aspect of the invention to provide a system for heating and cooling that automatically controls its operating mode to optimize efficiency and comfort.

[0033] It is a further aspect of the invention to provide a system for heating and cooling that maintains the coil leaving wet bulb temperature, thereby increasing system efficiency and comfort.

[0034] It is a further aspect of the invention to provide a system for heating and cooling that cleans the air during cooling mode.

[0035] It is a further aspect of the invention to provide a system for heating and cooling that utilizes drenched coil cooling but that is adapted to automatically switch off such cooling under conditions where such cooling is inefficient.

[0036] It is a further aspect of the invention to provide a system for heating and cooling that utilizes evaporative cooling but that is adapted to automatically switch to compression heating or cooling.

[0037] These aspects of the invention are not meant to be exclusive and other features, aspects, and advantages of the present invention will be readily apparent to those of ordinary skill in the art when read in conjunction with the following description, appended claims and accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0038] FIG. **1** is a block diagram showing the five subsystems that make up the overall system of the present invention.

[0039] FIG. **2** is a schematic diagram of the preferred air processor of the system of the present invention.

[0040] FIG. **3** is a schematic diagram of the air processor of FIG. **2** showing the piping inputs from the compression subsystem.

[0041] FIG. **4** is a schematic diagram of the air processor of FIG. **2** showing the piping inputs from the compression subsystem and an optional ice storage device.

[0042] FIG. **5** is a schematic diagram of the preferred embodiment of the heat box and compression sub-system operating in cooling mode.

[0043] FIG. **6** is a schematic diagram of the preferred embodiment of the heat box and compression sub-system operating in heating mode.

[0044] FIG. **7** is a schematic diagram of a preferred embodiment of the heat box and recuperator sub-system that includes thermal storage, a potable water heater, and a radiant heating unit.

DETAILED DESCRIPTION OF THE INVENTION

[0045] Referring first to FIG. **1**, the system **50** of the present invention includes five primary sub-systems **100**, **200**, **300**, **400**, **500**. The first sub-system **100** is referred to as the "air processor". The air processor **100** conditions air for human comfort and hygiene and moves the conditioned air into the desired space. The second sub-system is the compression sub-system **200**. The compression sub-system **200** moves heat in and out of the system **50**. The third sub-system **300** is referred to as the "heat box". The heat box **300** determines whether excess system heat is recovered for reuse or rejected to the atmosphere during the cooling cycle and whether the heat is taken into the system **100** from the atmosphere or from the thermal storage loop during the heating cycle. The fourth sub-system **400** is referred to as the "recuperator". The recuperator **400** is a heat storage system that allows heat to be stored for use at a later time, both during heating and cooling, and transferred to the air processor subsystem **100** when it is needed. The recuperator **400** is preferably made up of a solar array, thermal storage, piping and special valving to provide proper system operation. The final sub-system is referred to as the operating system **500**. The operating system **500** is the integrator for all other sub-systems and controls the other four sub-systems so that they operate efficiently.

[0046] Referring now to FIGS. **2**-**4**, the preferred air processor **100** of the system **50** of the present invention is shown. The preferred air processor **100** includes a housing **129** that is divided into two sections; the coil section **130** and the air output section **131**. All return air to be processed, whether fresh air or air returning from an air-conditioned space, first passes through the return air inlet **101** and into filter section **123**. Filter section **123** preferably includes a pre-filter **124** and a final filter **125**. The pre filter **124** is preferably a ten MERV filter that is dimensioned to gather larger particles, typically greater than 10 microns, and allows for a longer service life for the final filter **125**, preferably a sixteen MERV filter, which is more costly to replace and requires more fan energy as it becomes loaded with particles. In some embodiments, both the pre-filter **124** and final filter **125** are made up of multiple filters, while in others each is a single filter. In still others, filtration is performed prior to the air reaching the air processor **100** and, in such embodiments, the filter section **123** is omitted.

[0047] Once the air passes through the filter section **123**, it next passes by the bypass damper **102**. The bypass damper **102** increases the efficiency of supply fan **113** and provides the option to partially or totally bypass the coil section **130** and flow directly into air output section **131** during certain phases of the conditioning process. As an example, during low sensible heat ratios, the bypass damper **102** would be used to minimize reheat requirements. Also, the bypass damper **102** is useful during conditions calling for evaporative cooling by the evaporative cooling nozzles **111**, as it allows the components in the coil section **130** to be inoperative. However, although the preferred system includes the bypass damper **102**, the bypass damper **102** is eliminated in some embodiments of the system and all air flows through the coil section **130** of the housing **129**.

[0048] Air passing through the coil section **130** first passes through a preconditioning coil chamber **103**. The preconditioning coil chamber **103** includes a preconditioning refrigerant coil **135**A and a preconditioning thermal return coil **136**A. The preconditioning refrigerant coil **135**A is in fluid communication with the compression subsystem **200**. The preconditioning thermal return coil **136**A communicates with the post-conditioning thermal return coil **136**B in the post-conditioning chamber **115** in the air output section **131** and is part of a closed loop in which a heat transfer fluid is circulated between the coils **135**A, **135**B by thermal recirculating pump **114**.

[0049] The preconditioning coil chamber **103** acts both as a pre-conditioner, using cool liquid from the thermal return chamber **115** to pre-cool the return air for more effective dehumidification, and using the preconditioning refrigerant coil **135**A as an extended heat exchange surface during the heat pump cycle. The preconditioning refrigerant coil **135**A and preconditioning thermal return coil **136**A are preferably plate fin coils with intertwined circuitry in which every other tube is either circuited for refrigerant or heat transfer fluid. The preferred heat transfer fluid is a mixture of water and glycol, which is used as an additive that acts as antifreeze. The preferred refrigerant is R410A, as this is the most commonly used refrigerant for heat pump applications. However, other environmentally safe refrigerants, such as R290, may be substituted to achieve similar results.

[0050] In FIGS. **2** and **3**, the first tube bank, denoted by the solid color, is the preconditioning refrigerant coil **135**A, which is in communication with the refrigerant flowing to and from the compressor sub-system **200** during the heating cycle, and the intermediate tube bank, denoted by hatching, is the preconditioning thermal return coil **136**A. However, this arrangement of tubes is shown for illustrative purposes and other arrangements may be utilized to achieve similar results. As described below, other embodiments may include a third coil (not shown) that is in communication with the recuperator **400**. Such embodiments are useful where solar heating is applicable.

[0051] Air next passes over electric heating coil **104**. The electric heating coil **104** is normally turned off, but does function during the compressor-less humidification cycle, where the system is used solely to add humidity to the air when the compressor is not running. It is also used as a back-up heat source in the rare instance when defrosting of the outdoor coil of the heat box **300** is required.

[0052] Air next passes through a series of ultraviolet emitters **105**, which act as a germicidal system to kill mold spores, bacteria and other germs. In so doing, the drenched coil **108** and housing **129** is kept clean and efficient. The ultraviolet emitters **105** are preferably in operation all times the supply air fan **113** is in operation.

[0053] Air next passes over a series of humidification nozzles **106**, which are in communication with a source of high purity water. The humidification nozzles **106** spray a mist of water to maintain the desired wet bulb temperature of the process air during periods when the coil drenching spray system **107** is offline, which typically occurs at outdoor dry bulb temperatures consistently below 50° F. The humidification nozzles **106** are turned off when the coil drenching spray system **107** is online.

[0054] The air then passes over the coil drenching spray system **107** and the drenched coil **108**. The coil drenching spray system **107** is preferably a re-circulatory spray system that is activated at outdoor temperatures above 55° F. and deactivated and drained at temperatures below 50° F. The coil drenching spray system **107** includes the recirculatory spray pump **117** that is disposed within the spray sump **116**, and a series of spray nozzles **139** disposed over the drenched coil **108** such that water sprayed from the nozzles **139** contacts the entire drenched coil **108**. The coil drenching spray system **107** is only operable during compressor operation in the cooling mode and preferably sprays approximately four gallons per minute of water per square foot of surface area of the drenched coil **108**. The spraying of water over the drenched coil provides an extended heat transfer surface and increases the apparatus dew point temperature of the system. Further, the recirculation of water from the sump over the cooled coil **108** provides a flywheel effect and stabilized system operation as the water gives up energy to the coil **108**, resulting in cooled water in the sump, which is then recirculated by the recirculatory spray pump **117**. The use of the spray system **107** is a distinct advantage in cooling mode due to the greater ability of water to absorb heat, the ability to wash the air, and the ability to keep the heat transfer surfaces free of dirt and other contaminants.

[0055] The drenched coil **108** is a continuous coil through which refrigerant from the compression subsystem **200** is pumped. The drenched coil **108** is preferably manufactured of copper, but may be manufactured of any material commonly utilized for coils in the HVAC industry. The drenched coil **108** preferably has a substantially smooth cylindrical outer surface having an outer diameter of between one half inch and one inch with the bends of the coil **108** resulting in the tubes being spaced apart in a staggered arrangement. The spacing of the tubes is typically such that the space between each tube is slightly larger than the diameter of the tube.

[0056] The use of a coil drenching spray system **107** and drenched coil **108** provides a number of benefits. First, such a system **107** generates the atmosphere for wet-bulb control of the overall system. The wet-bulb (w.b.) temperature of air leaving the coil will generally be 20° F. above the spray water temperature. Such a system **107** also automatically provides consistent total heat (enthalpy) content of the conditioned air stream. The coil drenching spray system **107** continually cleanses the air and surfaces of the drenched coil **108**. The smooth surfaces of the coil array **108** eliminate the inherent problems of finned surface coils; namely air blockage due to frosting, dirt and bacteria buildup, which are not only unhealthy but also require excessive fan energy while providing lower system efficiency. Excess humidity condensed from the air becomes surplus water that is added to water used by the spray system **107** and this surplus water is automatically drained away along with any particulates. This feature eliminates unsanitary drain pans used in contemporary air conditioning systems. Further, air having low entering air wet-bulb conditions can absorb moisture from the sprays, which raises the leaving wet-bulb temperature to the control set point. As each pound of moisture absorbed into the air removes approximately 1000 BTU of sensible heat, the humidification of the air acts to reduce the amount of heat that needs to be removed by the compression circuit. The spray system **107** also provides a continuous defrosting of the surface of the drenched coil **108** and an averaging of coil surface temperatures, ensuring a consistent temperature of the leaving air mass.

[0057] After leaving the coil outlet, the air is turned upward into the air output portion **131** and the water from the coil drenching spray system **107** falls by gravity into the spray sump **116**. The use of gravity to remove the excess water from the air eliminates costly and energy robbing moisture eliminators and is another important feature of the air processor **100**.

[0058] The spray sump **116** is in fluid communication with an inlet control valve **109**, which controls a flow of potable water from a potable water supply line **119** and allows the spray sump **116** to be initially filled when outdoor temperatures are above 55° F. The spray sump **116** is also in fluid communication with a drain control valve **118** that allows spray sump **116** to be drained when outdoor temperatures are below 50° F. Finally, the spray sump **116** includes an overflow drain **141**, which allows excess water to automatically drain from the sump.

[0059] Air that has passed through the coil section **130** of the housing **129** next passes upward through the post-conditioning chamber **115**. Post-conditioning chamber **115** provides free reheat of return air when in cooling mode and pre-cooling of return air when in heating mode, which enhances dehumidification and system efficiency. As noted above, the coils **135**B, **136**B in the post-conditioning chamber **115** are in the same types of coils that pass through the preconditioning coil chamber **103**. Post-conditioning coil **135**B is in communication with piping from the recuperator system piping, thereby providing a first stage of heating without having to activate the compression subsystem **200** until second stage heat is required. Post conditioning thermal return coil **136**B is in communication with the thermal recirculating pump **114**, which causes the heat transfer fluid to flow through from the post-conditioning chamber **115** to the preconditioning coil chamber **103** and back again. The thermal recirculating pump **114** is preferably a relatively low pressure, low flow pump that is highly efficient and is selected and sized based upon the dimensions of the coils and the overall capacity of the system **50**.

[0060] After passing through the post-conditioning chamber **115**, the air is drawn into the supply fan **113**, passes over an electric heater **112** and out through the processed air outlet **142** into the room to be heated or cooled. The supply fan **113** is preferably a variable speed supply air fan that may be automatically adjusted as the heating or cooling load changes and is preferably sized for 400 CFM per ton of system capacity. The electric heater **112** is included as an emergency back-up and typically functions only when the compressor **200** is offline due to malfunction or low ambient temperatures. The electric heater **112** is preferably sized to match the basic heating capacity of the system **50**; i.e. if the system **50** is sized to produce 80,000 BTU of heating, the electric heater **112** would be selected to also produce 80,000 BTU of heating.

[0061] Return air that is diverted through the bypass damper **102** and directly into air output section **131** is referred to as “bypass return air”. Fresh air also passes through the economizer damper **110** in the fresh air inlet **145**, which is also located at the top of the housing **129** proximate to the air output section **131**. The economizer damper **110**, in conjunction with the bypass damper **102**, modulates fresh air and return air to provide free cooling when outdoor temperatures are low enough. The combined bypass return air and fresh air is next passed over evaporative cooling nozzles **110**, which function during low wet-bulb economizer operation to lower the conditioned air temperature and provide enthalpy correction. Finally, the combined bypass return air and fresh air is drawn into the supply fan **13**, where it mixes with air that has passed through the coil portion **131** of the housing **129**.

[0062] FIG. **3** shows the refrigerant input to the air processor **100** from the compression system **200**, the output of refrigerant from the air processor **100** back to the compression system **200** during the heating mode. Refrigerant is cooled or heated by the compression system **200** and is fed through pipes to the air processor **100**. A first check valve **120** and second check valve **121** are one way valves that direct the flow of the refrigerant to the coils **108**, **136** during the heating and cooling modes of operation.

[0063] FIG. **4** shows one embodiment of the system in which the air processor **100** is piped into an ice storage unit **160**. The ice storage unit **160** takes advantage of lower night energy costs by operating in ice building mode during night-time hours. The ice storage unit **160** includes four inlets for pumping heat transfer fluid into the unit, and an open chamber in which are disposed a plurality of four-inch diameter plastic balls that are filled with water, preferably those sold by Cryogel of San Diego, Calif., under the name Ice Ball™. The water within the plastic balls is frozen during ice building mode and act as an aid to cooling during daytime hours.

[0064] The embodiment of FIG. **4** includes a coaxial chiller **162** in addition to the ice storage unit **160**. The coaxial chiller **162** is preferably a tube-and-shell type heat exchange in which the heat transfer fluid is pumped through the shell by chiller pump **161** during ice building mode, where it is cooled by refrigerant passing through the tubes. During ice building mode, the flow of air through the air processor **100** is greatly reduced, which results in the refrigerant passing through the drenched coil **108** to drop well below the freezing temperature of water. This low temperature refrigerant passes into the coaxial chiller **162** where it cools the heat transfer fluid to a temperature that is also below the freezing temperature of water. This low temperature heat transfer fluid is then pumped into the ice storage unit **160** where it surrounds and slowly freezes the water filled plastic balls for later during cooling mode when air cooling is required.

[0065] When the system switches from ice building mode to cooling mode, the chiller pump **161** is shut off and the thermal recirculating pump **114** and three way valve **164** are activated so as to pump heat transfer fluid through the ice storage unit **160** where it surrounds the plastic balls and gives up heat by melting the stored ice within the plastic balls. The heat transfer fluid then passes back to the air processor **100** where it may be mixed with warmed heat transfer fluid from the post-conditioning chamber **115**, or be pumped by the thermal recirculating pump **114** directly back to the pre-conditioning chamber **103**.

[0066] The preferred compression sub-system **200** is shown in FIGS. **5** and **6**, with FIG. **5** showing the flow of refrigerant through the compression sub-system **200** when the system **50** is in cooling mode and FIG. **6** showing the flow of refrigerant through the compression sub-system **200** when the system **50** is in heating mode.

[0067] The compression subsystem includes compressor **202**, which provides variable refrigerant flow to match compression requirements to load. Compressor **202** may be any industry available compressor that is sized to match the desired output and is adapted to work in variable speed mode. Refrigerant flows through the compressor discharge line **226** to the reversing valve **204**, which works in concert with the manifold check valve **206** to redirect refrigerant flow as required for the cooling or heating cycle. The accumulator **208** stores excess liquid refrigerant from the air processor **50** during the cooling cycle and from the heat box **300** during the heating cycle. Condensed liquid is further sub-cooled by the internal heat exchanger **209** located within the accumulator **208**, which increases overall cycle efficiency. The suction line heat exchanger **210** dries the saturated suction gas slightly such that only gas is fed to the compressor **202**. A sub-cooling control valve **212**, preferably an expansion valve, allows liquid refrigerant to flow from the heat exchanger **209** after being sub cooled slightly, generally by about ten degrees Fahrenheit. A liquid booster pump **214** is provided to increase liquid refrigerant pressure, thereby increasing the sub-cooling effect. The liquid booster pump **214** is a refrigerant pump and also provides motive pressure for actuation of the de-super heating function.

[0068] During compression, the inefficiencies of the cycle are added to the gas leaving the compressor. This results in the refrigerant going through three phases in the condenser sub-system **200**. The first phase is de-superation, which is a sensible heat process that occurs through the de-superheater line **228** and de-super heater valve **216**; preferably a solenoid valve that is closed during the heating cycle and open during the cooling cycle. The de-super heater valve **216** cools the hot refrigerant to its saturation temperature, thereby freeing up more surface of the condenser for condensing rather than de-superation. The second phase is condensation, which occurs after the refrigerant is de-superheated. While in a saturated state, without any temperature change the latent heat of condensation is removed from the gas by the condensing surfaces. The third phase is sub-cooling, which is another sensible heat process that uses a condensing surface to cool the liquid refrigerant below its saturation temperature. It is noted that, although this process is preferred, duperheating may also be accomplished via a heat recovery unit connected to the recuperator subsystem **300**. Further, in lieu of the liquid booster pump **214** for subcooling and de-superheating, an evaporatively cooled sub-cooling coil could be applied.

[0069] As shown in FIG. **5**, when the system **50** is operated in cooling mode, the compression sub-system **200** takes warmed refrigerant from the air processor **50** and moves it into the accumulator **208**. Refrigerant in a gaseous state is then taken from the accumulator **208**, passes through the suction line heat exchanger **210** and moves into the compressor **202** where it is compressed. The compressed refrigerant then moves through the heat box **300** and into the manifold check valve **206**, which directs the refrigerant through the liquid booster pump **214** and back upward through the suction line heat exchanger **210**. The refrigerant passes through the heat exchanger **209** within the accumulator **108** through the filter drier **218** and subcooling valve **212** and back through the manifold check valve **206** where it is directed to the air processor **100**.

[0070] As shown in FIG. **6**, when the system **50** is operated in heating mode, the compression sub-system **200** takes cooled refrigerant from the air processor **100** and passes it through the manifold check valve **206**, which directs the refrigerant through the liquid booster pump **214** and back upward through the suction line heat exchanger **210**. The refrigerant passes through the heat exchanger **209** within the accumulator **108** through the filter drier **218** and subcooling valve **212** and back through the manifold check valve **206** where it is directed to the heat box **300**. The refrigerant passes from the heat box **300** into the accumulator **109**. Gaseous refrigerant is then drawn from the accumulator **208** through the suction line heat exchanger **210** and into the compressor **202**, where it is compressed and fed through the discharge line to the reversing valve **204**. The reversing valve **204** reverses the flow of the refrigerant back through the discharge line to the air processor **100**.

[0071] Referring now to FIG. **7**, the heat box **300** and recuperator sub-system **400** are shown in detail. The heat box **300** is preferably a cross flow plate fin type heat exchanger that includes both a refrigerant line **310** and a heat exchange line **312** containing a heat exchange liquid, such as glycol. The refrigerant line **310** and heat exchange line **312** are preferably disposed in an intertwined circuit and are put into heat conducting relation by a series of aluminum plates (not shown) that are attached to and deposed between the lines **310**, **312**. A series of motorized shutters **314** are disposed on end of its housing **318** and a fan **316** is disposed on another end of the housing **316**. The heat box **300** performs different functions depending upon whether the system **50** is in cooling or heating mode.

[0072] When the system **50** is in cooling mode, the heat box **300** routes heat as appropriate to atmosphere, to the recuperator **400**, to a potable water heater **410**, to a radiant heat water heater **420** or to a swimming pool heat exchanger (not shown) in order to use the waste heat from the process productively. During the heating cycle, the heat box **300** utilizes atmospheric or recuperator heat to provide increased operating efficiency. Further, during extreme low ambient conditions the heat box fan **316** shuts down, the shutters **314** are closed and total heat is supplied from the recuperator **400**, allowing efficient heat pump operation without the need to activate the defrost function. During daylight hours with mild temperatures, the heat box **300** is controlled to direct ambient heat for heat pump operation and the recuperator **400** is recharged by solar heating through the solar collector array **402**.

[0073] The recuperator sub-system **400** improves the overall efficiency of the system **50**, both on a daily and year round basis. This is accomplished by taking advantage of daytime heat energy and storing it for nighttime use, and/or by taking advantage of low nighttime electric energy rates to store additional heat for daytime use. Regardless of whether it is used in heating or cooling mode, thermal energy is stored in the thermal storage mass **404**, which is the stabilizer required for efficient heat pump operation.

[0074] The thermal storage mass **404** is essentially a large water filled tank **406** through which a heat transfer line **408** is disposed. During the winter months, latent heat is available from the thermal storage mass **404** of the recuperator **400** for cold weather heat pump operation. Effectively, it allows the heat pump to operate at 20° F. below zero as if it was 30° F. above zero. During the summer months the solar collector pump **416** runs a nocturnal cooling cycle in which the heat transfer fluid is pumped through the heat transfer line **408** and through the solar collector array **402**, which acts as a heat sink that releases excess stored heat to the atmosphere. This maintains the glycol below degradation temps and lowers the temperature of the thermal storage mass **404** to assist with daytime cooling. During winter months, the unique hydronic piping arrangement allows utilization of special nighttime electric rates to charge the thermal storage with low cost heat for daytime use, thereby allowing first stage heating, which improves the overall efficiency of the system.

[0075] The operating sub-system **500** is preferably a direct digital control (DDC) system, such as a properly configured EXCELL 5000 system as manufactured by Honeywell International, Inc., of Golden Valley, Minn., which provides seamless management and integration of all sub-systems **100**, **200**, **300**, **400** to capitalize on inherent design flexibility, while providing truly automatic and energy efficient operation. The operating sub-system **500** utilizes algorithms that perform a number of different functions. One algorithm resets parameters due to changing ambient conditions i.e. as the ambient wet-bulb temperature increases, unit operating wet-bulb temperature is reset to a lower level. Others police system operation: ensuring, integrity and continuous efficiencies. Still others provide notification and automatic switching to backup systems.

[0076] The operating sub-system **500** is similar in many respects to those utilized to control current HVAC systems and there are a number of DDC systems currently on the market that are readily adapted to perform the control functions required of the operating sub-system **500**. The primary requirements of the operating sub-system **500** are that it accept inputs from at least one user control, an internal temperature sensor and an external temperature sensor, that it include a processor that will process the user and temperature information and determine the appropriate system operating conditions based upon this processing, and that it include outputs that control the operation of the various system components.

[0077] Although the present invention has been described in considerable detail with reference to certain preferred versions thereof, other versions would be readily apparent to those of ordinary skill in the art. Therefore, the spirit and scope of the appended claims should not be limited to the description of the preferred versions contained herein.

What is claimed is:

1. An air processor for use in a heating and cooling system, said air processor comprising:

a housing comprising a top, a bottom, a coil section and an air output section;

an air inlet in communication with said top of said housing;

a bypass damper in communication with said air inlet and said air output section of said housing;

a preconditioning coil chamber disposed within said coil section of said housing and proximate to said air inlet, said preconditioning coil chamber comprising a first portion of a refrigerant coil in communication with a source of refrigerant and a first portion of a thermal return coil;

a coil drenching spray system disposed within said coil section of said housing between said at least one humidification nozzle and said bottom of said housing, said coil drenching spray system comprising a spray sump dimensioned to hold a volume of water, a recirculatory spray pump in fluid communication with said spray sump, a drenched coil comprising a refrigerant inlet in communication with said source of refrigerant and a refrigerant outlet, and at least one spray nozzle in communication with said recirculatory spray pump and disposed over said drenched coil such that water sprayed from said at least one nozzle contacts said drenched coil;

a post-conditioning chamber disposed within said air output section between said bottom of said housing and said bypass damper, said post-conditioning chamber comprising a second portion of said thermal return coil and a first stage heating coil in communication with a source of heat transfer fluid; and

a processed air outlet disposed within said air output section of said housing between said bypass damper and said post-conditioning chamber.

2. The air processor as claimed in claim **1** further comprising at least one ultraviolet emitter disposed within said coil section of said housing between said preconditioning coil chamber and said bottom or said housing.

3. The air processor as claimed in claim **1** further comprising at least one humidification nozzle disposed within said coil section of said housing between said at least one ultraviolet emitter and said bottom of said housing, said at least one humidification nozzle comprising a connector for connection to a supply of high purity water.

4. The air processor as claimed in claim **1** further comprising a filter section.

5. The air processor as claimed in claim **4** wherein said filter section comprises a pre-filter and a final filter.

6. The air processor as claimed in claim **1** further comprising at least one evaporative cooling nozzle disposed within said air output section between said bypass damper and said processed air outlet, wherein said at least one evaporative cooling nozzle comprises a connector for connection to a supply of high purity water.

7. The air processor as claimed in claim **1** further comprising a supply fan in fluid communication with said processed air outlet.

8. The air processor as claimed in claim **1** further comprising at least one electric heater.

9. The air processor as claimed in claim **8** comprising a first electric heater disposed within said coil section of said housing between said recirculatory spray system and said top of said housing and a second electric heater disposed within said processed air outlet.

10. The air processor as claimed in claim **1** wherein said spray sump further comprises a inlet control valve for attachment to a potable water line and a drain control valve for attachment to a drain line.

11. The air processor as claimed in claim **1** further comprising a fresh air inlet and an economizer damper disposed between said fresh air inlet and said air output section of said housing.

12. A heating and cooling system comprising:

an air processor comprising:

a housing comprising a top, a bottom, a coil section and an air output section;

an air inlet in communication with said top of said housing;

a bypass damper in communication with said air inlet and said air output section of said housing;

a preconditioning coil chamber disposed within said coil section of said housing and proximate to said air inlet, said preconditioning coil chamber comprising a first portion of a refrigerant coil and a first portion of a thermal return coil;

a coil drenching spray system disposed within said coil section of said housing between said at least one humidification nozzle and said bottom of said housing, said coil drenching spray system comprising a spray sump dimensioned to hold a volume of water, a recirculatory spray pump in fluid communication with said spray sump, a drenched coil comprising a refrigerant inlet and outlet, and at least one spray nozzle in communication with said recirculatory spray pump and disposed over said drenched coil such that water sprayed from said at least one nozzle contacts said drenched coil;

a post-conditioning chamber disposed within said air output section between said bottom of said housing and said bypass damper, said post-conditioning chamber comprising a second portion of said refrigerant coil and a second portion of said thermal return coil; and

a processed air outlet disposed within said air output section of said housing between said bypass damper and said post-conditioning chamber;

a compression subsystem in communication with said air processor, said compression subsystem comprising and accumulator, a compressor, a reversing valve and at least one refrigerant line;

a heat box comprising a refrigerant line in fluid communication with said at least one refrigerant line of said compression subsystem, a heat exchange line and a series of motorized shutters;

a recuperator comprising a thermal storage means, a supply pump and at least two heat exchange lines, wherein a first heat exchange line is in fluid communication with said heat exchange line of said heat box and wherein said second heat exchange line is in communication with said air processor; and

an operating system in electrical communication with said air processor, said compression subsystem, said heat box and said recuperator, wherein said operating system comprises at least one input from at least one user control, an internal temperature sensor and an external temperature sensor, a processor comprising a computer program product for processing user and temperature information and determining an appropriate system operating condition based upon said user and temperature information, and at least one output to each of said air processor, said compression subsystem, said heat box and said recuperator.

13. The heating and cooling system as claimed in claim **12** wherein said heat box further comprises a fan disposed such that air may be blown over said refrigerant line and said heat exchange line and wherein said output from said computer program product of said operating system controls an operation of said motorized shutters and said fan,

14. The heating and cooling system as claimed in claim **13** wherein said heat box further comprises a plurality of conductive plates attached to, and in heat conducting relation to, aid refrigerant line and said heat exchange line.

15. The heating and cooling system as claimed in claim **12** further comprising at least one of a potable water heater and a radiant heat water heater in communication with said heat exchange line of said heat box, wherein said output from said computer program product of said operating system controls a flow of heat transfer fluid from said heat box to at least one of said potable water heater and said radiant heat water heater when said system is in a cooling mode of operation.

16. The heating and cooling system as claimed in claim **12** wherein said recuperator further comprises at least one solar collector array in fluid communication with said thermal storage means.

17. The heating and cooling system as claimed in claim **12** further comprising an ice storage unit through which a heat transfer fluid line is disposed, wherein said heat transfer fluid line is in fluid communication with said air processor.

18. The heating and cooling system as claimed in claim **17** further comprising a coaxial chiller, wherein said heat transfer fluid line is disposed through said coaxial chiller and said ice storage unit and wherein said coaxial chiller is disposed relative to said ice storage unit such that a heat transfer fluid passing through said heat transfer fluid line passes through said coaxial chiller before passing through said ice storage unit.

19. The heating and cooling system as claimed in claim **12** further comprising a first check valve and a second check valve;

wherein said first check valve is in communication with one of said at least one refrigerant line from said compression subsystem and said refrigerant coil of said preconditioning coil chamber and is disposed so as to control a flow of refrigerant to said refrigerant coil of said preconditioning coil chamber;

wherein said second check valve is in communication with said refrigerant coil of said preconditioning coil chamber and said refrigerant inlet of said drenched coil of said coil drenching spray system; and

wherein said output from said computer program product of said operating system controls said first check valve and said second check valve based upon whether said system is in a cooling mode of operation or a heating mode of operation.

20. The heating and cooling system as claimed in claim **12** wherein said spray sump of said coil drenching spray system comprises an inlet control valve in communication with a potable water supply line and a drain control valve in fluid communication with an overflow drain;

wherein said inlet control valve and said drain control valve are computer controlled valves; and wherein said output from said computer program product of said operating system controls a position of said inlet control valve and said drain control valve based upon a signal from said external temperature sensor such that said spray sump is filled when an external temperature is at least 55° Fahrenheit and such that said spray sump is drained when said external temperature is below 50° Fahrenheit.

21. A heating and cooling system comprising:

an air processor;

a compression subsystem in communication with said air processor, said compression subsystem comprising and accumulator, a compressor, a reversing valve and at least one refrigerant line;

a heat box comprising a refrigerant line in fluid communication with said at least one refrigerant line of said compression subsystem, a heat exchange line and a series of motorized shutters;

a recuperator comprising a thermal storage means, a supply pump and at least two heat exchange lines, wherein a first heat exchange line is in fluid communication with said heat exchange line of said heat box and wherein said second heat exchange line is in communication with said air processor; and

an operating system in electrical communication with said air processor, said compression subsystem, said heat box and said recuperator, wherein said operating system comprises at least one inputs from at least one user control, an internal temperature sensor and an external temperature sensor, a processor comprising a computer program product for processing user and temperature information and determining an appropriate system operating condition based upon said user and temperature information, and at least one output to each of said air processor, said compression subsystem, said heat box and said recuperator.

22. The heating and cooling system as claimed in claim **21** wherein said heat box further comprises a fan disposed such that air may be blown over said refrigerant line and said heat exchange line and wherein said output from said computer program product of said operating system controls an operation of said motorized shutters and said fan,

23. The heating and cooling system as claimed in claim **22** wherein said heat box further comprises a plurality of conductive plates attached to, and in heat conducting relation to, aid refrigerant line and said heat exchange line.

24. The heating and cooling system as claimed in claim **21** wherein said recuperator further comprises at least one solar collector array in fluid communication with said thermal storage means.

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