

COMPUTER ROOM COOLING SYSTEM WITH BIFURCATED HEATED AIR RETURN PATHWAY

5 TECHNICAL CONTRIBUTION

The present disclosure relates to computer room cooling systems. More particularly, the present disclosure relates to a computer room cooling system with a bifurcated heated air return pathway.

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BACKGROUND

FIG. 1 is a block diagram illustrating a heated air return pathway, of the prior art, through a computer room **15**. To assist in the description of items in the figures, **FIG. 1** identifies several planar interfaces. The terms “plane” and “co-planar”, as used in this description, are intended to describe cross-sectional volumes (either horizontal or vertical) within the computer room **15**, rather than ideal planes having no volume. A first horizontal plane **21** is co-planar with an FCP top surface of the false ceiling plenum **16**. A second horizontal plane **22-a** is co-planar with the FCP bottom surface of the false ceiling plenum **16**, as well as the cold aisle ceiling **15A1** of the cold aisle **15A** and the hot aisle ceiling **15B1** of the hot aisle **15B**. A third horizontal plane **23** is co-planar with a top surface of a raised floor plenum **17**. A fourth horizontal plane **24** is co-planar with a bottom surface of the raised floor plenum **17**. A first vertical plane **31** is co-planar with a first side of the hot aisle **15B**. A second vertical plane **32** is co-planar with a second side of the hot aisle **15B**. A third vertical plane **33** is co-planar with one side edge of the false ceiling plenum **16**.

The computer room **15** of **FIG. 1** includes a cold aisle **15A** and a hot aisle **15B** separated by a server rack row **15C**. The cold aisle **15A** receives cooled air via a raised floor plenum inlet **15D1-a** and/or a fan wall inlet **15D1-b**. The cooled air in the cold aisle **15A** is drawn through the server rack rows **15C** into the hot aisle **15B**, heated by electronics (e.g., servers and/or data storage devices) mounted in the server rack rows **15C**. The heated air is drawn from the hot aisle **15B** through a hot aisle ceiling **15B1** (often comprised of perforated ceiling tiles in the prior art) into a false ceiling plenum **16** and back to an air handling unit (not shown, see item

14 of **FIG. 2**) via a heated air collection duct (HACD) **14C** and the heated air outlet (not shown, see item **15D2** of **FIG. 2**). The heated air collection duct (HACD) **14C** is mounted at the third vertical plane **33** on one side edge of the false ceiling plenum **16**.

5 **FIG. 2** is a block diagram illustrating a dual coil cooling system **10**, of the prior art, for a computer room **15** employing a free cooling tower **11** and a chiller **13**. As in **FIG. 1**, the computer room **15** includes a cold aisle **15A** and a hot aisle **15B** separated by a server rack row **15C**. The cold aisle **15A** receives cooled air from an air handling unit (AHU) **14** via a cooled air inlet **15D1**. The cooled air is drawn through the cold aisle **15A** and heated by electronics
10 (e.g., servers and/or data storage devices) mounted in the server rack row **15C**. Heated air is drawn from the hot aisle **15B** to back the AHU for cooling via a heated air outlet **15D2**. The AHU **14** includes a free cooling coil **14A** and a trim cooling coil **14B** for the cooling of the heated air received from the hot aisle **15B**. The free cooling coil **14A** receives a first free coolant flow from a free cooling tower **11** to pre-cool the heated air. The trim cooling coil **14B**
15 receives a trim coolant flow from an evaporator passage **13B** of the chiller **13** to further cool the heated air. The AHU includes a fan (not shown) to pump the heated air and the cooled air. The chiller **13** includes a condenser passage **13A** to receive a second free coolant flow from the free cooling tower **11**. The free cooling tower **11** receives ambient air **12** from an outer environment to cool the free coolant delivered via: (i) the first free coolant flow to the free
20 coiling coil **14A** of the AHU **14**; and (ii) the second free coolant flow to the condenser passage **13A** of the chiller **13**.

Free cooling towers **11** derive their cooling benefit from a relatively low ambient air temperature (in comparison to the heated air of the computer room **15**) of an outside
25 environment and the evaporation of water vapor within the free cooling tower **11**. Free cooling towers **11** are most efficient therefore when they interact with the ambient air **12** of an outside environment with both a relatively low temperature and a low humidity (for greater evaporation of water vapor). While the trim cooling coil **14B** of the AHU **14** can be employed to further cool the heated air of a computer room **15** located in a tropical or otherwise high humidity
30 environment, chillers **13** require substantial electrical power to function. The high expense of cooling for data centers located in tropical or otherwise high humidity environments can force these businesses to outsource their data computing to offshore data center locations. Such

offshoring can complicate the management of the business' data computing functions and complicate the business' procedures for local data privacy rules compliance.

5 What is needed, therefore, is a computer room cooling system that can be maximize the efficiency of free coiling towers for computer rooms **15** operating in the tropics or otherwise high humidity environments.

Heat generation within a computer room **15** can also fluctuate due to uneven computing needs during weekly or daily cycles, activation of new server rack rows **15C**, maintenance schedules
10 requiring server downtime, removal of old servers from the computer room **15**, or revamping of a business computing strategy. What is needed, therefore, is a computer room cooling system that can maintain high cooling efficiency with varying heat generation loads during each day, week, or month.

15 As described in the detailed description of this specification and illustrated in **FIGs. 4A to 6**, the invention employs a damper **20** of the prior art. **FIG. 3** is a block diagram illustrating the damper **20**, of the prior art, which including a series of louvers **21** in mechanical connection with a mechanical thermostat **22**. The damper **20** is illustrated as viewed from a first side view **20-X** along a length of the damper **20**. The damper **20** is also illustrated as viewed from a
20 second side view **20-Y** along a width of the damper **20**. The damper **20** is further illustrated as viewed from a top view **20-Z** as viewed from below the damper **20** (as it is mounted in a hot aisle ceiling **15B1** as described in the detailed description section of this specification). Note that, as described in the detailed description section of this specification, the height of a damper **20** (e.g., as seen in the first side view **20-X** or second side view **20-Y**) can be mounted co-
25 planar with one of the horizontal planes or one of the vertical planes of the computer room **15** when installed according to the invention.

The damper **20** includes a series of louvers **21**. The series of louvers **21** is configured to open and close when activated by mechanical connection to a mechanical thermostat **22**. When the
30 series of louvers **21** are twisted more open, the louver free area percentage of the damper **20** increases to reduce air resistance across the series of louvers **21**, and thereby increase a volume of a variable air flow across the series of louvers **21** (e.g., cubic meters of air per minute) at a given pressure differential across the series of louvers **21**. When the series of louvers **21** are

twisted closed, the louver free area percentage of the damper **20** decreases to increase air resistance across the series of louvers **21**, and thereby decrease the volume of the variable air flow across the series of louvers **21** at the given pressure differential across the series of louvers **21**.

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After installation and during use, each mechanical thermostat **22** is exposed to an adjacent heated air having an adjacent temperature. The mechanical thermostat **22** is mounted on the side of the damper **20** exposed to the heated air (of the adjacent temperature) that is to be regulated by the opening and closing of the series of louvers **21**. The damper **20** can include more than one mechanical thermostat **22**. The mechanical thermostat **22** need not be connected to a power source and need not be networked as an internet of things device. The mechanical thermostat **22** is configured to: (1) increase the louver free area percentage of the series of louvers **21** in mechanical connection to the mechanical thermostat **22** when the adjacent temperature for the mechanical thermostat **22** is above a preset threshold temperature for the mechanical thermostat **22**; and (2) decrease the louver free area percentage of the series of louvers **21** in mechanical connection to the mechanical thermostat **22** when the adjacent temperature for the mechanical thermostat **22** is below the preset threshold temperature.

Sets of dampers **20** can include a preset thermostat setting that includes: (1) a preset threshold temperature; and (2) a minimum louver free area percentage for the preset minimum louver free area percentage for the series of louvers **21**. The preset threshold is the adjacent temperature at which the mechanical thermostat **22** will twist open the series of louvers **21** to increase the louver free area percentage which increased the variable air flow across the damper **20**. For instance, if the preset threshold temperature is set at 40 degrees Celsius, then the mechanical thermostat **22** will begin opening the series of louvers **21** more when the adjacent temperature of the mechanical thermostat **22** exceeds 40 degrees Celsius, and begin closing the series of louvers **21** more when the adjacent temperature of the mechanical thermostat **22** drops below 40 degrees Celsius. In this manner, each damper **20** can modulate an airflow across the damper **20** and (assuming that a higher air flow reduces the adjacent temperature of the air) maintain a general temperature range within a volume of air that is partially confined by the damper **20**. Different sets of dampers **20** can have different preset thermostat settings (e.g., the preset thermostat settings can vary between sets of dampers **20**, not every set of dampers **20** requires the same preset thermostat settings).

The setting of a minimum louver free area percentage for the preset minimum louver free area percentage for the series of louvers **21** can act as a safety feature to avoid excessive heat buildup in a room and/or reduce the probability of suffocation of work staff due to lack of oxygen, a buildup of carbon dioxide, or a build up of other poisonous gases. For instance, if the damper **20** is preset with a 10 percent minimum louver free area percentage, there will always be an airflow across the damper **20** (assuming there is a pressure differential across the damper **20**).

SUMMARY

In its most general form, the invention is a computer room cooling system including a plurality of bifurcated heated air return pathways for heated air generated by a plurality of server rack rows operating in a computer room with a false ceiling plenum and a heated air collection duct. A first heated air return pathway routes the heated air from a hot aisle duct into a heated air collection duct. A second heated air return pathway routes the heated air from the hot aisle duct into a voluminous false ceiling plenum before the heated air is routed into the heated air collection duct. Dampers with mechanical thermostats are employed to control airflow between the hot aisle duct and the voluminous false ceiling plenum. The invention can be employed to maintain a minimum delta temperature between the heated air and a first free coolant flow received by an air handling unit from a free cooling tower operating in an outer environment with high humidity.

A primary embodiment of the invention is a computer room cooling system including a plurality of bifurcated heated air return pathways for heated air generated by a plurality of server rack rows operating in a computer room with a false ceiling plenum and a heated air collection duct. Each bifurcated heated air return pathway is associated with one server rack row in the computer room, one hot aisle located adjacent the one server rack row, and one hot aisle duct positioned above a ceiling of the one hot aisle, and further each bifurcated heated air return pathway includes: (i) a first heated air return pathway for the heated air generated by the one server rack row; and (ii) a second heated air return pathway for the heated air generated by the one server rack row. The first heated air return pathway progresses: (1) from the one server rack row associated with the bifurcated heated air return pathway; (2) into the one hot aisle located adjacent the one server rack row; (3) through a plurality of first dampers mounted on the ceiling of the one hot aisle; (4) into the one hot aisle duct positioned above the ceiling of

the one hot aisle; and (5) into the heated air collection duct. The second heated air return pathway progresses: (1) from the one server rack row associated with the bifurcated heated air return pathway; (2) into the one hot aisle located adjacent the one server rack row; (3) through a plurality of first dampers mounted on the ceiling of the one hot aisle; (4) into the one hot aisle duct positioned above the ceiling of the one hot aisle; (5) through a plurality of second dampers mounted on sides or atop the one hot aisle duct; (6) into the false ceiling plenum; (7) through a plurality of third dampers mounted between the false ceiling plenum and the heated air collection duct; and (8) into the heated air collection duct.

10 In the primary embodiment of the invention, each of the first dampers, each of the second dampers, and each of the third dampers include at least one mechanical thermostat in mechanical connection to a series of louvers. Each mechanical thermostat is exposed to an adjacent heated air having an adjacent temperature, the mechanical thermostat configured to increase or decrease a louver free area percentage of the series of louvers in mechanical connection to the mechanical thermostat in response to each change in the adjacent temperature such that: (1) the mechanical thermostat is configured to increase the louver free area percentage of the series of louvers in mechanical connection to the mechanical thermostat when the adjacent temperature for the mechanical thermostat is above a preset threshold temperature for the mechanical thermostat; and (2) the mechanical thermostat is configured to decrease the louver free area percentage of the series of louvers in mechanical connection to the mechanical thermostat when the adjacent temperature for the mechanical thermostat is below the preset threshold temperature. Each first damper associated with each hot aisle is configured to: (i) control a first variable airflow of the heated air from the hot aisle into the hot aisle duct associated with the hot aisle; and (ii) preset a first thermostat setting. The first thermostat setting includes: (1) a first threshold temperature for the preset threshold temperature for the mechanical thermostat of the first damper; and (2) a first minimum louver free area percentage for the preset minimum louver free area percentage for the series of louvers of the first damper. Each second damper associated with each hot aisle duct is configured to: (i) control a second variable airflow of the heated air from the hot aisle duct into the false ceiling plenum; and (ii) preset a second thermostat setting. The second thermostat setting includes: (1) a second threshold temperature for the preset threshold temperature for the mechanical thermostat of the second damper; and (2) a second minimum louver free area percentage for the preset minimum louver free area percentage for the series of louvers of the second damper. Each third damper

is configured to: (i) control a third variable airflow of the heated air from the false ceiling plenum to the heated air collection duct; and (ii) preset a third thermostat setting. The third thermostat setting includes: (1) a third threshold temperature for the preset threshold temperature for the mechanical thermostat of the third damper; and (2) a third minimum louver
5 free area percentage for the preset minimum louver free area percentage for the series of louvers of the third damper.

In an alternative embodiment of the primary embodiment of the invention, each hot aisle duct includes: (i) an HAD top surface of the hot aisle duct along a first horizontal plane, the first
10 horizontal plane co-planar with an FCP top surface of the false ceiling plenum; and (ii) an HAD bottom surface of the hot aisle duct along a second horizontal plane. The second horizontal plane is: (1) co-planar with the hot aisle ceiling associated with the hot aisle duct; and (2) co-planar with an FCP bottom surface of the false ceiling plenum. Each of the first dampers of each hot aisle duct is mounted: (i) in the second horizontal plane; and (ii) between the hot aisle
15 ceiling and the HAD bottom surface of the hot aisle duct. Each of the second dampers of each hot aisle duct is mounted: (i) in at least one of a first vertical plane along a first vertical side of the hot aisle duct and a second vertical plane along a second vertical side of the hot aisle duct; and (ii) between the first vertical side or the second vertical side of the hot aisle duct and the false ceiling plenum.

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In an alternative embodiment of the primary embodiment of the invention, each hot aisle duct includes: (i) an HAD top surface of the hot aisle duct along a second horizontal plane, the second horizontal plane co-planar with an FCP bottom surface of the false ceiling plenum; and
(ii) an HAD bottom surface of the hot aisle duct along a second alternative horizontal plane.
25 The second alternative horizontal plane is: (1) co-planar with the hot aisle ceiling associated with the hot aisle duct; and (2) located in parallel and between the second horizontal plane and a third horizontal plan that is co-planar with a floor area of the hot aisle associated with the hot aisle duct. Each of the first dampers of each hot aisle duct is mounted: (i) in the second alternative horizontal plane; and (ii) between the hot aisle ceiling and the HAD bottom surface
30 of the hot aisle duct. Each of the second dampers of each hot aisle duct is mounted: (i) in the second horizontal plane; and (ii) between the HAD top surface of the hot aisle duct and the FCP bottom surface of the false ceiling plenum.

A secondary embodiment of the invention further includes, in addition to the technical elements of the primary embodiment of the invention: (a) for each server rack row, at least one cooled air inlet into a cold aisle associated with the server rack row; and (b) an air handling unit (AHU). The AHU is in fluid connection with: (i) the heated air collection duct; and (ii) the at least one cooled air inlet of each cold aisle. The AHU is configured to receive the heated air via the heated air collection duct to create cooled air. The at least one cooled air inlet is configured to receive the cooled air from the AHU.

In an alternative embodiment of the secondary embodiment of the invention, the system further includes a free cooling tower and a chiller. The AHU includes a free cooling coil configured to receive a first free coolant flow from the free cooling tower. The AHU includes a trim cooling coil configured to receive a trim coolant flow from an evaporator passage of the chiller. In this embodiment, the chiller may include a condenser passage to receive a second free coolant flow from the free cooling tower. In this embodiment, the free cooling tower may receive ambient air from an outer environment in an ambient temperature range of 25 to 32 degrees Celsius.

In an alternative embodiment of the secondary embodiment of the invention: (a) the AHU further includes an AHU controller and a variable speed fan; and (b) each bifurcated heated air return pathway includes a plurality of networked temperature sensors. Each networked temperature sensor is configured to: (i) detect a series of current local temperature; and (ii) transmit the series of current local temperature to the AHU controller. The AHU controller is configured to: (i) reduce a speed of the variable speed fan of the AHU when at least one of the current local temperatures received from one of the networked temperature sensors is below a heated air threshold temperature; and (ii) increase the speed of the variable speed fan of the AHU when at least one of the current local temperatures received from one of the networked temperature sensors is above the heated air threshold temperature. In this embodiment, the heated air threshold temperature may be selected from a heated air threshold temperature range of 38 to 42 degrees Celsius.

The invention is directed toward creating a computer room cooling system that provides maximum energy efficiency for data computing centers located in the tropics or otherwise high humidity environments. The primary benefit of the invention is accomplished by maintaining

a high delta temperature between: (i) the temperature of the heated air received from the heated air collection duct; and (ii) the free tower coolant received from the free cooling tower.

The first dampers act to regulate a first variable airflow between the hot aisles and the hot aisle duct. The first dampers allow the heated air temperature in the hot aisles to reach a first threshold temperature before a substantial portion of this heated air is permitted into the hot aisle duct.

The second dampers have a lower minimum louver free air percentage than the first dampers. The first dampers preferably have a minimum louver free air percentage in a range of 8 to 12 percent. The second dampers preferably have a minimum louver free air percentage in a range of 0 to 3 percent. The second threshold temperature of the mechanical thermostats of the second dampers can also be set at a preset thermostat temperature that is higher than the first threshold temperature of the mechanical thermostats of the first dampers.

Therefore, if there is a low rate of heat generation by the server rack row associated with the hot aisle duct, the heated air generated by that server rack row is limited primarily to the volume of the hot aisle and the first volume of the hot aisle duct. Airflow from this low heat generation server rack row can progress to the heated air collection duct via the first heated air return pathway.

On the other hand, if there is a high rate of heat generation in a particular server rack row, the extra heat can flow into the second volume of the false ceiling plenum. The false ceiling plenum, thereby, acts as a heat reservoir for the cooling system, permitting for fluctuations in heat generation between the server rack rows of the computer room. The third dampers only permit heated air in the false ceiling plenum to enter the heated air collection duct (for completion of the second heated air return pathway) if the mechanical thermostats in these third dampers meet a third threshold temperature. The dampers thus enable dynamic adjustment to the total heated air reservoir volume for the computer room cooling system.

The AHU also includes a variable speed fan that can slow down to reduce the volume of heated air removed from the computer room during times of low heat generation, or increase in speed during times of high heat generation. Together, the dampers creating the bifurcated heated air

return pathway and the variable speed fan of the AHU provide a computer room cooling system that can maintain a more consistent high delta temperature between the temperature of the heated air drawn into the AHU and the temperature of the free tower coolant. This high delta temperature increases the efficiency and benefit of the free coolant tower and thereby decreases the reliance on the trim cooling coil to cool the heated air to reduce energy consumption by the chiller.

Electronics mounted in the server rack rows are protected from excessive temperatures (e.g., temperatures above 40 degrees Celsius) because the mechanical thermostat damper design prevents any single point of failure. If one of the first dampers fails, the heated air will escape the hot aisle through other first dampers that are in functioning order. Also, the first dampers have preferably a first minimum louver free area percentage in the range of 8 to 12 percent, permitting a minimum heated air flow out of the hot aisles. The mechanical thermostats also do not rely on electrical power or network communication. Thus, if there is a power outage or network failure, the dampers are not affected.

The dampers are also easy to install in buildings that are not custom designed to function as a data computing center. E.g., the existing perforated ceiling tiles in the hot aisle ceiling can be replaced with first dampers. E.g., the existing false ceiling plenum can be used for the second heated air return pathway.

The invention also improves the performance of a dual coil cooling system, of the prior art. The invention produces a higher delta temperature, such that the higher temperature heated air passing through the air handling unit is first cooled by a first free coolant flow (from the free coiling tower) to a greater degree than if the heated air was of a lower temperature.

Together, all the technical aspects of the invention work together to maintain a high delta temperature and thereby maximize the efficiency of a free cooling tower in tropical or otherwise high humidity environments. At the same time, the invention prevents overheating of electronics in the server racks and provides flexibility for computer room operations.

BRIEF DESCRIPTION OF THE DRAWINGS

Embodiments of the present disclosure are described herein with reference to the drawings in which:

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FIG. 1 is a block diagram illustrating a heated air return pathway, of the prior art, through a computer room.

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FIG. 2 is a block diagram illustrating a dual coil cooling system, of the prior art, for a computer room employing a free cooling tower and a chiller.

FIG. 3 is a block diagram illustrating a damper, of the prior art, including a series of louvers in mechanical connection with a mechanical thermostat.

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FIGs. 4A and **4B** are block diagrams illustrating, in a vertical plane side view of a computer room, alternative bifurcated heated air return pathway designs for a hot aisle duct, in alternative embodiments of the invention.

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FIG. 5 is a block diagram illustrating, in a horizontal plane top view of a computer room, a bifurcated heated air return pathway design for a hot aisle duct in an embodiment of the invention.

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FIG. 6 is a block diagram illustrating, in a simplified format, a first heated air return pathway and a second heated air return pathway for a computer room in an embodiment of the invention.

DETAILED DESCRIPTION

In the following detailed description, reference is made to the accompanying drawings, which form a part hereof. The illustrative embodiments described in the detailed description, drawings and claims are not meant to be limiting. Other embodiments can be utilized, and other changes can be made, without departing from the spirit or scope of the subject matter presented herein. Unless specified otherwise, the terms “comprising,” “comprise,” “including” and “include” used herein, and grammatical variants thereof, are intended to represent “open” or “inclusive” language such that they include recited elements but also permit inclusion of additional, unrecited elements.

As described in this specification, the server racks rows can house various computing devices generating heated air, such as servers and data storage devices. The terms “plane” and “coplanar” are intended to describe cross-sectional volumes (either horizontal or vertical) within the computer room. These cross-sectional volumes can include, for instance a height of a damper, a height of a ceiling tile or flooring tile. E.g., “plane” and “coplanar” are not meant to designate an ideal plane possessing no volume.

As used in this specification, the term “damper” is not meant to be limited to any specific form factor. Dampers used in the invention may be off-the-shelf purchased dampers or customized dampers of various dimensions. However, to ensure no single point of failure, the term “damper” is meant to describe discrete, separate devices, wherein each damper include its own mechanical thermostat and series of louvers. In this manner, if one or more dampers fail, there is a low likelihood of damage to the electronics mounted in the server rack rows, as the remaining dampers remain functional. The dampers also have the benefit of enabling a fast upgrade methodology for prior art computer rooms (e.g., by replacing the perforated ceiling tiles of the hot aisle ceilings with first dampers).

For convenience, each of the items referenced in the figures by number are listed below.

No.	Items
10	dual coil cooling system
11	free cooling tower
12	ambient air
13	chiller
13A	condenser passage
13B	evaporator passage
14	air handling unit (AHU)
14A	free cooling coil
14B	trim cooling coil
14C	heated air collection duct (HACD)
14D	variable speed fan
15	computer room
15A	cold aisle
15A1	cold aisle ceiling
15B	hot aisle
15B1	hot aisle ceiling
15C	server rack row
15D1	cooled air inlet
15D1-a	raised floor plenum inlet
15D1-b	fan wall inlet
15D2	heated air outlet
16	false ceiling plenum (FCP)
17	raised floor plenum
18	hot aisle duct (HAD)
20	damper
20A	first dampers
20A1	first variable outflow
20B	second dampers
20B1	second variable outflow
20C	third dampers

20C2	third variable outflow
20-X	side view of damper
20-Y	end view of damper
20-Z	bottom view of damper
21	first horizontal plane
21	series of louvers
22	mechanical thermostat
22-a	second horizontal plane
22-b	second alternative horizontal plane
23	third horizontal plane
24	fourth horizontal plane
31	first vertical plane
32	second vertical plane
33	third vertical plane
34	fourth vertical plane
61	first heated air return pathway
62	second heated air return pathway

FIGs. 1 to 3 have been described in the background section of this specification.

FIGs. 4A and **4B** are block diagrams illustrating, in a vertical plane side view of a computer room **15**, alternative bifurcated heated air return pathway designs for a hot aisle duct **18**, in alternative embodiments of the invention. As in **FIGs. 1** and **2**, the computer rooms **15** depicted in **FIGs. 4A** and **4B** include a cold aisle **15A** and a hot aisle **15B** separated by a server rack row **15C**. The cold aisle **15A** receives cooled air via a raised floor plenum inlet **15D1-a** and/or a fan wall inlet **15D1-b** for the cooled air inlet **15D1**. The cooled air in the cold aisle **15A** is drawn into the hot aisle **15B** through and heated by electronics (e.g., servers and/or data storage devices) mounted in the server rack row **15C**.

As in **FIG. 2**, to assist in the description of the items in the figures, **FIGs. 4A** and **4B** identify several planar interfaces. The terms “plane” and “co-planar”, as used in this description, are intended to describe cross-sectional volumes (either horizontal or vertical) within the computer room **15**, rather than ideal planes having no volume. A first horizontal plane **21** is co-planar with an FCP top surface of the false ceiling plenum **16**. A second horizontal plane **22-a** is co-planar with the FCP bottom surface of the false ceiling plenum **16** and the cold aisle ceiling **15A1** of the cold aisle **15A** and the hot aisle ceiling **15B1** of the hot aisle **15B**. A third horizontal plane **23** is co-planar with a top surface of a raised floor plenum **17**. A fourth horizontal plane **24** is co-planar with a bottom surface of the raised floor plenum **17**. A first vertical plane **31** is co-planar with a first side of the hot aisle **15B**. A second vertical plane **32** is co-planar with a second side of the hot aisle **15B**. A third vertical plane **33** is co-planar with one side edge of the false ceiling plenum **16**.

In **FIGs. 4A** and **4B**, the heated air in the hot aisle **15B** is drawn into a hot aisle duct **18** through first dampers **20A** (see arrows **20A1**) mounted in the hot aisle ceiling **15B1** along the second horizontal plane **22-a**, replacing the perforated ceiling tiles of the prior art design detailed in **FIG. 1**. The heated air can return to an air handling unit **14** (not shown) along the length of the hot aisle duct **18** in a first heated air return pathway **61** (see also **FIG. 5** for a top view of the computer room **15**). The heated air can also return to the AHU **14** (not shown) in a second heated air return pathway **62**: starting from the hot aisle duct **18** after passage through second dampers **20B** (mounted in the first vertical plane **31**, see arrows **20B1**), into the false ceiling plenum **16**, through third dampers **20C** (mounted in the third vertical plane **33**, see arrows **20C1**), into a heated air collection duct (HACD) **14C**, and lastly into a heated air outlet **15D2** (not shown). The cold aisle **15A** receives cooled air via a raised floor plenum inlet **15D1-a** and/or a fan wall inlet **15D1-b** for the cooled air inlet **15D1**.

In the **FIG. 4A** embodiment of the invention, the hot aisle duct **18** includes an HAD top surface of the hot aisle duct **18** along the first horizontal plane and an HAD bottom surface of the hot aisle duct **18** along a second horizontal plane **22-a**. The second horizontal plane **22-a** is co-planar with the hot aisle ceiling **15B1** associated with the hot aisle duct **18**. E.g., when retrofitting an industrial office location to use the **FIG. 4A** embodiment of the invention, the hot aisle ducts **18** are mounted within the existing false ceiling plenum **16**. Each of the first dampers **20A** of the hot aisle duct **18** is mounted in the second horizontal plane **22-a** between

the hot aisle ceiling **15B1** and the HAD bottom surface of the hot aisle duct **18**. Second dampers **20B** are mounted in a first vertical side of the hot aisle duct **18** in the first vertical plane **31**, between the first vertical side of the hot aisle duct **18** and a first portion of the false ceiling plenum **16**.

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While not shown in **FIG. 4A** (see top view of this embodiment depicted in **FIG. 5**), the second dampers **20B** of the hot aisle duct **18** can also be mounted in the second vertical plane **32** along a second vertical side of the hot aisle duct **18**. These second dampers **20B** would be mounted between the second vertical side of the hot aisle duct **18** and a second portion of the false ceiling plenum **16** (not shown in **FIG. 4A**, see top view of this embodiment depicted in **FIG. 5**).

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Third dampers **20C** are mounted in a third vertical plane **33** between the false ceiling plenum **16** and the heated air collection duct (HACD) **14C**.

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In the **FIG. 4B** embodiment of the invention, the hot aisle duct **18** includes an HAD top surface of the hot aisle duct **18** along the second horizontal plane **22-a** and an HAD bottom surface of the hot aisle duct **18** along a second alternative horizontal plane **22-b**. The second alternative horizontal plane **22-b** is co-planar with the hot aisle ceiling **15B1** associated with the hot aisle duct **18**. Each of the first dampers **20A** of the hot aisle duct **18** is mounted in the second alternative horizontal plane **22-b** between the hot aisle ceiling **15B1** and the HAD bottom surface of the hot aisle duct **18**. E.g., in the **FIG. 4B** embodiment of the invention, the hot aisle ceiling **15B1** is lowered such that the hot aisle duct **18** is mounted below the false ceiling plenum **16**. Each of the second dampers **20B** are mounted in the second horizontal plane **22-a** between the HAD top surface of the hot aisle duct **18** and the bottom surface of the false ceiling plenum **16**.

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FIG. 5 is a block diagram illustrating, in a horizontal plane top view of a computer room **15**, a bifurcated heated air return pathway design for a hot aisle duct **18** in the embodiment of the invention depicted in **FIG. 4A**.

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As in **FIGs. 2, 4A, and 4B**, to assist in the description of the items in the figures, **FIG. 5** identifies several planar interfaces. The terms “plane” and “co-planar”, as used in this description, are intended to describe cross-sectional volumes within the computer room **15**,

rather than ideal planes having no volume. A first vertical plane **31** is co-planar with a first side of the hot aisle **15B**. A second vertical plane **32** is co-planar with a second side of the hot aisle **15B**. A third vertical plane **33** is co-planar with one side edge of the false ceiling plenum **16**. **FIG. 5** introduces a fourth vertical plane **34** along the right side of the figure.

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As in **FIGs. 4A** and **4B**, in **FIG. 5** the heated air in the hot aisle **15B** is drawn into a hot aisle duct **18** through via first dampers **20A** (not shown, see **FIG. 4A** and arrows **20A1**). The heated air can return to an AHU **14** (not shown) along the length of the hot aisle duct **18** in a first heated air return pathway **61**. The heated air can also return to the AHU **14** (not shown) in a second heated air return pathway **62** from the hot aisle duct **18** after passage through second dampers **20B** (mounted in the first vertical plane **31**, see arrows **20B1**), into the first portion of the false ceiling plenum **16**, through third dampers **20C** (mounted in the third vertical plane **33** and the fourth vertical plane **34**, see arrows **20C1**), into a heated air collection duct (HACD) **14C**, and a heated air outlet **15D2**.

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As in **FIG. 4A**, the second dampers **20B** in **FIG. 5** are mounted in a first vertical side of the hot aisle duct **18** in the first vertical plane **31**. The second dampers **20B** of the hot aisle duct **18** are also illustrated in **FIG. 5** as mounted in the second vertical plane **32** along a second vertical side of the hot aisle duct **18**. These second dampers **20B** are mounted between the second vertical side of the hot aisle duct **18** and a second portion of the false ceiling plenum **16**.

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Third dampers **20C** are mounted in the third vertical plane **33** and the fourth plane between the false ceiling plenum **16** and the heated air collection duct (HACD) **14C**.

Note that **FIG. 5** is not drawn to scale. In particular, preferably, the first volume of each hot aisle duct **18** is less than 25 percent of the second volume of the false ceiling plenum **16**.

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FIG. 6 is a block diagram **6-00** illustrating, in a simplified format, a first heated air return pathway **61** and a second heated air return pathway **62** for a computer room **15** in an embodiment of the invention. The first heated air return pathway **61** proceeds from the server rack rows **15C**, into the hot aisle **15B**, through the first dampers **20A** (see arrows **20A1**), into the hot aisle duct **18**, and into the heated air collection duct (HACD) **14C**. The second heated air return pathway **62** proceeds from the server rack rows **15C**, into the hot aisle **15B**, through

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the first dampers **20A** (see arrows **20A1**), into the hot aisle duct **18**, through the second dampers **20B** (see arrows **20B1**), into the false ceiling plenum **16**, through the third dampers **20C** (see arrows **20C1**), and into the heated air collection duct (HACD) **14C**. The heated air from the first heated air return pathway **61** and the second heated air return pathway is directed into the
5 air handling unit (AHU) **14** via the heated air outlet **15D2**.

The heated air collected from the first heated air return pathway **61** and the second heated air return pathway **62** is directed into the AHU **14**. The AHU **14** includes a variable speed fan **14D**, a free cooling coil **14A**, and a trim cooling coil **14B**. Cooled air from the AHU **14** is directed
10 into the cold aisle **15A** via a raised floor plenum inlet **15D1-a** and/or a fan wall inlet **15D1-b**.

In its most general form, the invention is a computer room cooling system including a plurality of bifurcated heated air return pathways for heated air generated by a plurality of server rack rows **15C** operating in a computer room **15** with a false ceiling plenum **16** and a heated air
15 collection duct (HACD) **14C**. A first heated air return pathway **61** routed the heated air from a hot aisle duct **18** into a heated air collection duct (HACD) **14C**. A second heated air return pathway **62** routes the heated air from the hot aisle duct **18** into a voluminous false ceiling plenum **16** before the heated air is routed into the heated air collection duct (HACD) **14C**. Dampers **20** with mechanical thermostats **22** are employed to control airflow between the hot
20 aisle duct **18** and the voluminous false ceiling plenum **16**. The invention can be employed to maintain a minimum delta temperature between the heated air and a first free coolant flow received by an air handling unit (AHU) **14** from a free cooling tower **11** operating in an outer environment with high humidity.

25 A primary embodiment of the invention is a computer room cooling system including a plurality of bifurcated heated air return pathways for heated air generated by a plurality of server rack rows **15C** operating in a computer room **15** with a false ceiling plenum **16** and a heated air collection duct (HACD) **14C**. Each bifurcated heated air return pathway is associated with one server rack row **15C** in the computer room **15**, one hot aisle **15B** located adjacent the
30 one server rack row **15C**, and one hot aisle duct **18** positioned above a ceiling of the one hot aisle **15B**, and further each bifurcated heated air return pathway includes: (i) a first heated air return pathway **61** for the heated air generated by the one server rack row **15C**; and (ii) a second heated air return pathway **62** for the heated air generated by the one server rack row **15C**. The

first heated air return pathway **61** progresses: (1) from the one server rack row **15C** associated with the bifurcated heated air return pathway; (2) into the one hot aisle **15B** located adjacent the one server rack row **15C**; (3) through a plurality of first dampers **20A** (see arrows **20A1**) mounted on the ceiling of the one hot aisle **15B**; (4) into the one hot aisle duct **18** positioned above the ceiling of the one hot aisle **15B**; and (5) into the heated air collection duct (HACD) **14C**. The second heated air return pathway **62** progresses: (1) from the one server rack row **15C** associated with the bifurcated heated air return pathway; (2) into the one hot aisle **15B** located adjacent the one server rack row **15C**; (3) through a plurality of first dampers **20A** (see arrows **20A1**) mounted on the ceiling of the one hot aisle **15B**; (4) into the one hot aisle duct **18** positioned above the ceiling of the one hot aisle **15B**; (5) through a plurality of second dampers **20B** (see arrows **20B1**) mounted on sides or atop the one hot aisle duct **18**; (6) into the false ceiling plenum **16**; (7) through a plurality of third dampers **20C** (see arrows **20C1**) mounted between the false ceiling plenum **16** and the heated air collection duct (HACD) **14C**; and (8) into the heated air collection duct (HACD) **14C**.

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In the primary embodiment of the invention, each of the first dampers **20A**, each of the second dampers **20B**, and each of the third dampers **20C** include at least one mechanical thermostat **22** in mechanical connection to a series of louvers **21**. Each mechanical thermostat **22** is exposed to an adjacent heated air having an adjacent temperature, the mechanical thermostat **22** configured to increase or decrease a louver free area percentage of the series of louvers **21** in mechanical connection to the mechanical thermostat **22** in response to each change in the adjacent temperature such that: (1) the mechanical thermostat **22** is configured to increase the louver free area percentage of the series of louvers **21** in mechanical connection to the mechanical thermostat **22** when the adjacent temperature for the mechanical thermostat **22** is above a preset threshold temperature for the mechanical thermostat **22**; and (2) the mechanical thermostat **22** is configured to decrease the louver free area percentage of the series of louvers **21** in mechanical connection to the mechanical thermostat **22** when the adjacent temperature for the mechanical thermostat **22** is below the preset threshold temperature. Each first damper **20A** associated with each hot aisle **15B** is configured to: (i) control a first variable airflow of the heated air from the hot aisle **15B** into the hot aisle duct **18** associated with the hot aisle **15B**; and (ii) preset a first thermostat setting. The first thermostat setting includes: (1) a first threshold temperature for the preset threshold temperature for the mechanical thermostat **22** of the first damper **20A**; and (2) a first minimum louver free area percentage for the preset

minimum louver free area percentage for the series of louvers **21** of the first damper **20A**. Each second damper **20B** associated with each hot aisle duct **18** is configured to: (i) control a second variable airflow of the heated air from the hot aisle duct **18** into the false ceiling plenum **16**; and (ii) preset a second thermostat setting. The second thermostat setting includes: (1) a second threshold temperature for the preset threshold temperature for the mechanical thermostat **22** of the second damper **20B**; and (2) a second minimum louver free area percentage for the preset minimum louver free area percentage for the series of louvers **21** of the second damper **20B**. Each third damper **20C** is configured to: (i) control a third variable airflow of the heated air from the false ceiling plenum **16** to the heated air collection duct (HACD) **14C**; and (ii) preset a third thermostat setting. The third thermostat setting includes: (1) a third threshold temperature for the preset threshold temperature for the mechanical thermostat **22** of the third damper **20C**; and (2) a third minimum louver free area percentage for the preset minimum louver free area percentage for the series of louvers **21** of the third damper **20C**.

In an alternative embodiment of the primary embodiment of the invention, each hot aisle duct **18** includes: (i) an HAD top surface of the hot aisle duct **18** along a first horizontal plane **21**, the first horizontal plane **21** co-planar with an FCP top surface of the false ceiling plenum **16**; and (ii) an HAD bottom surface of the hot aisle duct **18** along a second horizontal plane **22-a**. The second horizontal plane **22-a** is: (1) co-planar with the hot aisle ceiling **15B1** associated with the hot aisle duct **18**; and (2) co-planar with an FCP bottom surface of the false ceiling plenum **16**. Each of the first dampers **20A** of each hot aisle duct **18** is mounted: (i) in the second horizontal plane **22-a**; and (ii) between the hot aisle ceiling **15B1** and the HAD bottom surface of the hot aisle duct **18**. Each of the second dampers **20B** of each hot aisle duct **18** is mounted: (i) in at least one of a first vertical plane **31** along a first vertical side of the hot aisle duct **18** and a second vertical plane **32** along a second vertical side of the hot aisle duct **18**; and (ii) between the first vertical side or the second vertical side of the hot aisle duct **18** and the false ceiling plenum **16**.

In an alternative embodiment of the primary embodiment of the invention, each hot aisle duct **18** includes: (i) an HAD top surface of the hot aisle duct **18** along a second horizontal plane **22-a**, the second horizontal plane **22-a** co-planar with an FCP bottom surface of the false ceiling plenum **16**; and (ii) an HAD bottom surface of the hot aisle duct **18** along a second alternative horizontal plane **22-b**. The second alternative horizontal plane **22-b** is: (1) co-planar

- with the hot aisle ceiling **15B1** associated with the hot aisle duct **18**; and (2) located in parallel and between the second horizontal plane **22-a** and a third horizontal plan that is co-planar with a floor area of the hot aisle **15B** associated with the hot aisle duct **18**. Each of the first dampers **20A** of each hot aisle duct **18** is mounted: (i) in the second alternative horizontal plane **22-b**;
5 and (ii) between the hot aisle ceiling **15B1** and the HAD bottom surface of the hot aisle duct **18**. Each of the second dampers **20B** of each hot aisle duct **18** is mounted: (i) in the second horizontal plane **22-a**; and (ii) between the HAD top surface of the hot aisle duct **18** and the FCP bottom surface of the false ceiling plenum **16**.
- 10 In an alternative embodiment of the primary embodiment of the invention, the third dampers **20C** are mounted: (a) in a third vertical plane **33** along at least one edge side of the false ceiling plenum **16**; and (b) between the false ceiling plenum **16** and the heated air collection duct (HACD) **14C**.
- 15 In an alternative embodiment of the primary embodiment of the invention, a first volume of each hot aisle duct **18** is less than 25 percent of a second volume of the false ceiling plenum **16**.
- In an alternative embodiment of the primary embodiment of the invention: (a) the first
20 threshold temperature is selected from a first threshold temperature range from 35 to 39 degrees Celsius; and (b) the second threshold temperature is selected from a second threshold temperature range from 37 to 41 degrees Celsius.
- In an alternative embodiment of the primary embodiment of the invention, the first minimum
25 louver free area percentage is in a first free area range of 8 to 12 percent.
- In an alternative embodiment of the primary embodiment of the invention, the second minimum louver free area percentage is in a second free area range of 0 to 3 percent.
- 30 In an alternative embodiment of the primary embodiment of the invention: (a) a maximum louver free area percentage of each of the first dampers **20A**, each of the second dampers **20B**, and each of the third dampers **20C** is in a maximum free area range of 25 to 35 percent; (b) each of the mechanical thermostats **22** has an adjacent temperature response time of less than

15 seconds; and (c) each of the mechanical thermostats **22** has an optimized temperature response range of 30 to 45 degrees Celsius.

5 In an alternative embodiment of the primary embodiment of the invention, the at least one mechanical thermostat **22** associated with each series of louvers **21** is mounted on an upstream side of the series of louvers **21**.

A secondary embodiment of the invention further includes, in addition to the technical elements of the primary embodiment of the invention: (a) for each server rack row **15C**, at least one
10 cooled air inlet **15D1** into a cold aisle **15A** associated with the server rack row **15C**; and (b) an air handling unit (AHU) **14**. The AHU **14** is in fluid connection with: (i) the heated air collection duct (HACD) **14C**; and (ii) the at least one cooled air inlet **15D1** of each cold aisle **15A**. The AHU **14** is configured to receive the heated air via the heated air collection duct (HACD) **14C** to create cooled air. The at least one cooled air inlet **15D1** is configured to receive
15 the cooled air from the AHU **14**.

In an alternative embodiment of the secondary embodiment of the invention: (a) the cooled air received into each cold aisle **15A** from the AHU **14** is in a cooled air temperature range of 23 to 27 degrees Celsius; and (b) the heated air received by the AHU **14** via the heated air
20 collection duct (HACD) **14C** is in a heated air temperature range of 38 to 42 degrees Celsius.

In an alternative embodiment of the secondary embodiment of the invention, the system further includes a free cooling tower **11** and a chiller **13**. The AHU **14** includes a free cooling coil **14A** configured to receive a first free coolant flow from the free cooling tower **11**. The AHU **14**
25 includes a trim cooling coil **14B** configured to receive a trim coolant flow from an evaporator passage **13B** of the chiller **13**. In this embodiment, the chiller **13** may include a condenser passage **13A** to receive a second free coolant flow from the free cooling tower **11**. In this embodiment, the free cooling tower **11** may receive ambient air **12** from an outer environment in an ambient temperature range of 25 to 32 degrees Celsius.

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In an alternative embodiment of the secondary embodiment of the invention: (a) the AHU **14** further includes an AHU controller and a variable speed fan **14D**; and (b) each bifurcated heated air return pathway includes a plurality of networked temperature sensors. Each

networked temperature sensor is configured to: (i) detect a series of current local temperature; and (ii) transmit the series of current local temperature to the AHU controller. The AHU controller is configured to: (i) reduce a speed of the variable speed fan **14D** of the AHU **14** when at least one of the current local temperatures received from one of the networked temperature sensors is below a heated air threshold temperature; and (ii) increase the speed of the variable speed fan **14D** of the AHU **14** when at least one of the current local temperatures received from one of the networked temperature sensors is above the heated air threshold temperature. In this embodiment, the heated air threshold temperature may be selected from a heated air threshold temperature range of 38 to 42 degrees Celsius.

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While various aspects and embodiments have been disclosed herein, it will be apparent that various other modifications and adaptations of the invention will be apparent to the person skilled in the art after reading the foregoing disclosure without departing from the spirit and scope of the invention and it is intended that all such modifications and adaptations come within the scope of the appended claims. The various aspects and embodiments disclosed herein are for purposes of illustration and are not intended to be limiting, with the true scope and spirit of the invention being indicated by the appended claims.

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CLAIMS

1. A computer room cooling system including a plurality of bifurcated heated air return pathways for heated air generated by a plurality of server rack rows operating in a computer room with a false ceiling plenum and a heated air collection duct,
 - (a) wherein each bifurcated heated air return pathway is associated with one server rack row in the computer room, one hot aisle located adjacent the one server rack row, and one hot aisle duct positioned above a ceiling of the one hot aisle, and further each bifurcated heated air return pathway includes:
 - (i) a first heated air return pathway for the heated air generated by the one server rack row, the first heated air return pathway progressing:
 - (1) from the one server rack row associated with the bifurcated heated air return pathway;
 - (2) into the one hot aisle located adjacent the one server rack row;
 - (3) through a plurality of first dampers mounted on the ceiling of the one hot aisle;
 - (4) into the one hot aisle duct positioned above the ceiling of the one hot aisle; and
 - (5) into the heated air collection duct; and
 - (ii) a second heated air return pathway for the heated air generated by the one server rack row, the second heated air return pathway progressing:
 - (1) from the one server rack row associated with the bifurcated heated air return pathway;
 - (2) into the one hot aisle located adjacent the one server rack row;
 - (3) through the plurality of first dampers mounted on the ceiling of the one hot aisle;
 - (4) into the one hot aisle duct positioned above the ceiling of the one hot aisle;
 - (5) through a plurality of second dampers mounted on sides or atop the one hot aisle duct;
 - (6) into the false ceiling plenum;
 - (7) through a plurality of third dampers mounted between the false ceiling plenum and the heated air collection duct; and
 - (8) into the heated air collection duct;

- (b) wherein each of the first dampers, each of the second dampers, and each of the third dampers include at least one mechanical thermostat in mechanical connection to a series of louvers,
 - (i) wherein each mechanical thermostat is exposed to an adjacent heated air having an adjacent temperature, the mechanical thermostat configured to increase or decrease a louver free area percentage of the series of louvers in mechanical connection to the mechanical thermostat in response to each change in the adjacent temperature such that:
 - (1) the mechanical thermostat is configured to increase the louver free area percentage of the series of louvers in mechanical connection to the mechanical thermostat when the adjacent temperature for the mechanical thermostat is above a preset threshold temperature for the mechanical thermostat; and
 - (2) the mechanical thermostat is configured to decrease the louver free area percentage of the series of louvers in mechanical connection to the mechanical thermostat when the adjacent temperature for the mechanical thermostat is below the preset threshold temperature; and
 - (ii) wherein each of the louvers of the series of louvers has a preset minimum louver free area percentage;
- (c) wherein each first damper associated with each hot aisle is configured to:
 - (i) control a first variable airflow of the heated air from the hot aisle into the hot aisle duct associated with the hot aisle; and
 - (ii) preset a first thermostat setting, the first thermostat setting including:
 - (1) a first threshold temperature for the preset threshold temperature for the mechanical thermostat of the first damper; and
 - (2) a first minimum louver free area percentage for the preset minimum louver free area percentage for the series of louvers of the first damper;
- (d) wherein each second damper associated with each hot aisle duct is configured to:
 - (i) control a second variable airflow of the heated air from the hot aisle duct into the false ceiling plenum; and
 - (ii) preset a second thermostat setting, the second thermostat setting including:
 - (1) a second threshold temperature for the preset threshold temperature for the mechanical thermostat of the second damper; and

- (2) a second minimum louver free area percentage for the preset minimum louver free area percentage for the series of louvers of the second damper; and
 - (e) wherein each third damper is configured to:
 - (i) control a third variable airflow of the heated air from the false ceiling plenum to the heated air collection duct; and
 - (ii) preset a third thermostat setting, the third thermostat setting including:
 - (1) a third threshold temperature for the preset threshold temperature for the mechanical thermostat of the third damper; and
 - (2) a third minimum louver free area percentage for the preset minimum louver free area percentage for the series of louvers of the third damper.
2. The system of claim 1,
- (a) wherein each hot aisle duct includes:
 - (i) a hot aisle duct top surface of the hot aisle duct along a first horizontal plane, the first horizontal plane co-planar with a false ceiling plenum top surface of the false ceiling plenum; and
 - (ii) a hot aisle duct bottom surface of the hot aisle duct along a second horizontal plane that is:
 - (1) co-planar with the hot aisle ceiling associated with the hot aisle duct; and
 - (2) co-planar with a false ceiling plenum bottom surface of the false ceiling plenum;
 - (b) wherein each of the first dampers of each hot aisle is mounted:
 - (i) in the second horizontal plane; and
 - (ii) between:
 - (1) the hot aisle ceiling; and
 - (2) the hot aisle duct bottom surface of the hot aisle duct; and
 - (c) wherein each of the second dampers of each hot aisle duct is mounted:
 - (i) in at least one of:
 - (1) a first vertical plane along a first vertical side of the hot aisle duct; and
 - (2) a second vertical plane along a second vertical side of the hot aisle duct; and
 - (ii) between:

- (1) the first vertical side or the second vertical side of the hot aisle duct; and
 - (2) the false ceiling plenum.
- 3. The system of claim 1,
 - (a) wherein each hot aisle duct includes:
 - (i) a hot aisle duct top surface of the hot aisle duct along a second horizontal plane, the second horizontal plane co-planar with a false ceiling plenum bottom surface of the false ceiling plenum; and
 - (ii) a hot aisle duct bottom surface of the hot aisle duct along a second alternative horizontal plane that is:
 - (1) co-planar with the hot aisle ceiling associated with the hot aisle duct; and
 - (2) located in parallel and between the second horizontal plane and a third horizontal plane that is co-planar with a floor area of the hot aisle associated with the hot aisle duct; and
 - (b) wherein each of the first dampers of each hot aisle is mounted:
 - (i) in the second alternative horizontal plane; and
 - (ii) between:
 - (1) the hot aisle ceiling; and
 - (2) the hot aisle duct bottom surface of the hot aisle duct; and
 - (c) wherein each of the second dampers of each hot aisle duct is mounted:
 - (i) in the second horizontal plane; and
 - (ii) between:
 - (1) the hot aisle duct top surface of the hot aisle duct; and
 - (2) the false ceiling plenum bottom surface of the false ceiling plenum.
- 4. The system of claim 1, wherein the third dampers are mounted:
 - (a) in a third vertical plane along at least one edge side of the false ceiling plenum; and
 - (b) between the false ceiling plenum and the heated air collection duct.
- 5. The system of claim 1, wherein a first volume of each hot aisle duct is less than 25 percent of a second volume of the false ceiling plenum.

6. The system of claim 1,
 - (a) wherein the first threshold temperature is selected from a first threshold temperature range from 35 to 39 degrees Celsius; and
 - (b) wherein the second threshold temperature is selected from a second threshold temperature range from 37 to 41 degrees Celsius.
7. The system of claim 1, wherein the first minimum louver free area percentage is in a first free area range of 8 to 12 percent.
8. The system of claim 1, wherein the second minimum louver free area percentage is in a second free area range of 0 to 3 percent.
9. The system of claim 1,
 - (a) wherein a maximum louver free area percentage of each of the first dampers, each of the second dampers, and each of the third dampers is in a maximum free area range of 25 to 35 percent;
 - (b) wherein each of the mechanical thermostats has an adjacent temperature response time of less than 15 seconds; and
 - (c) wherein each of the mechanical thermostats has an optimized temperature response range of 30 to 45 degrees Celsius.
10. The system of claim 1, wherein the at least one mechanical thermostat associated with each series of louvers is mounted on an upstream side of the series of louvers.
11. The system of any of the preceding claims, the system further including:
 - (a) for each server rack row, at least one cooled air inlet into a cold aisle associated with the server rack row; and
 - (b) an air handling unit (AHU) in fluid connection with:
 - (i) the heated air collection duct, wherein the AHU is configured to receive the heated air via the heated air collection duct to create cooled air; and

- (ii) the at least one cooled air inlet of each cold aisle, wherein the at least one cooled air inlet is configured to receive the cooled air from the AHU.
- 12. The system of claim 11,
 - (a) wherein the cooled air received into each cold aisle from the AHU is in a cooled air temperature range of 23 to 27 degrees Celsius; and
 - (b) wherein the heated air received by the AHU via the heated air collection duct is in a heated air temperature range of 38 to 42 degrees Celsius.
- 13. The system of claim 11, the system further including a free cooling tower and a chiller,
 - (a) wherein the AHU includes a free cooling coil configured to receive a first free coolant flow from the free cooling tower; and
 - (b) wherein the AHU includes a trim cooling coil configured to receive a trim coolant flow from an evaporator passage of the chiller.
- 14. The system of claim 13, wherein the chiller includes a condenser passage to receive a second free coolant flow from the free cooling tower.
- 15. The system of claim 13, wherein the free cooling tower receives ambient air from an outer environment in an ambient temperature range of 25 to 32 degrees Celsius.
- 16. The system of claim 11,
 - (a) wherein the AHU further includes an AHU controller and a variable speed fan;
 - (b) wherein each bifurcated heated air return pathway includes a plurality of networked temperature sensors, each networked temperature sensor configured to:
 - (i) detect a series of current local temperatures; and
 - (ii) transmit the series of current local temperatures to the AHU controller; and
 - (c) wherein the AHU controller is configured to:
 - (i) reduce a speed of the variable speed fan of the AHU when at least one of the current local temperatures received from one of the networked temperature sensors is below a heated air threshold temperature; and

(ii) increase the speed of the variable speed fan of the AHU when at least one of the current local temperatures received from one of the networked temperature sensors is above the heated air threshold temperature.

17. The system of claim 16, wherein the heated air threshold temperature is selected from a heated air threshold temperature range of 38 to 42 degrees Celsius.