



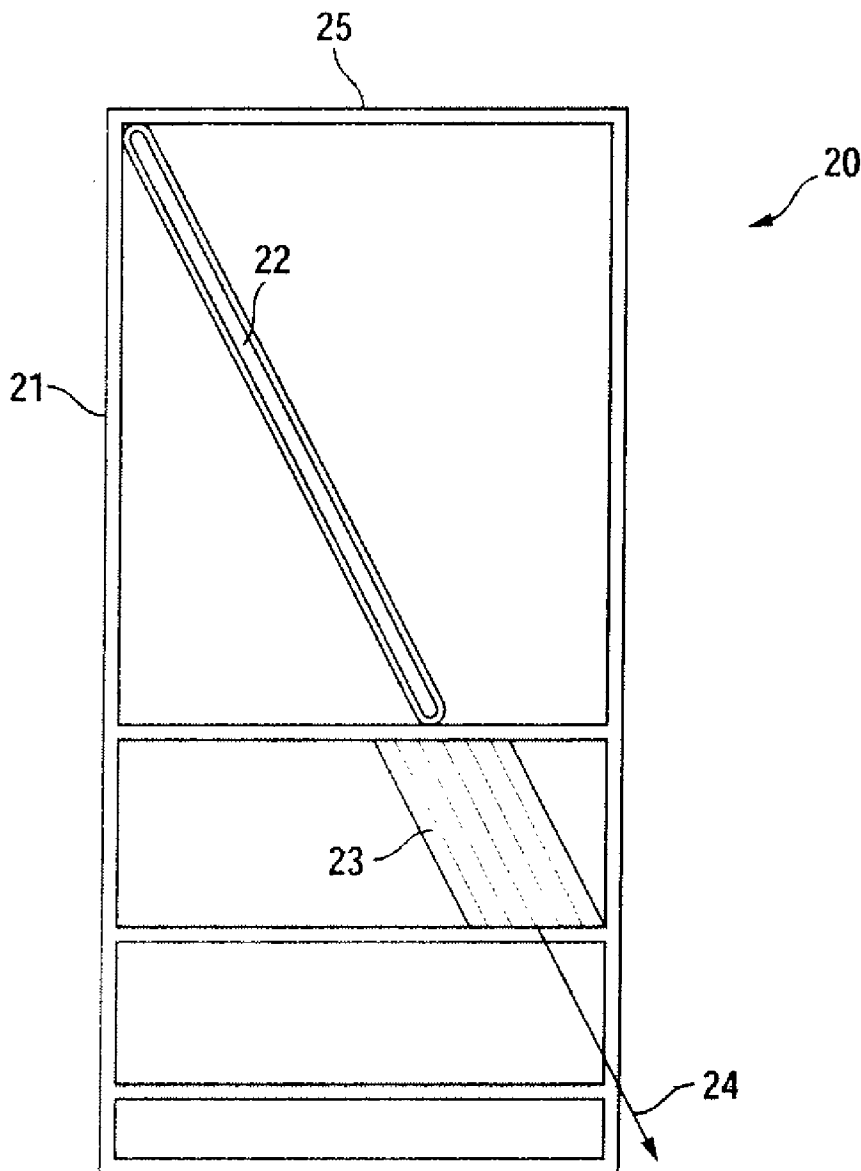
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(19) **United States**(12) **Patent Application Publication**  
**Cockrell**(10) **Pub. No.: US 2010/0107658 A1**(43) **Pub. Date: May 6, 2010**(54) **DATA CENTER COOLING DEVICE AND METHOD**(76) Inventor: **Richard Erwin Cockrell, Napa, CA (US)**

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(21) Appl. No.: **12/264,648**(22) Filed: **Nov. 4, 2008****Publication Classification**(51) **Int. Cl.****F25D 23/12** (2006.01)**F25B 1/00** (2006.01)(52) **U.S. Cl.** ..... **62/62; 62/259.2; 62/498; 62/208**(57) **ABSTRACT**

A cooling system and method for cooling devices housed in a data center. A cabinet housing a set of condenser coils is located within the data center positioned on its floor and including fans for drawing air passed the condenser coils and exiting the device angularly to the floor of the data center. The present invention also contemplates the use of redundant compressors and condensers, a system that includes a secondary evaporator coil and configuration which enables the device, under certain conditions, to bypass its compressor.



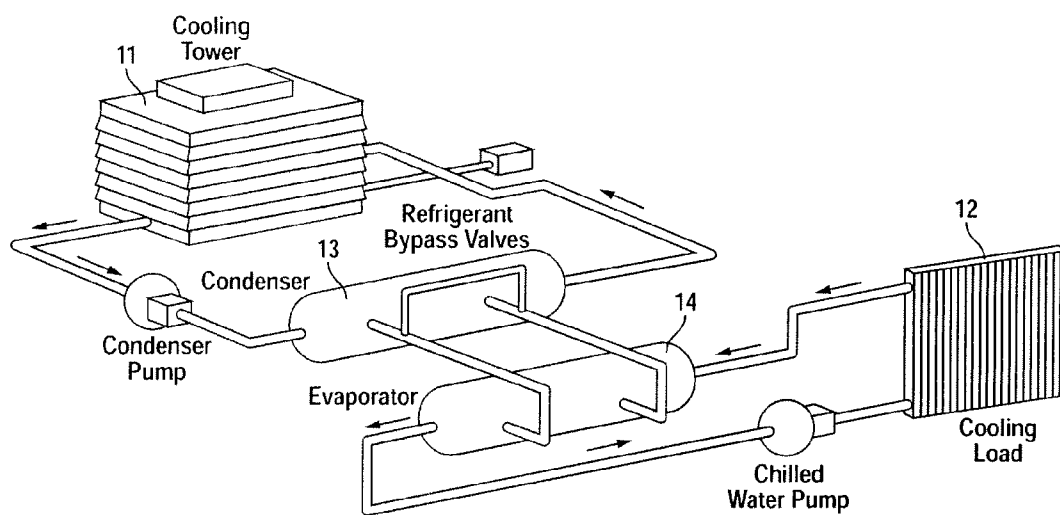


**FIG. 1**  
(Prior Art)

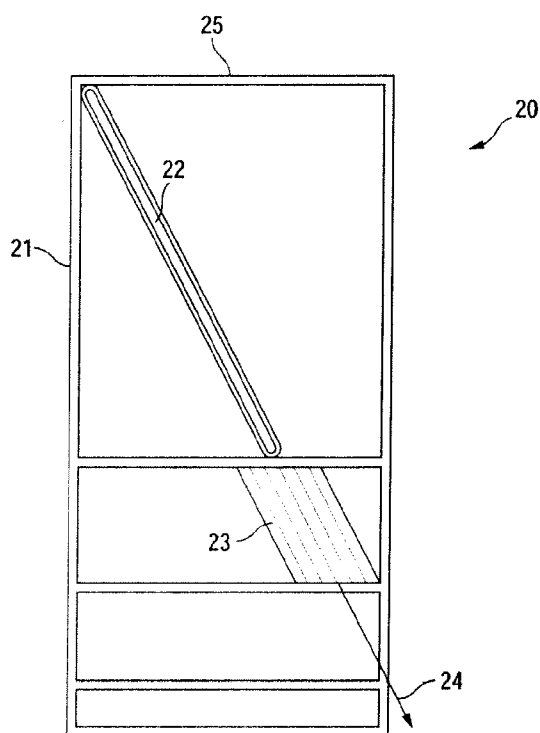


**FIG. 2**

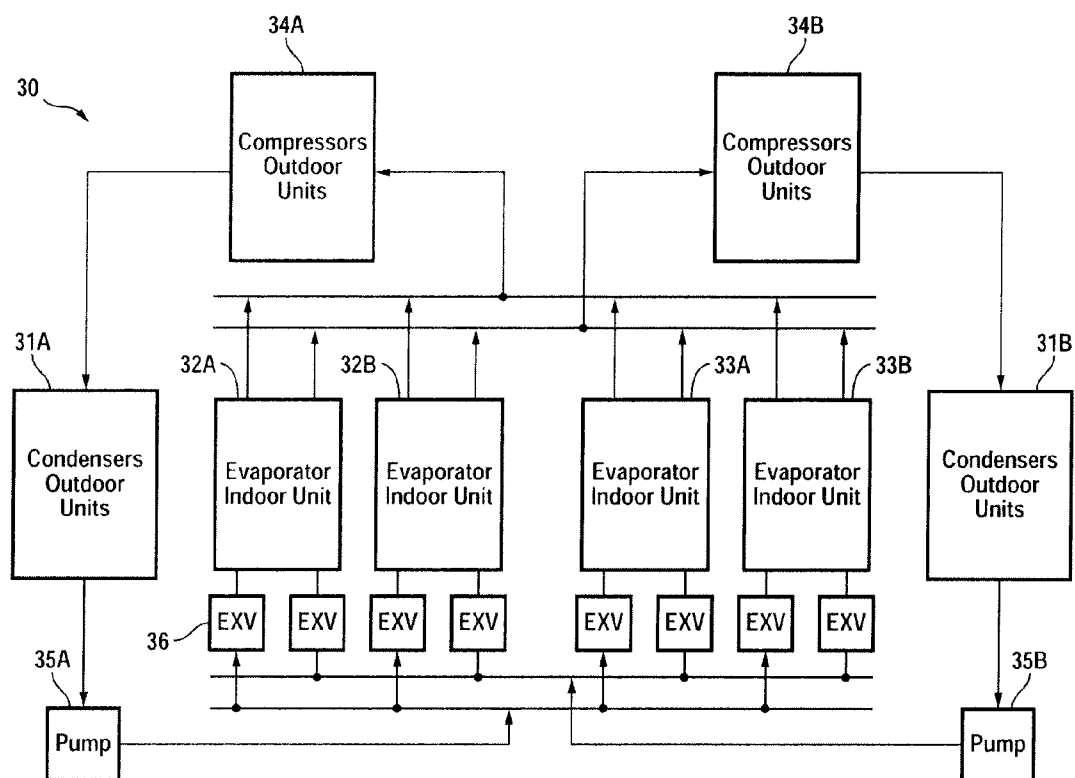


FIG. 3

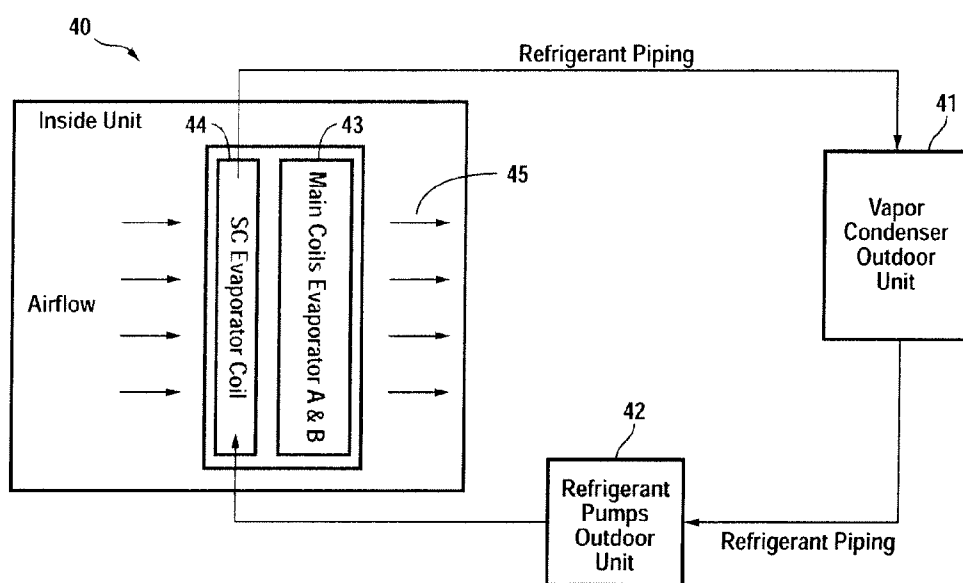


FIG. 4

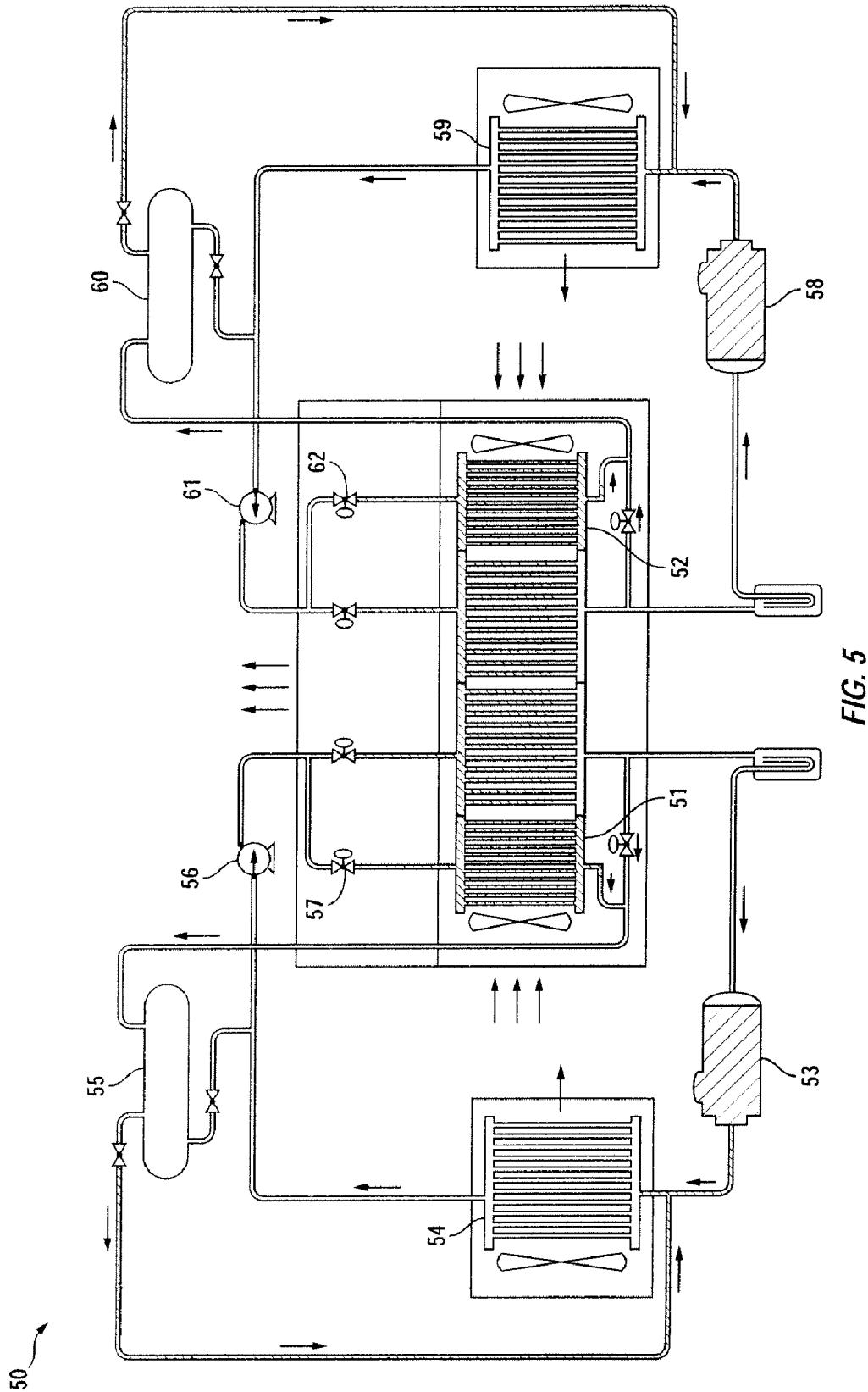


FIG. 5

## DATA CENTER COOLING DEVICE AND METHOD

### TECHNICAL FIELD

**[0001]** The present invention involves a cooling system and method for its operation used for cooling devices in a data center. Data centers are rooms that contain electronic systems generally arranged on racks, the standard rack being defined by the EIA as an enclosure approximately 78" high, 24" wide and 40" deep. These racks are employed to house printed circuit board-based devices which, under normal operation, can generate significant amounts of heat. For the proper operation of such devices and for maintaining them throughout their normal life cycle, proper temperature and humidity must be maintained.

### BACKGROUND OF THE INVENTION

**[0002]** Historically, computer room air conditioning (CRAC) systems were manufactured by those who supplied residential and commercial air conditioning systems, generally. The design philosophy was to build such systems at the lowest possible cost, that is, the cost of manufacturing being more important than the operational cost of the system. These CRAC systems were built to do as much work as possible while occupying the smallest possible space within the data center. Energy consumption in running these systems was less of a consideration than the floor space that the units would occupy in a typical data center location.

**[0003]** These design considerations have changed considerably over time as computing systems of the type typically located within a data center consume considerable amounts of energy while generating heat necessitating CRAC systems of greater efficiency. With the increasing popularity of the Internet, data centers are now considered to be the number one energy consumer in the United States.

**[0004]** There have been three fundamental CRAC system designs referred to, for the sake of simplicity, as CRAC1, CRAC2 and CRAC3.

**[0005]** CRAC1 is a split refrigeration system with outdoor air cooled condensing. This system is characterized by having two main components, namely, the CRAC unit itself located inside of the data center and a condenser located external thereto. The indoor unit houses the systems' compressors, evaporators, controls and cooling fans. The outdoor unit houses the condenser and condenser fans which inter-connect to the indoor unit with piping through which the refrigerant travels.

**[0006]** The CRAC2 system also employs two main components, namely, the CRAC units located within the data center and heat exchanger components located external thereto. The indoor unit houses the compressor, condenser, evaporator, system controls and cooling fans. The outdoor unit is composed of a heat exchanger from which heat from the system is rejected as well as pumps used to move heat transfer fluid from the indoor to outdoor units. This design can also have an optional heat exchanger located in series with the indoor heat exchangers. When the fluid temperature from the outdoor heat exchanger is below the return air temperature, a valve opens allowing the heat transfer fluid to pass through the lead heat exchanger. The fluid removes heat from the return air stream.

**[0007]** CRAC3 systems employ CRAC units located in the data center and fluid chillers located external thereto. The

indoor unit houses the indoor heat exchanger, indoor fan systems and controls. The outside unit is composed of either a self-contained refrigeration system which chills the heat transfer fluid which is usually air cooled or a split chiller system which is composed of a compressor, evaporator, fluid cooled condenser and fluid cooled heat exchanger.

**[0008]** Regardless of the system type, the design philosophy in sizing and installing CRAC systems in a data center is quite consistent from installation to installation. The typical installation involves adding a sufficient number of units to meet the anticipated heat load of the facility and one additional unit for redundancy. Thus, as facilities grow, more indoor and outdoor units are added to the system noting that, typically, each CRAC unit operates independently of other units. Thus, the control valves of each unit are turned on and off independently of other units to meet and maintain building loads. Indoor fans never shut off to maintain the load imposed upon the facility. Centrifugal fans are commonly employed for supply side air. Small fans are employed even though smaller fans are generally more inefficient than those which are larger. Regardless of fan type, current CRAC installations are based upon a "one load, one system" methodology. Such installations exhibit the same efficiency when operating under normal or emergency conditions. These systems do not integrate redundancy in the form of additional heat exchange area in order to make them more efficient. Parameters seldom change dramatically unless loads change dramatically. The redundancy of this type of system is based upon adding units which are brought on line as needed.

**[0009]** It is quite apparent that previously suggested CRAC systems made no attempt to maximize operating efficiencies as most prior designs were created well before energy became as expensive as it is today and before the explosive use of Internet-based communications and information downloading created such a severe impact upon energy usage and resultant heat generation.

**[0010]** Thus, it is an object of the present invention to provide CRAC systems having several unique and innovative design criteria to make such systems much more efficient to operate while maximizing their ability to effectively cool a data center both under ordinary conditions and when emergencies require supplemental cooling capacity.

**[0011]** It is yet a further object of the present invention to provide a data center cooling system which, depending upon environmental conditions, can transfer coolant while bypassing the systems' compressor.

**[0012]** Although the discussion which appears below reveals a unique system capable, under certain conditions, to provide coolant to condenser coils without use of a compressor, the present invention is not the first instance in which compressor-free cooling has been suggested. In this regard, reference is made to FIG. 1 representing a schematic drawing of such a system commercially available from Trane Co. Specifically, when water returning from cooling tower 11 is colder than the chilled water circulating through cooling load 12, refrigerant pressure within condenser 13 is slightly lower than that in evaporator 14. This pressure differential drives the refrigerant vapor "boiled off" in evaporator 14 to condenser 13, where it condenses and flows by gravity back to evaporator 14. As long as the proper pressure difference exists between evaporator 14 and condenser 13, refrigerant flow and consequent "free cooling" continues. According to its manufacture, the system shown in FIG. 1 is capable of refrigerant migration "free cooling" up to as much as 40% of the chiller's

design tonnage. Since the chiller and “free cooling” cycle cannot operate simultaneously, free cooling of this type can only be used when the cooling capacity of water tower 11 is sufficient to meet the entire building load. As “free cooling” capacity is available only when the ambient wet bulb temperature is below 50 degrees F., accessories such as chilled water pumps, condenser water pumps and cooling tower fans must continue to operate in their conventional manner while the chiller operates in the “free cooling mode.” This minimizes the energy savings from such a system which is realized only from its ability to bypass its compressor.

#### SUMMARY OF THE INVENTION

**[0013]** As a first embodiment, the present invention involves a cooling system for cooling devices housed in a data center, the device comprising a cabinet, a set of evaporator coils, an inlet and outlet and at least one fan for drawing air from within the data center through said cabinet and for movement of the air over said evaporator coils to the data center heat loads. The improvement comprises angling the air flow emanating from the cabinet proximate 45° to 70° to the plane of the flooring.

**[0014]** As a second embodiment, the invention is directed to a cooling system for cooling a data center to a predetermined temperature and humidity, the cooling system comprising a set of evaporator coils and a fan for moving air within the data center passed the set of evaporator coils. At least two sets of compressors, two sets of condensers and two independent control systems are located external to the data center and positioned in parallel to provide coolant to the set of evaporator coils.

**[0015]** The third embodiment involves a cooling system comprising a compressor, a condenser, coolant, pump and primary evaporator coil for cooling. The improvement comprises a secondary evaporator coil in series with the primary evaporator coil, the secondary evaporator coil being a flooded coil piped to the condenser.

**[0016]** As yet another embodiment, the invention involves a cooling system comprising a compressor, condenser, condensable coolant, pump and evaporator coils. The improvement comprises a measurement device and actuator wherein when the measurement device measures the wet-bulb temperature and when it is no greater than a preselected value, the compressible coolant is circulated by the pump between the condenser and evaporator coils while bypassing the compressor.

#### BRIEF DESCRIPTION OF THE FIGURES

**[0017]** FIG. 1 is a schematic depiction of a commercially available chiller of the prior art.

**[0018]** FIG. 2 is a side view of a portion of the present invention showing evaporator coils and fans to be housed in a cabinet used for cooling an appropriate data center according to the present invention.

**[0019]** FIG. 3 is a schematic view of a system according to the present invention including two circuits provided for redundancy and for increased efficiency.

**[0020]** FIG. 4 is a schematic view of a part time economizing system using a scavenger coil in series with main evaporator coils to increase efficiency of the present invention.

**[0021]** FIG. 5 is yet another schematic view of an economizing circuit similar to that depicted in FIG. 3.

#### DETAILED DESCRIPTION OF THE INVENTION

**[0022]** Turning first to FIG. 2, housing 20 is depicted with its side walls removed for illustrative purposes. Frame members 21 support sets of evaporator coils 22 receiving coolant from compressors and related hardware located external to the data center being cooled.

**[0023]** In operation, ambient air within the data center is drawn through open top 25 passed sets of evaporator coils 22 through the use of prop or axial fans 23. Ideally, multiple fans are employed sufficient to maintain a positive static pressure within a space beneath the flooring. Although not shown, cool air created by housing 20 is discharged proximate racks of circuit boards and similar solid state devices through openings strategically located proximate thereto.

**[0024]** A feature of the present invention is the orientation of fans 23 in directing cooled air in the direction of arrows 24. CRAC units of the prior art generally employ centrifugal fans that blow air directly at the floor. This increases the static pressure load on the fans as the air is forced to change direction by 90 degrees upon impacting the floor. The present invention employs prop or axial fans 23 directing air discharge as shown by arrows 24 by mounting the fans at a 20 to 45 degree angle from vertical or 45 to 70 degree angle proximate to the plane of the floor. This provides a much improved approach angle of the cold air discharge relative to the floor and reduces the pressure drop characterized by prior systems. All such expedients are considered to be embraced within the present invention. Sufficient fans are employed for maintaining static pressure and air flow within the space noting that output can be varied to maintain the required static pressure via static pressure sensors.

**[0025]** Yet a further embodiment of the present invention can be appreciated by reference to FIG. 3. In its basic terms, system 30 is composed of two simple circuits, operating in parallel. Specifically, parallel condensers 31A and 31B as well as parallel compressors 34A and 34B operate externally to the data center each set operating in conjunction with pumps 35A and 35B, respectively, to supply coolant to expansion valves 36 and onto evaporators 32A/32B and 33A/33B, located within the data center. Redundant condensers and evaporators are operated together at part load while increasing the heat exchange surface area resulting in a decrease in the temperature differences within the system; that is, the temperature difference between the coolant temperature and the air temperature flowing over the coil. By decreasing this temperature difference, pressures are generally higher on the evaporator side and lower on the condenser side of the system thereby decreasing the compression ratio of the coolant and reducing the energy the compressors consume to compress the coolant gas.

**[0026]** A main function of the present system is that it allows for reduced compression operation. Compression ratio is a reference to the difference between the suction and the discharge pressures measured in absolute pressure. There are several main reasons why the present invention can accomplish reduced compression where others cannot.

**[0027]** As background, typical systems compression ratios are derived by the use and control of the condensing pressure. Typical systems control the condensing pressure by either staging the condenser fans off and on to meet a set point of condensing pressure or speed control fans to meet that spe-

cific point. The present system utilizes a unique form of control to allow for reduced compression. Instead of turning fans on and off or slowing them down to meet a specific point, the present system utilizes a variable set point. Ideally, this set point establishes a condensing temperature that is 8 degrees F. higher than the wet bulb temperature. Condensers are controlled to match loads in ton and to match a true constant set point.

**[0028]** It should be noted that every major compressor manufacturer establishes proper operational conditions for its products. It is common for manufacturers to state that a compression ratio of 1.5 to 1 is the lowest allowable compression ratio as anything less is not warrantable. Increased mass flow rate is the main reason manufacturers do not want lower compression ratios. As compression ratios decrease, a machine's capability of pumping refrigerant increases. As an example, at a 2 to 1 compression ratio, a machine may be capable of pumping 50 tons of coolant while at a 1.5 to 1 compression ratio a machine may be capable of pumping 75 tons of coolant and at 1.05 to 1, that same machine may be capable of pumping 100 tons of coolant. As the mass flow rates increase thru the compressor restriction, friction increases as well, as much as double in some cases. This causes a higher amount of wear and tear on machine parts as gas flows thru the compressor ports, pipe and valves.

**[0029]** The present system commonly operates at compression ratios of 1.05 to 1-1.51 to 1 and in most cases it operates well under a manufacture's published allowable compression ratio for long periods of time. This is done by not exceeding the machine's designed mass flow rate rather than compression ratio. This is achieved by reducing the speed of the compressor to only allow the machine to pump coolant to match its maximum mass flow rate.

**[0030]** To enable the present system to perform at reduced compression levels, it must be able to compensate for what normal systems cannot do. Low compression ratios create lower flow rates through typical metering devices. Every metering device is rated based on pressure differential across its valve. For example, a common metering device may be rated at 15 tons under common conditions, but as a system's compression ratio or pressure differential drops, that same valve may be only rated for 5 to 10 tons.

**[0031]** Ideally, metering valves used herein are rated and designed at a 1.3 to 1 compression ratio. These metering valves are provided with a constant pressure differential by amplifying liquid pressure entering the valve with the use of a liquid coolant pump and speed control. Pump speed is varied to maintain a constant pressure drop across the metering devices.

**[0032]** Yet a further embodiment of the present invention can be appreciated by reference to FIG. 4. Specifically, system 40 is depicted whereby coolant from pump 42 located externally to the data center urges coolant through a separate evaporator coil 44 which is called a "scavenger coil." The scavenger coil is located in series with main evaporator coils 43 through which air flows in the direction of arrows 45 for cooling the data center. Vapor condenser 41 is also located externally to the data center to complete the circuit.

**[0033]** Again referring to FIG. 4, scavenger coil 44 is a flooded coil that is piped directly back to condenser 41. When the coolant temperature is lower than the return air temperature, bypass valve 47 opens allowing coolant into the scavenger coil where it removes heat from the data center. The coolant then returns directly back to condenser 41, via flash

vessel 33 without moving through a compressor, thus enhancing system efficiency. As condenser 41 still uses energy to remove heat and pumps use energy to pump coolant, some energy is still employed to operate system 40. However, energy usage is far more efficient than in a typical vapor compressor cycle.

**[0034]** As is quite apparent, coolant from the pump goes through an entirely separate cooling coil called the scavenger coil (SC) in series with the main evaporator coils. This SC coil is a flooded coil that is direct piped back to the condenser. When the condensing liquid temperature is lower than the return air temperature a valve opens allowing refrigerant into the scavenger coil where it removes heat and goes directly back to the condenser to extract the heat from the room. If, for example, the return air temperature is 68° F. and the condensing liquid temperature is 65° F., heat from the return air is absorbed into the refrigerant (hot goes to cold). The larger the differential is between the return air temperature and the refrigerant temperature, the more energy is removed with this coil. Since a BTU is a BTU the condensers still use energy to remove the heat and the pumps use energy to pump the refrigerant there still is energy used. This energy usage is far more efficient than a typical vapor compressor cycle.

**[0035]** To summarize, coolant pump 42 pumps liquid refrigerant to feed devices 49 and into the scavenger coils 44. Inside the scavenger coils, the liquid refrigerant removes heat while still in a semi liquid form. Liquid refrigerant leaves the scavenger coils and flows to flash vessel 46. Vapor leaves flash vessel 46 and enters the condenser 41 to be condensed. Flash vessels 46 level is approximately 2 feet below condenser 41 outlet for purposes of maintaining a proper liquid trap. Flash vessel 46 maintains a liquid level based on the weight of the refrigerant and acts as an expansion tank.

**[0036]** The present system is also designed, under certain conditions, to allow for "free cooling." This means that the system operates under the physics of a thermo-siphon or through migration cooling as was suggested when discussing FIG. 1. However, in this instance, when the wet bulb temperature is less than approximately 41-45 degrees F., the "free cooling" cycle operates. Instead of operating with gravity controlling the flow rate as in the prior art, the present system employs a pump to ensure there is enough of a pressure difference to allow the coolant to flow through the metering valve and the evaporator where it is boiled off and routed through a motorized valve to the condenser where it condenses without moving through a compression cycle. If the system detects a lack of movement of the coolant or if a pulse is detected indicating a break in natural migration from the condenser to the evaporator, the compressor is activated by a sensor enabling the system to operate normally.

**[0037]** To fully appreciate the system architecture of the present invention, as its preferred embodiment, reference is made to FIG. 5. It is noted that system 50 is, in effect, one system having two circuits. Multiple evaporator coils 51 and 52 are located within the data center to be cooled. A first circuit comprised of compressor 53, condenser 54, expansion receiver 55, pump 56 and metering valves 57 is employed in conjunction with parallel elements comprised of compressor 58, condenser 59, expansion receiver 60, pump 61 and metering valves 62. Both circuits work together but are capable of working independently in case of system failures or emergencies. Each air handling unit has both circuits operating in parallel comprised of the same components as in any typical refrigeration system. The systems can be expanded to meet

growing loads. Indoor and outdoor units can be added as demand or as planned expansion requires. Further, through the use of pumps **56** and **61** together with metering valves **57** and **62**, economizing can be carried out as explained above, by circulating coolant without use of compressors **53** and **58** if outdoor wet bulb temperatures so dictate.

**[0038]** What was discussed above represents examples of various embodiments of the present invention. It is assumed that other embodiments will be readily apparent to those skilled in the art. It is intended that the specification is to be considered illustrative of the present invention, the scope of which is to be limited only by the claims.

What is claimed is:

**1.** In a cooling system for cooling devices housed in a data center, said device comprising a cabinet, a set of evaporator coils, an inlet and outlet and at least one fan for drawing air from within said data center through said inlet and outlet and for movement of said air over said evaporator coils to a plenum providing cooler air to said data center, the improvement comprising angling the air flow emanating from said cabinet proximate to the plane of said flooring.

**2.** The cooling system of claim **1** wherein said at least one fan comprises a prop or axial fan.

**3.** The cooling system of claim **2** wherein said at least one fan comprises a fan having a blade diameter of approximately 24" to 28".

**4.** The cooling system of claim **2** wherein sufficient fans are employed for maintaining static pressure and air flow within said space and being capable of changing their output to maintain the required static pressure via multiple static pressure sensors.

**5.** A cooling system for cooling a data center to a predetermined temperature and humidity level, said cooling system comprising a set of evaporator coils and at least one fan for moving air within said data center passed said set of evaporator coils, at least two sets of compressors and two sets of condensers located external to said data center, positioned in parallel to provide coolant to said set of evaporator coils.

**6.** The cooling system of claim **5** wherein each of said compressors and condensers operate at a load that is less than the load imposed upon said cooling system if only a single compressor and single condenser was used to operate said cooling system to maintain said evaporator coils at a selected temperature difference between the temperature of coolant passing within said evaporator coils and air passing over said evaporator coils within said data center.

**7.** The cooling system of claim **6** wherein a single set comprising a compressor and condenser, acting alone, is sized to enable them to operate said evaporator coils at said predetermined temperature difference.

**8.** In a cooling system comprising a compressor, a condenser, coolant, pump and primary evaporator coil for cooling, the improvement comprising a secondary evaporator coil in series with said primary evaporator coil, said secondary evaporator coil being a flooded coil directly piped to a flash vessel to ensure said condenser only receives coolant in the appropriate state.

**9.** The cooling system of claim **8** further comprising a valve wherein when said coolant temperature is lower than ambient room temperature, said valve selectively allowing for introduction of coolant into flooded secondary evaporator coil.

**10.** The cooling system of claim **9** wherein said coolant is returned to said condenser, via the flash vessel from said flooded secondary evaporator coil while bypassing said compressor.

**11.** In a cooling system comprising a compressor, condenser, coolant, pump and evaporator coils, the improvement comprising a measurement device and actuator wherein when said measurement device measures a wet bulb temperature and when less than or equal to a preselected value, said coolant is circulated by said pump between said condenser and evaporator coils wherein thermo-siphon automatically transfers coolant from said evaporator coils to said condenser, via a flash vessel while bypassing said compressor.

**12.** The cooling system of claim **11** further comprising two sensors, one for wet bulb temperature and one for return air temperature, the wet bulb temperature sensor being the primary trigger to activate and deactivate the transferring of coolant from evaporator to condenser, via said flash vessel through a bypass valve bypassing said compressor, said compressor being deactivated thereby.

**13.** The cooling system of claim **12** further comprising a return air sensor such that if the return air temperature rises to a preset level, said bypass valve is closed and said compressor is reactivated.

**14.** A method for cooling devices housed in a data center comprising positioning a set of evaporator coils on the floor of the data center, drawing ambient air from within said data center passed said set of evaporator coils and directing said air at an angle proximate to the plane of said floor.

**15.** The method of claim **14** wherein said air is directed passed said evaporator coils through the use of at least one prop or axial fan.

**16.** The method of claim **15** wherein said at least one fan comprises a fan having a blade diameter of approximately 24" to 28".

**17.** The method of claim **14** wherein said air emanating from said evaporator coils is directed towards said devices in a space where required static pressure is maintained via said at least one prop or axial fan.

**18.** A method for cooling devices in a data center to a predetermined temperature and humidity, said method comprising providing a set of evaporator coils, a fan, two sets of compressors and two sets of condensers located external to said data center positioned in parallel, moving air within said data center passed said set of evaporator coils and using said at least two sets of compressors and two sets of condensers to provide coolant to said set of evaporator coils.

**19.** The method of claim **18** wherein each of said compressors and condensers are operated at a load that is less than the load imposed upon said cooling system if only a single compressor and single condenser was used to operate said cooling system to maintain evaporator coils at a selected temperature difference between the temperature of the coolant passing within said evaporator coils and air passing over said evaporator coils for said data center.

**20.** The method of claim **18** wherein a single set comprising a compressor and condenser, acting alone, is sized to enable it to operate said evaporator coils at said predetermined temperature difference.

**21.** A method for cooling devices housed in a data center comprising a cooling system of a compressor, condenser, coolant, pump and primary evaporator coil for cooling, and further comprising a secondary evaporator coil in series with

said primary evaporator coil wherein said secondary evaporator coil is flooded by being directly piped to said condenser, via a flash vessel.

**22.** The method of claim **21** wherein when said coolant temperature is lower than room air temperature, coolant is introduced into said secondary evaporator coil.

**23.** The method of claim **22** wherein said coolant is returned to said condenser from said secondary evaporative coil, via said flash vessel while bypassing said compressor.

**24.** A method for cooling devices housed in a data center including a device comprising a compressor, condenser, coolant, pump and evaporator coils, wherein when the wet bulb temperature of outdoor air is below a preset value, said coolant is circulated by said pump between said condenser and evaporator coils, via a flash vessel, while bypassing said compressor.

**25.** The method of claim **24** wherein when said coolant ceases to travel from said condenser to said evaporator coils and back to said condenser, said compressor is activated for compressing said coolant.

**26.** In a cooling system comprising a compressor, condenser, coolant, pump and evaporator coils, the improvement comprising operating said compressor at compression ratios below approximately 1.5 and above 1.01 to 1.

**27.** The cooling system of claim **26** wherein condenser set points are variable and float 7° to 15° F. above outdoor wet bulb temperature.

**28.** The cooling system of claim **26** further comprising metering devices whereby coolant pumps, through speed control, maintain the selected pressure differentials and flow rates through said metering devices.

**29.** The cooling system of claim **26** further comprising sensors for controlling the speed of said compressor such that as the compression ratios are reduced, mass flow rates of said compressor is not exceeded beyond a preselected value.

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