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(54) **DATA CENTER**

(52) **U.S. Cl. 361/679.53**

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(57) **ABSTRACT**

(21) **Appl. No.: 13/195,817**

A data center inside a shipping container having a lower plenum and an upper plenum in its interior. Heated air in the upper plenum exits therefrom into a plurality of heat exchangers adjacent thereto. Air cooled by the heat exchangers travels toward and enters the lower plenum. The data center includes a plurality of carriages each having an equipment receiving portion located between an open bottom portion in open communication with the lower plenum, and an open top portion in open communication with the upper plenum. Fans inside each of the carriages draw cooled air up from the lower plenum into the open bottom portion of the carriage, blow the cooled air up through the equipment receiving portion thereby cooling any computing equipment received therein, and vent the cooled air through the open top portion into the upper plenum.

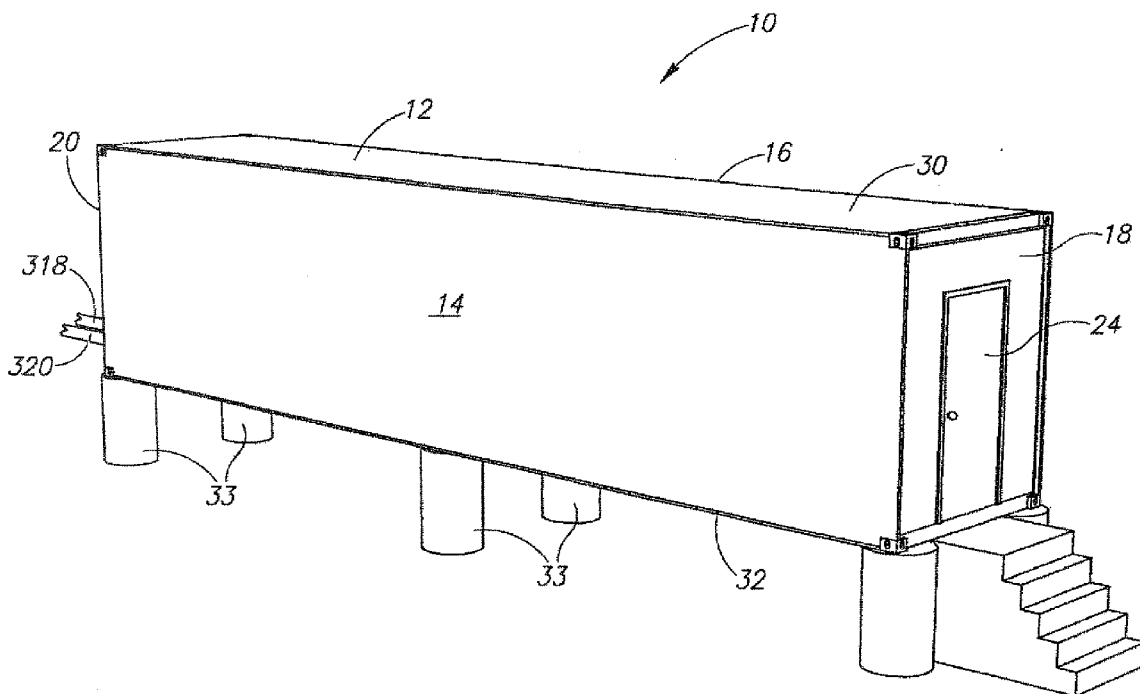
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Publication Classification

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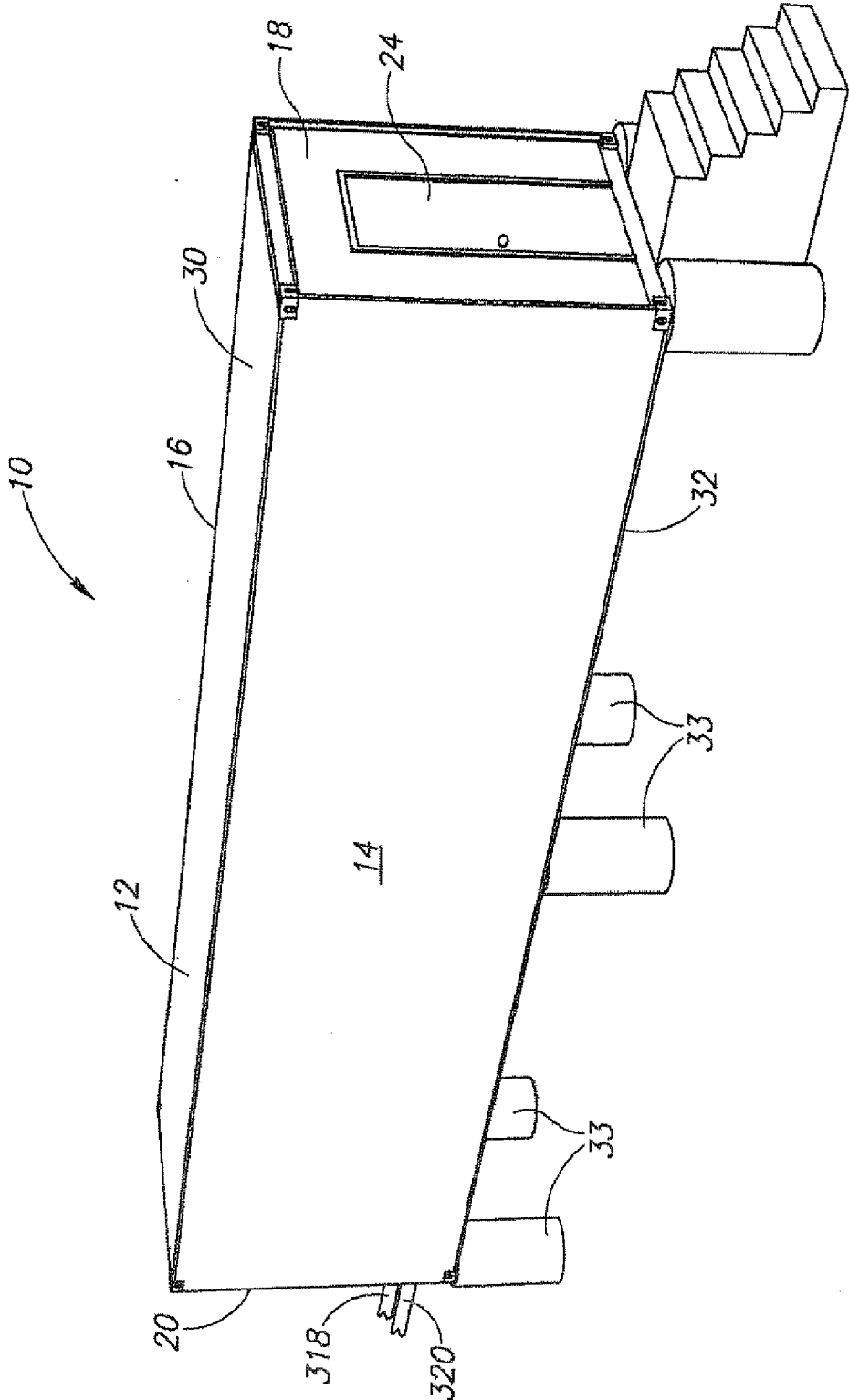


FIG.1

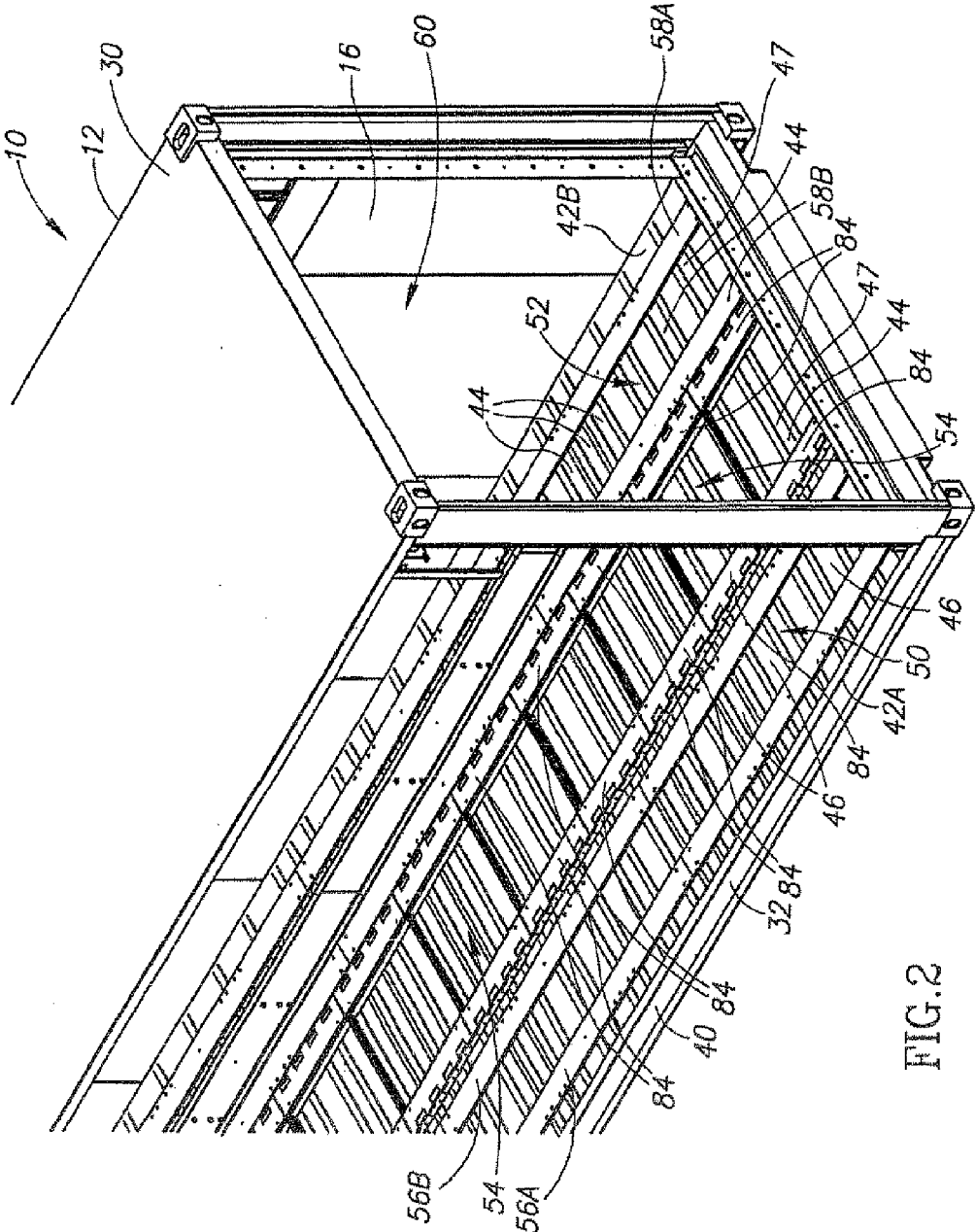


FIG.2

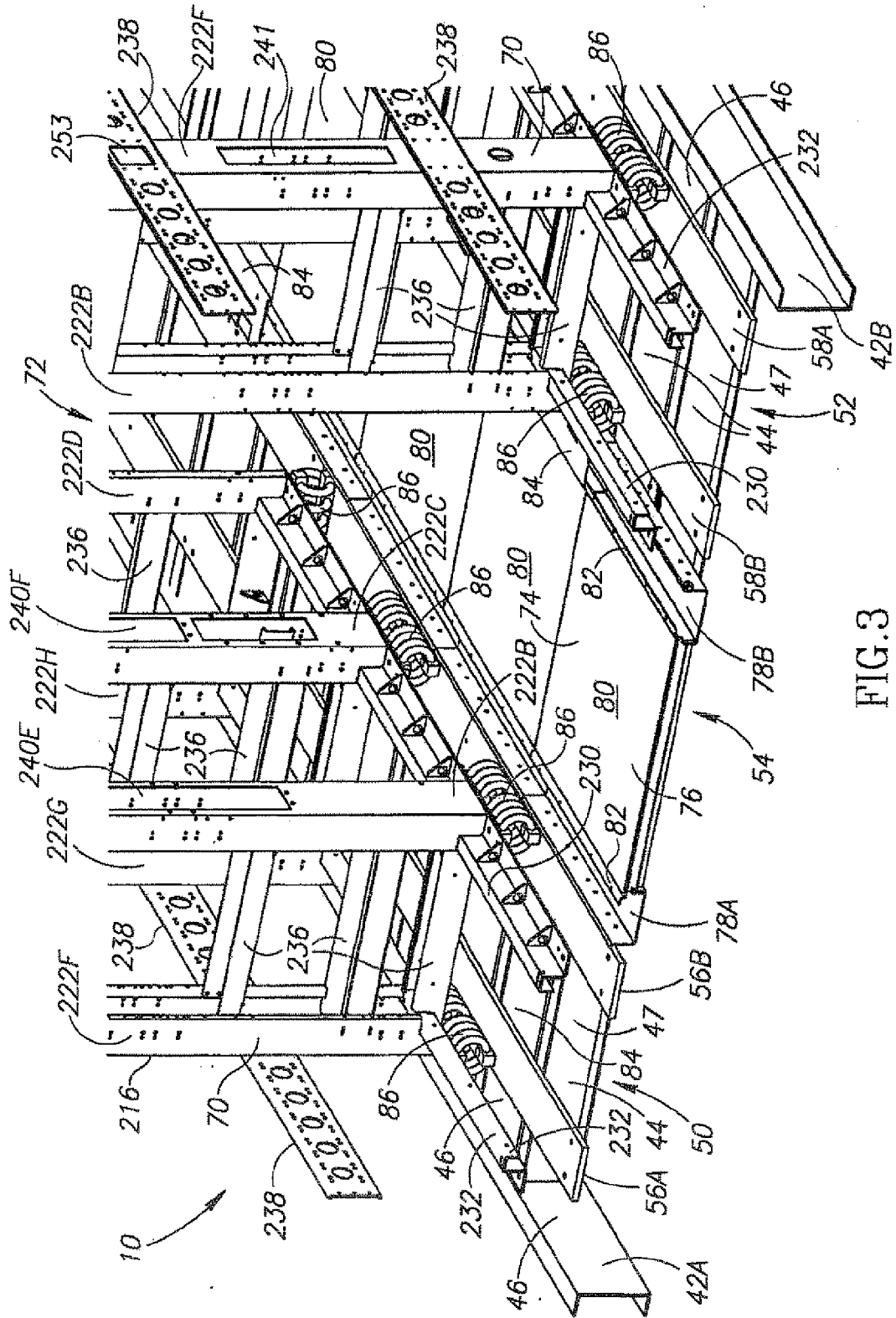


FIG. 3

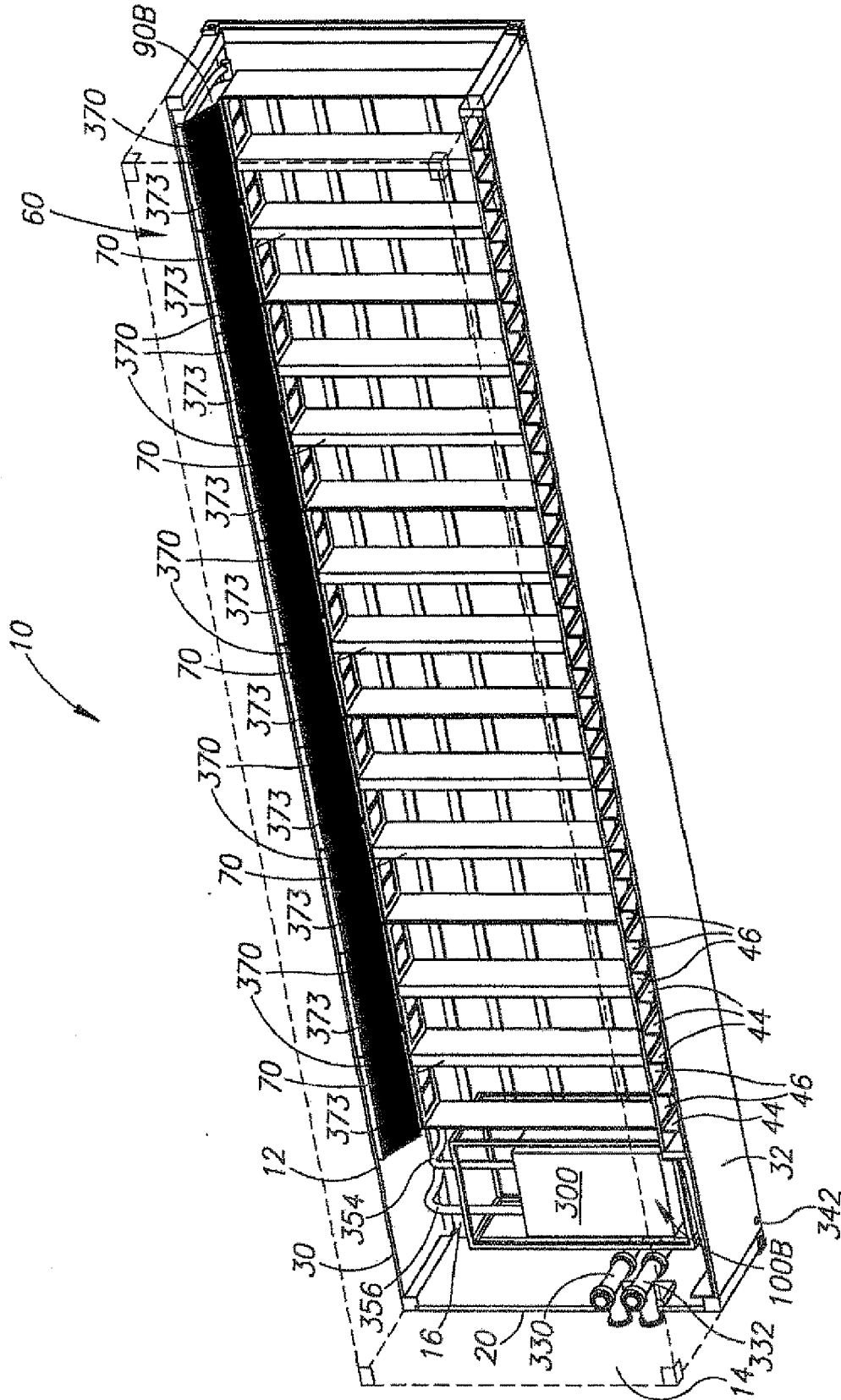


FIG. 4

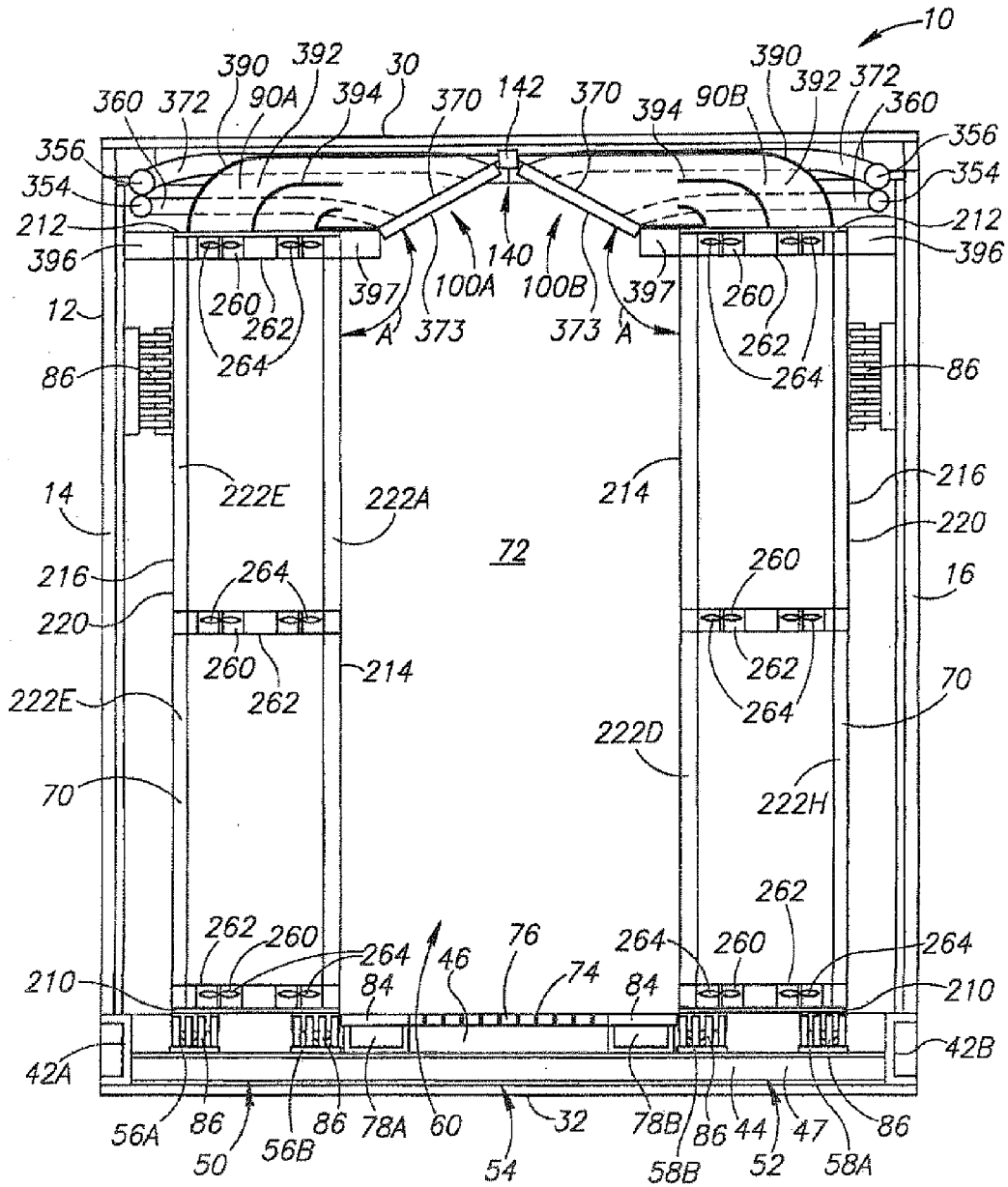


FIG. 5

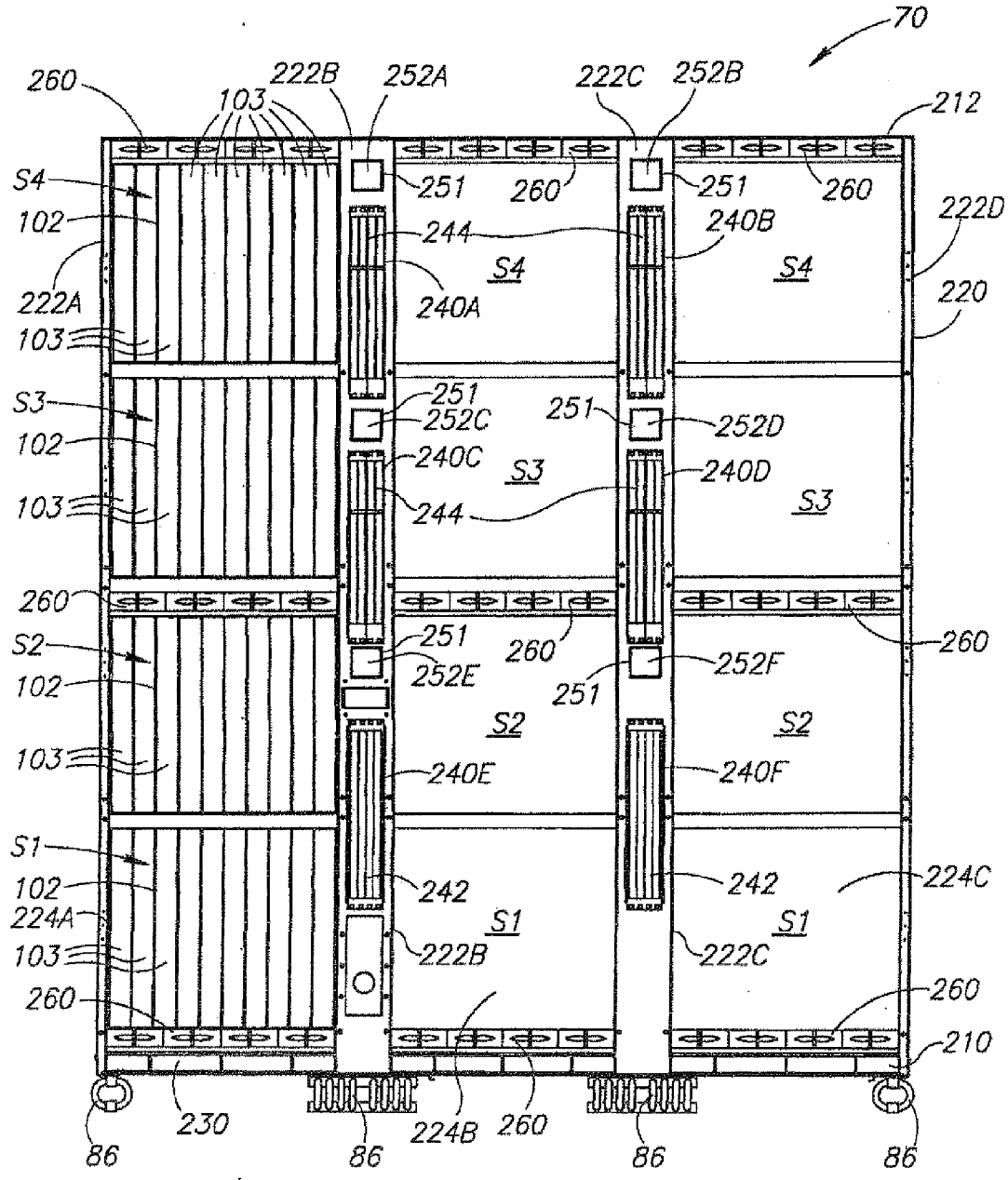


FIG. 6

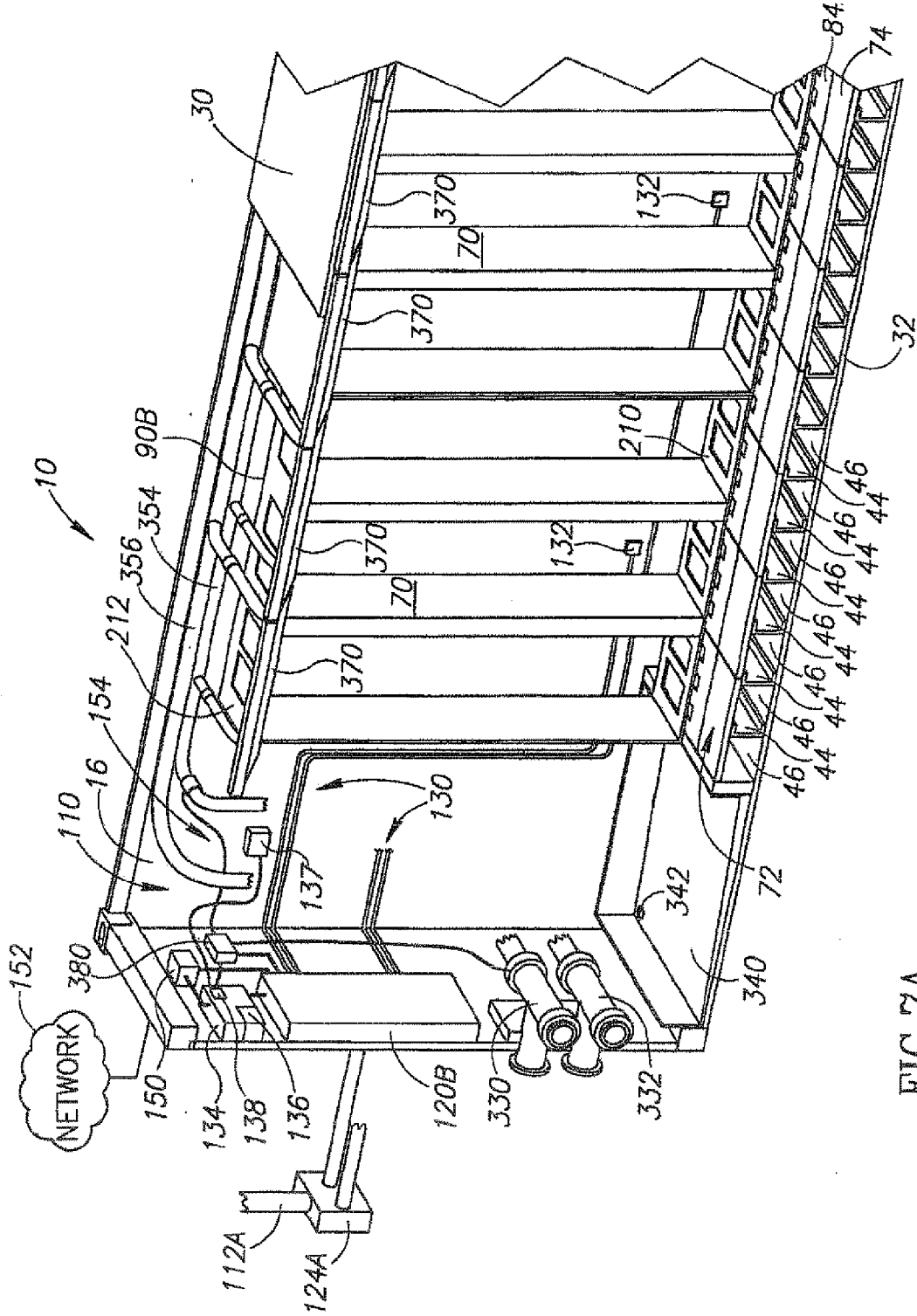


FIG. 7A

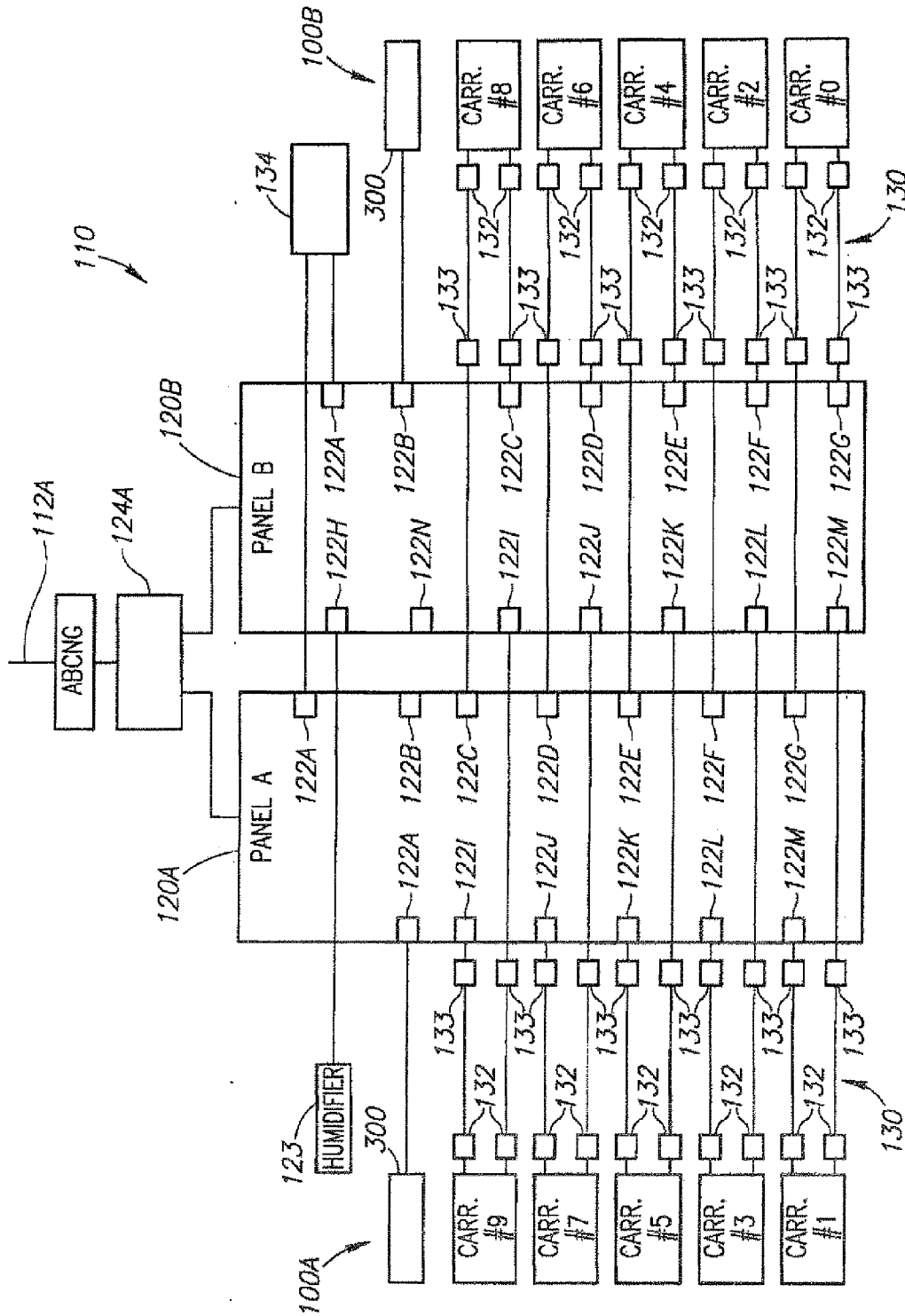


FIG. 7B

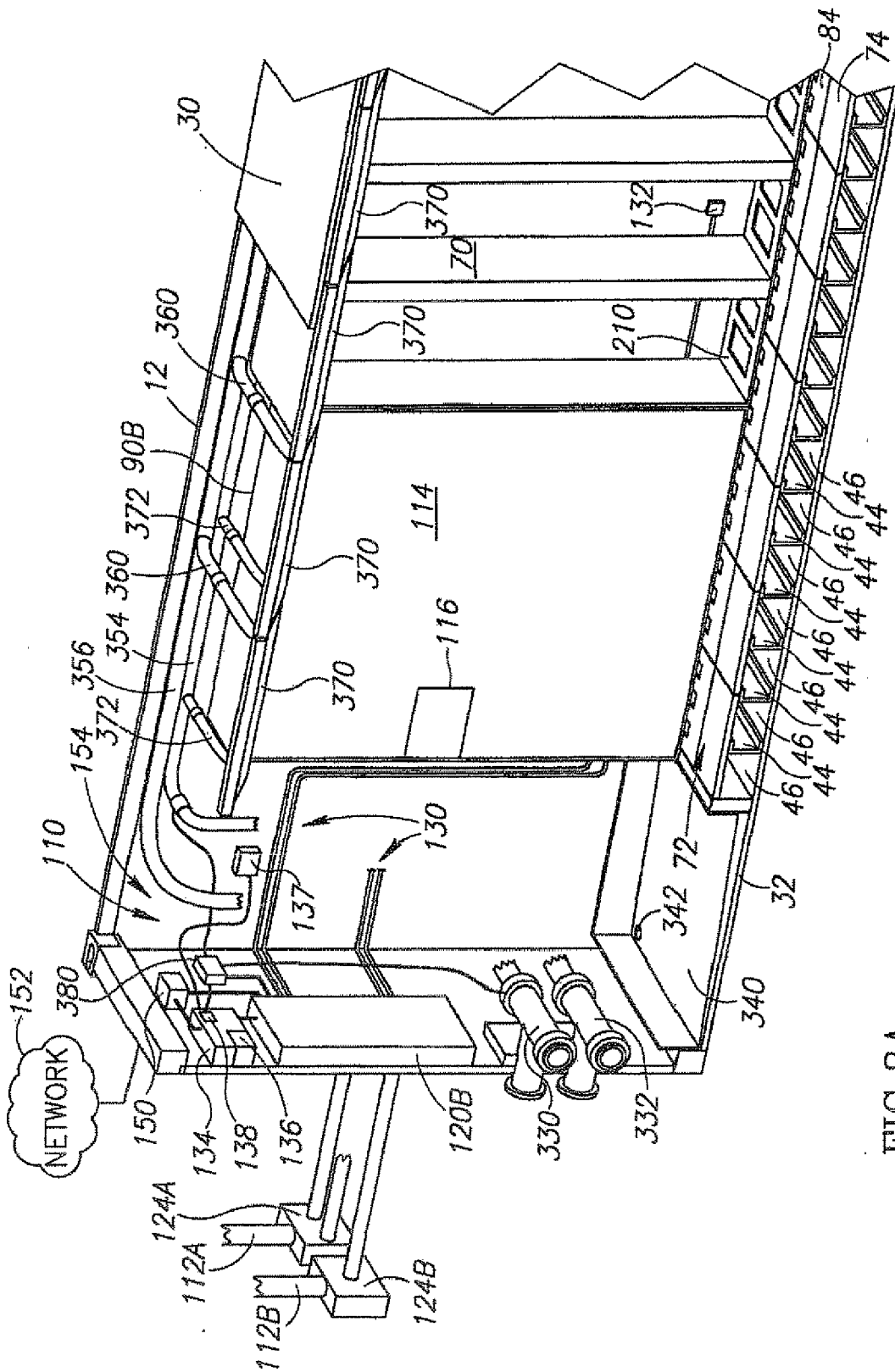


FIG. 8A

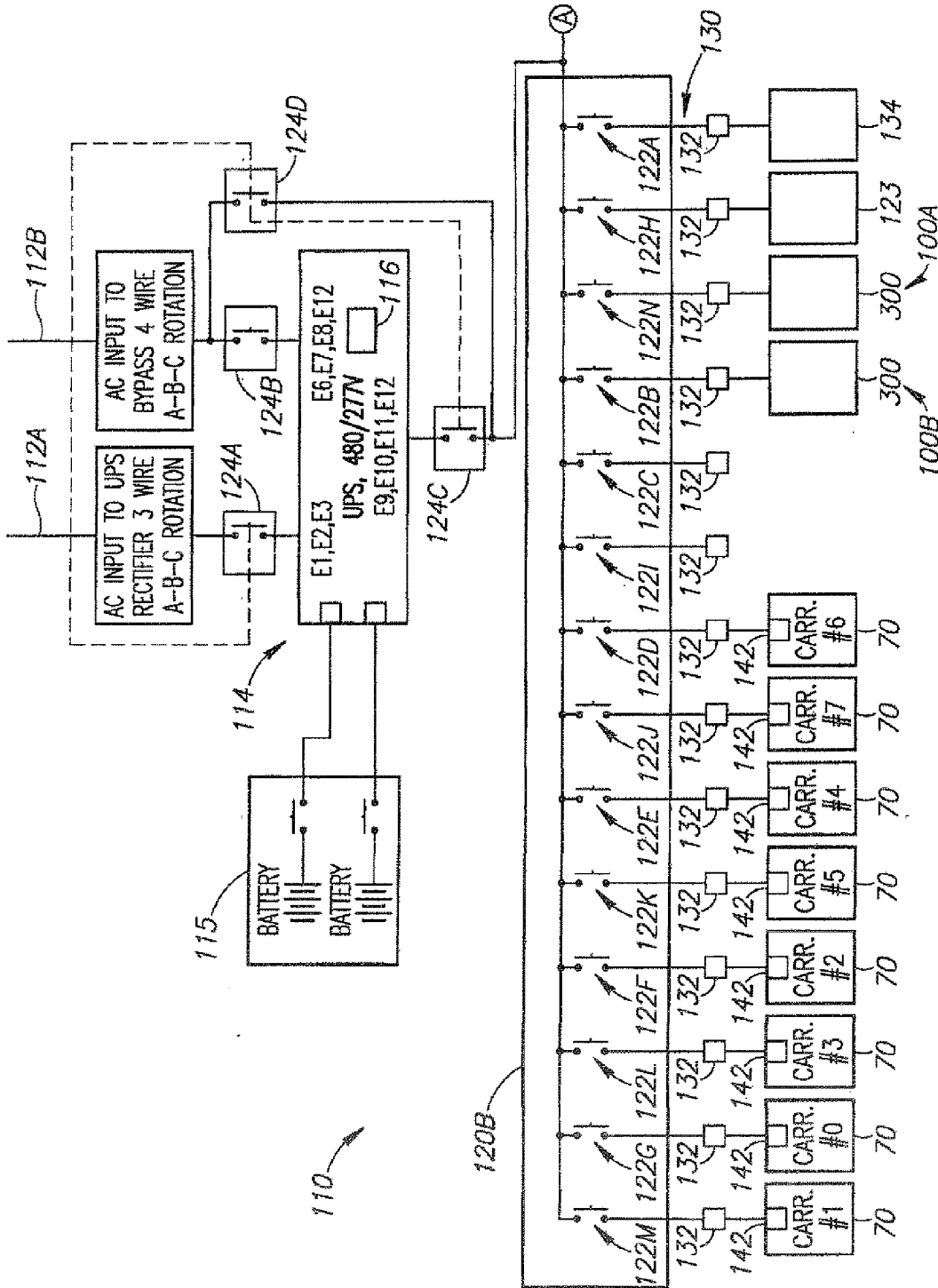


FIG. 8B

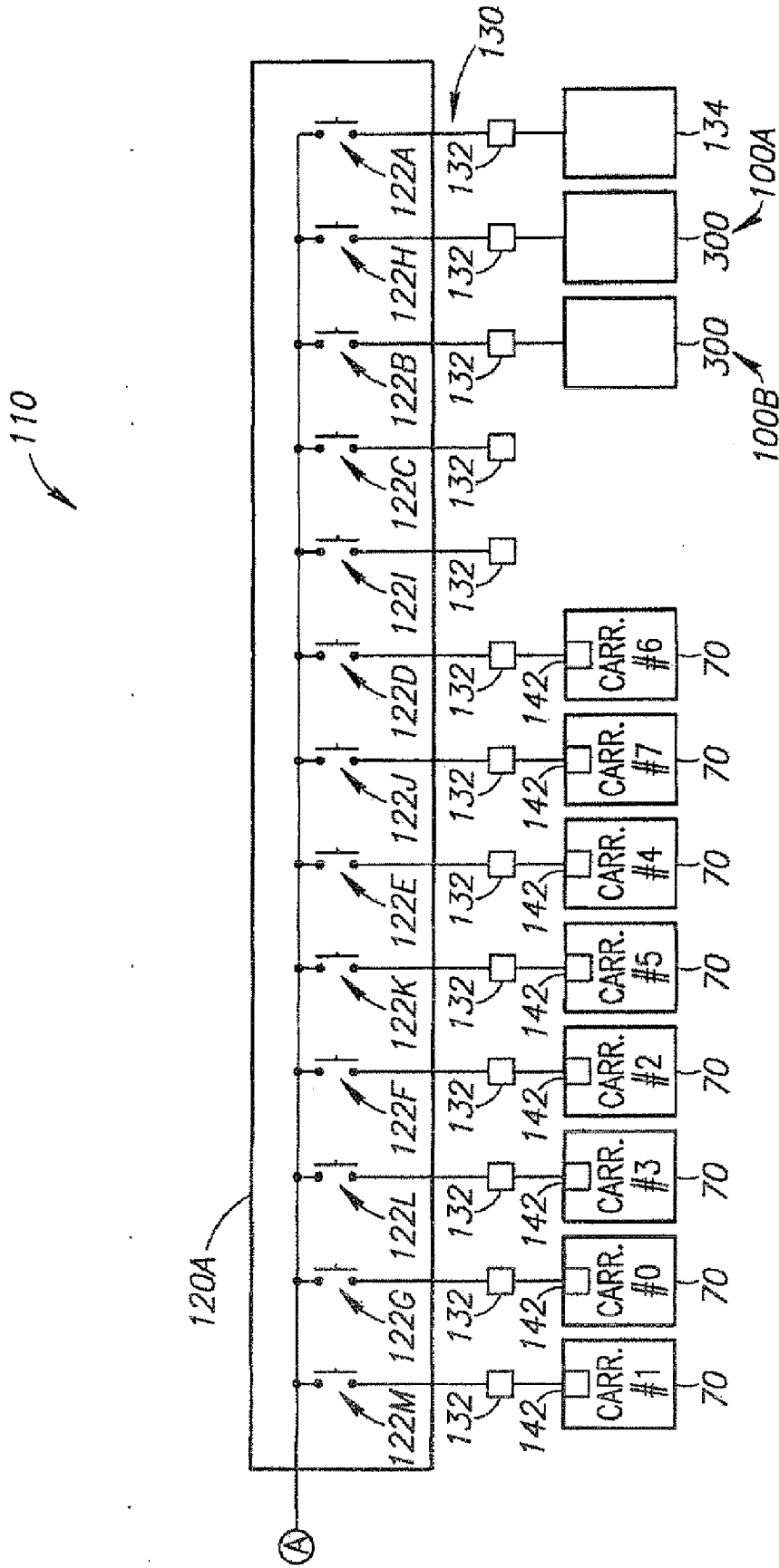


FIG.8C

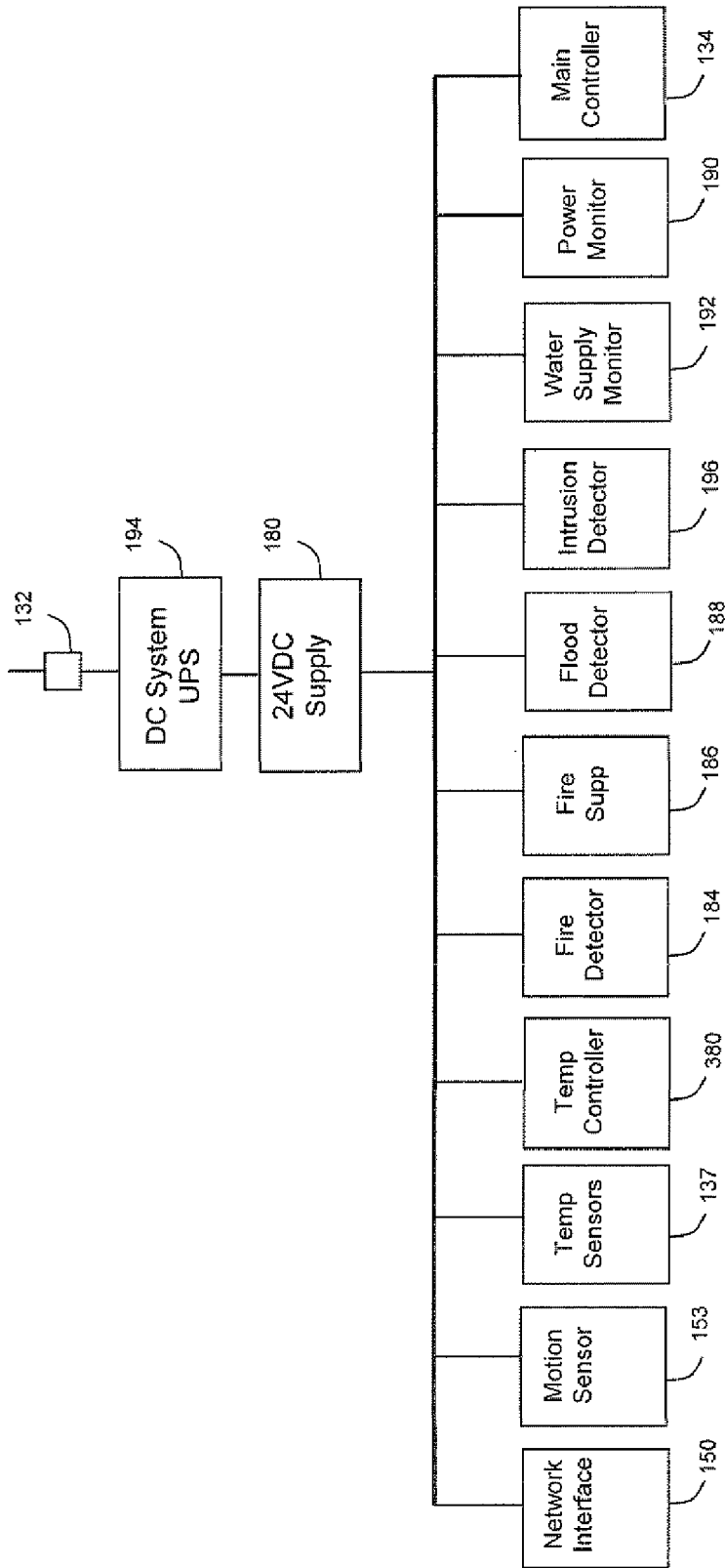


FIG. 8D

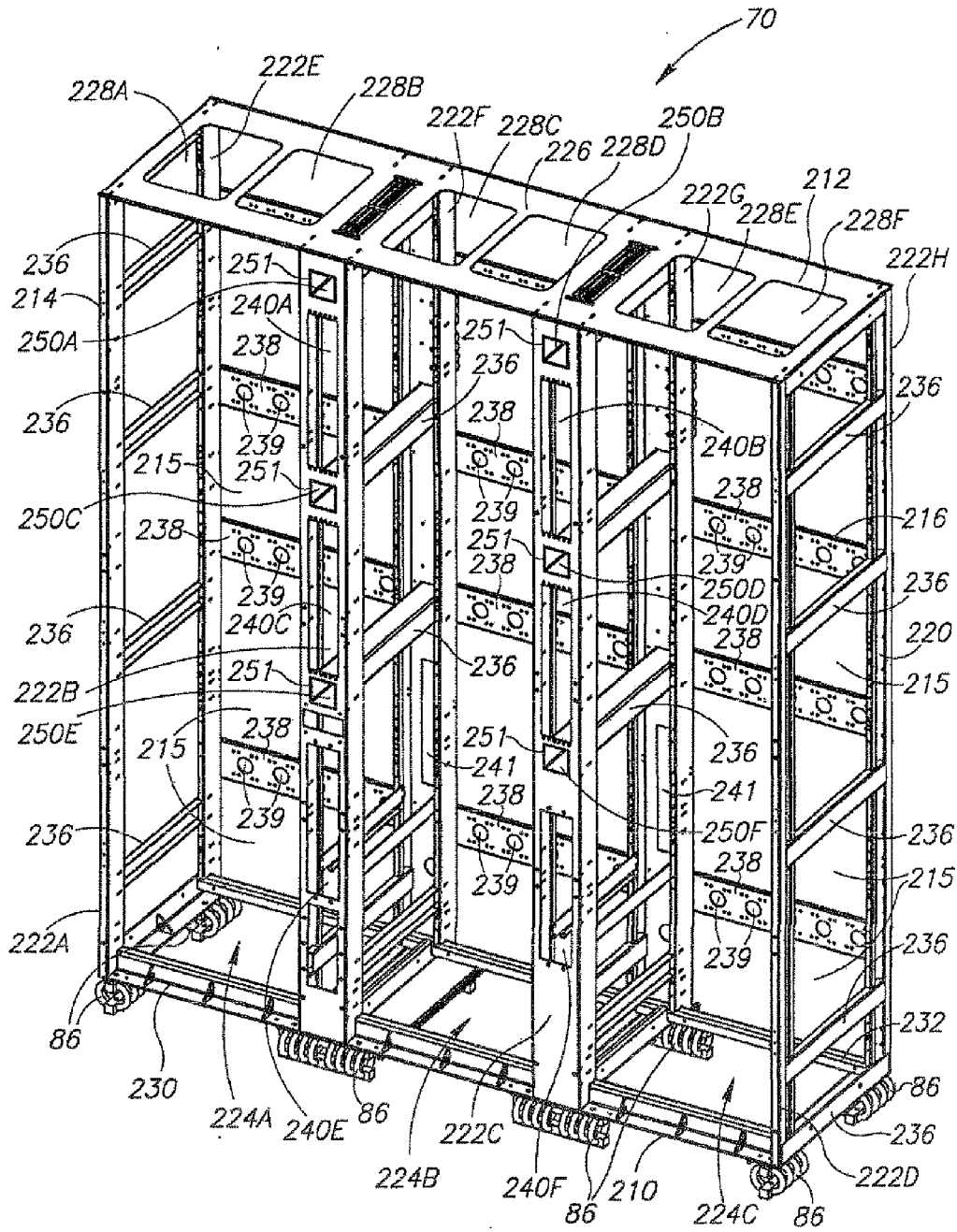


FIG. 9

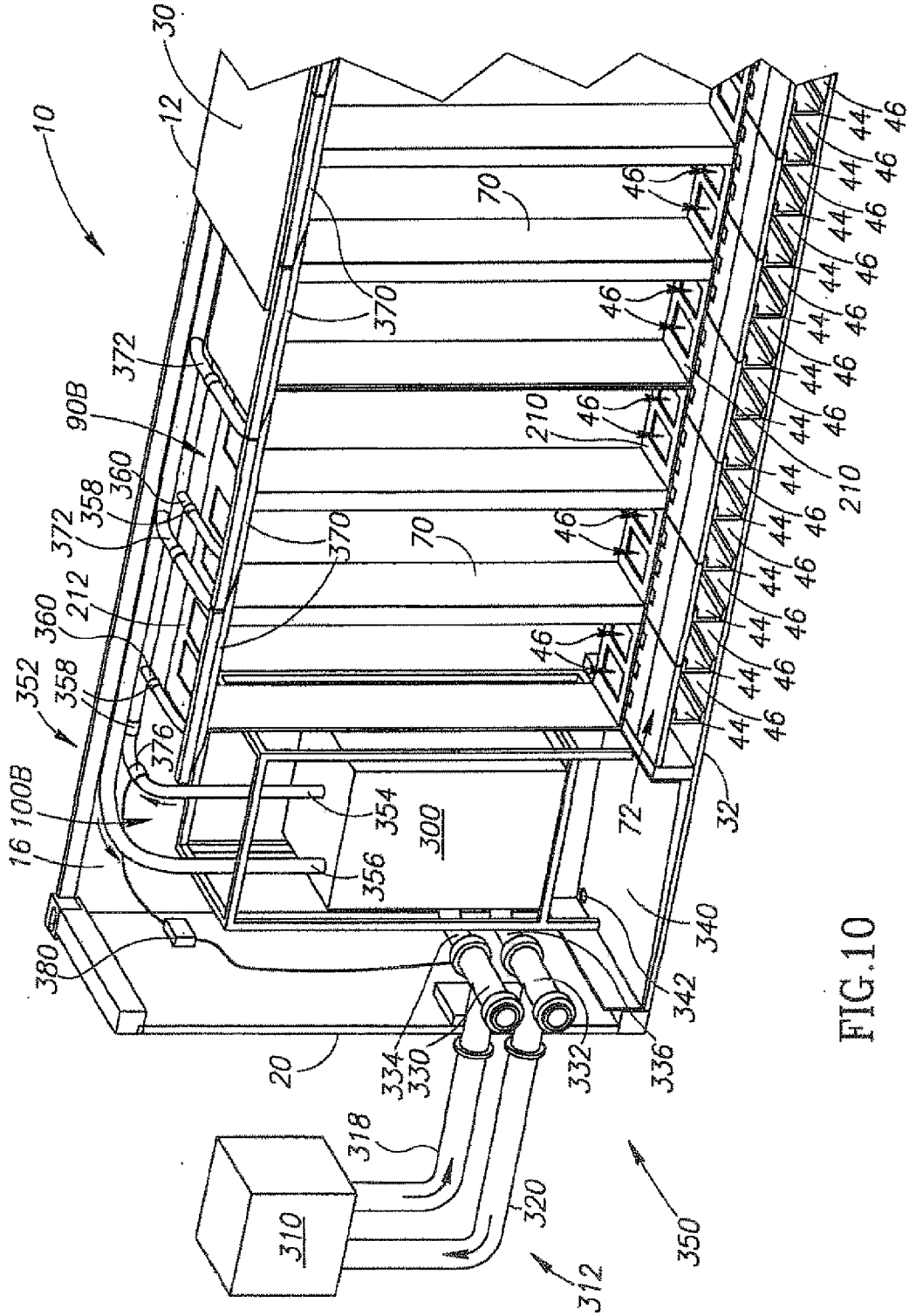


FIG.10

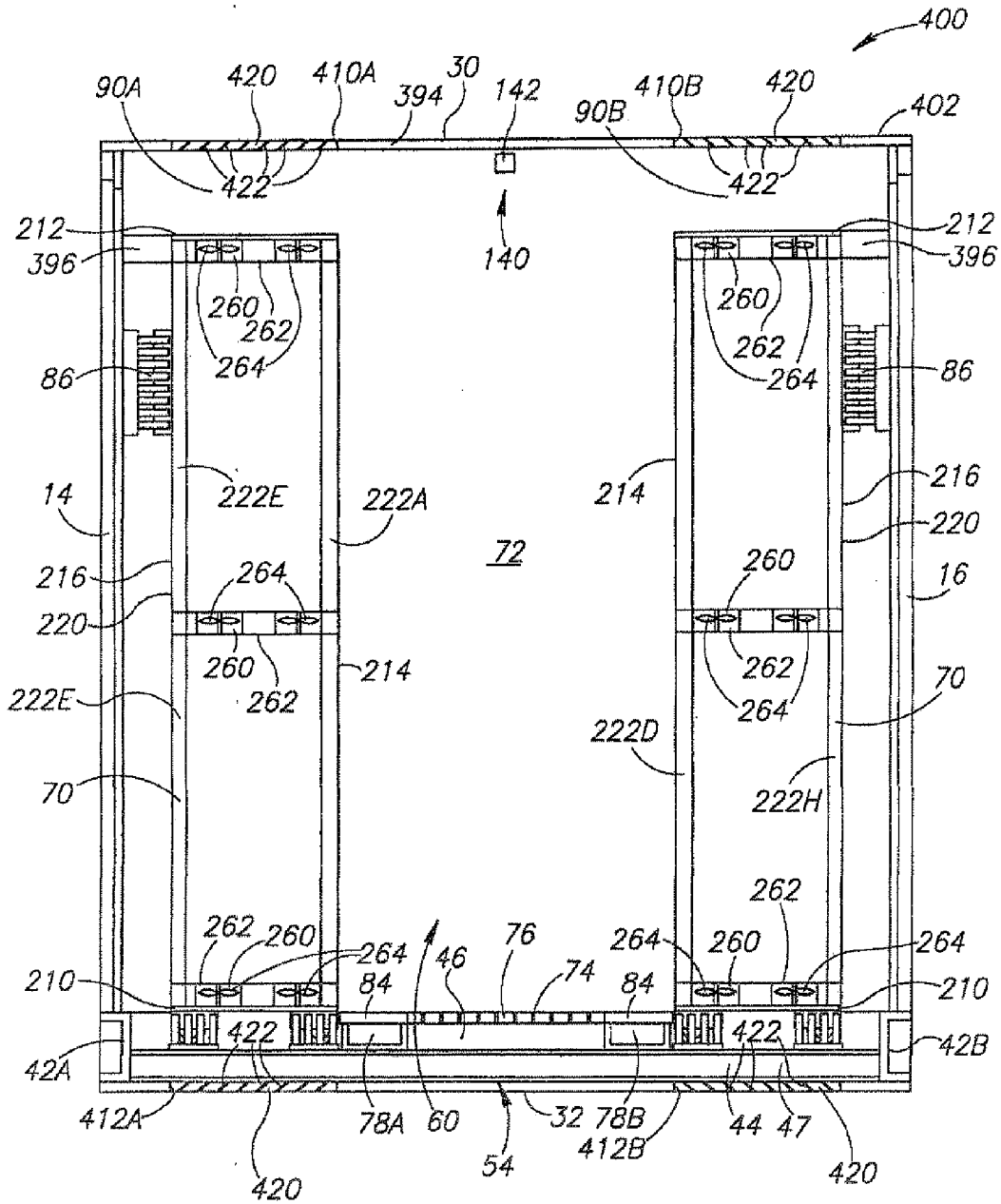


FIG. 11

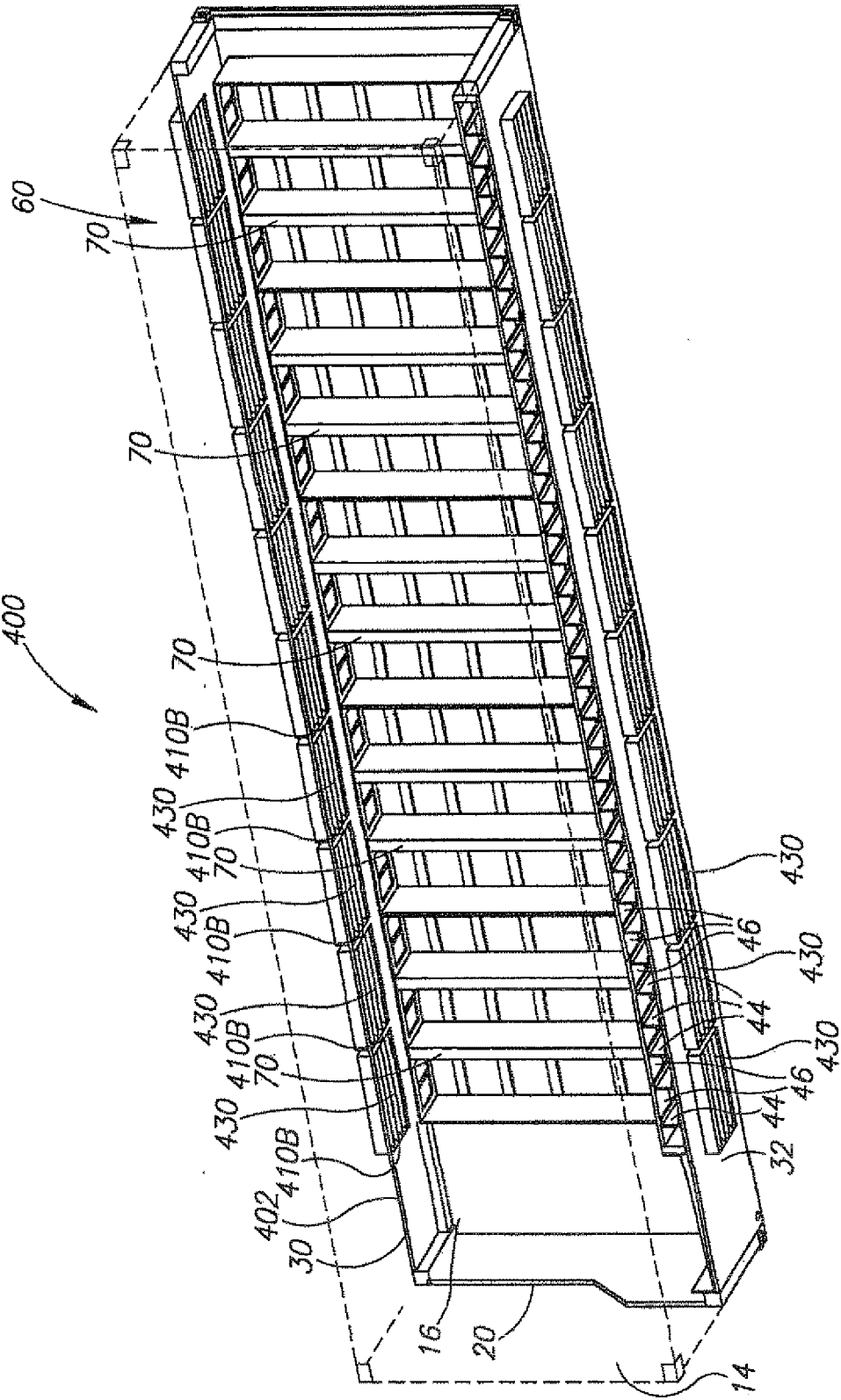


FIG.12

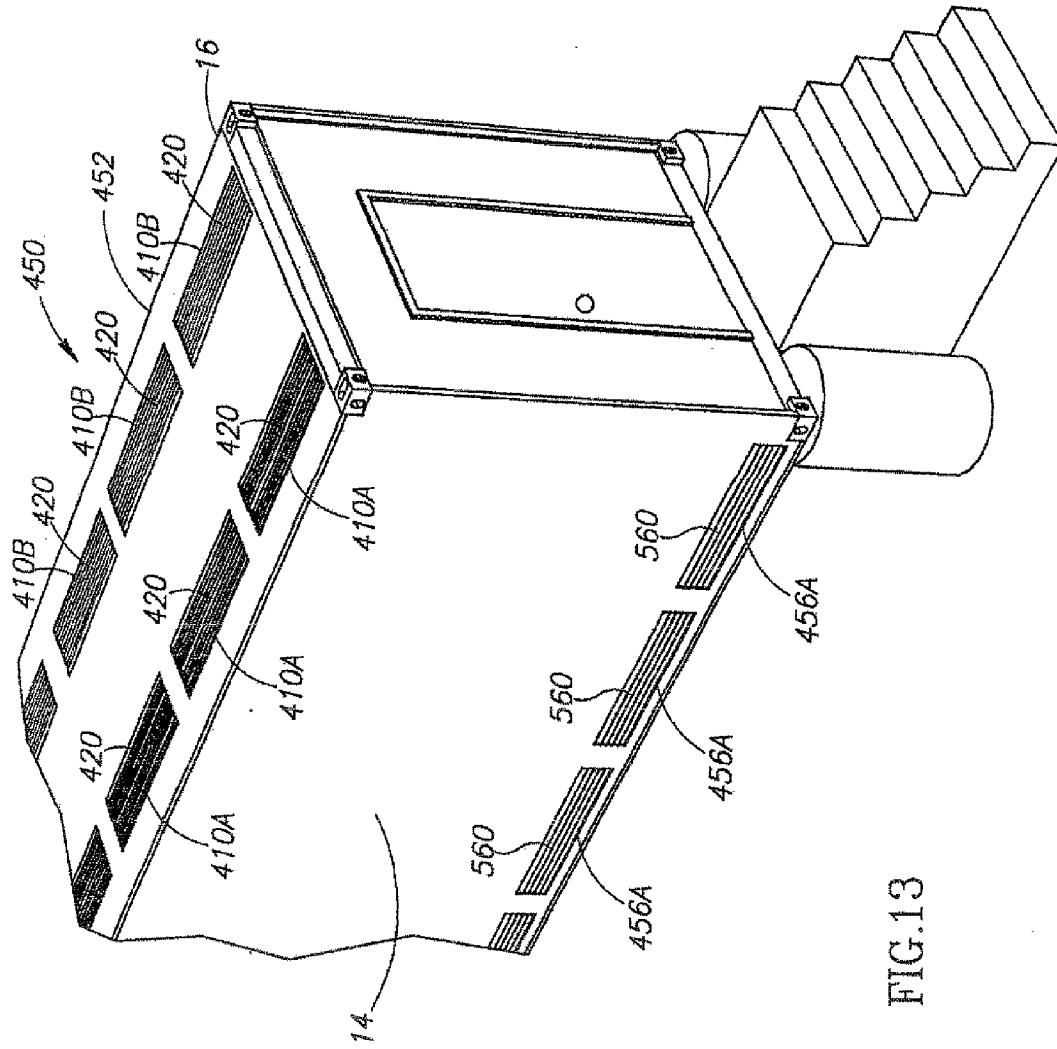


FIG.13

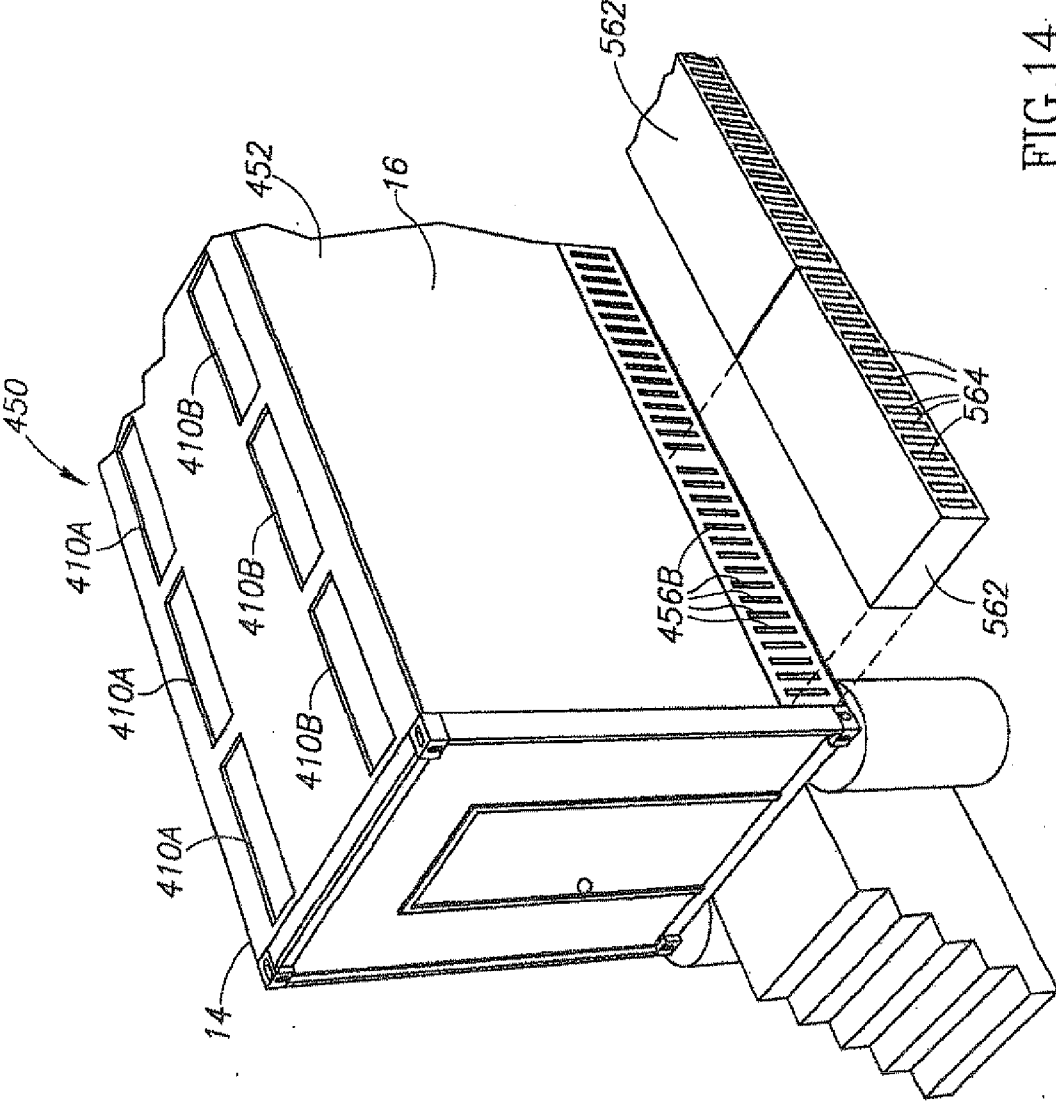


FIG. 14

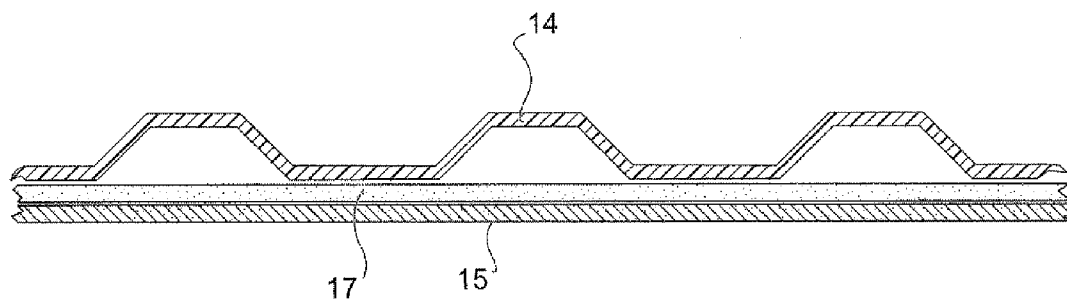


FIG. 15

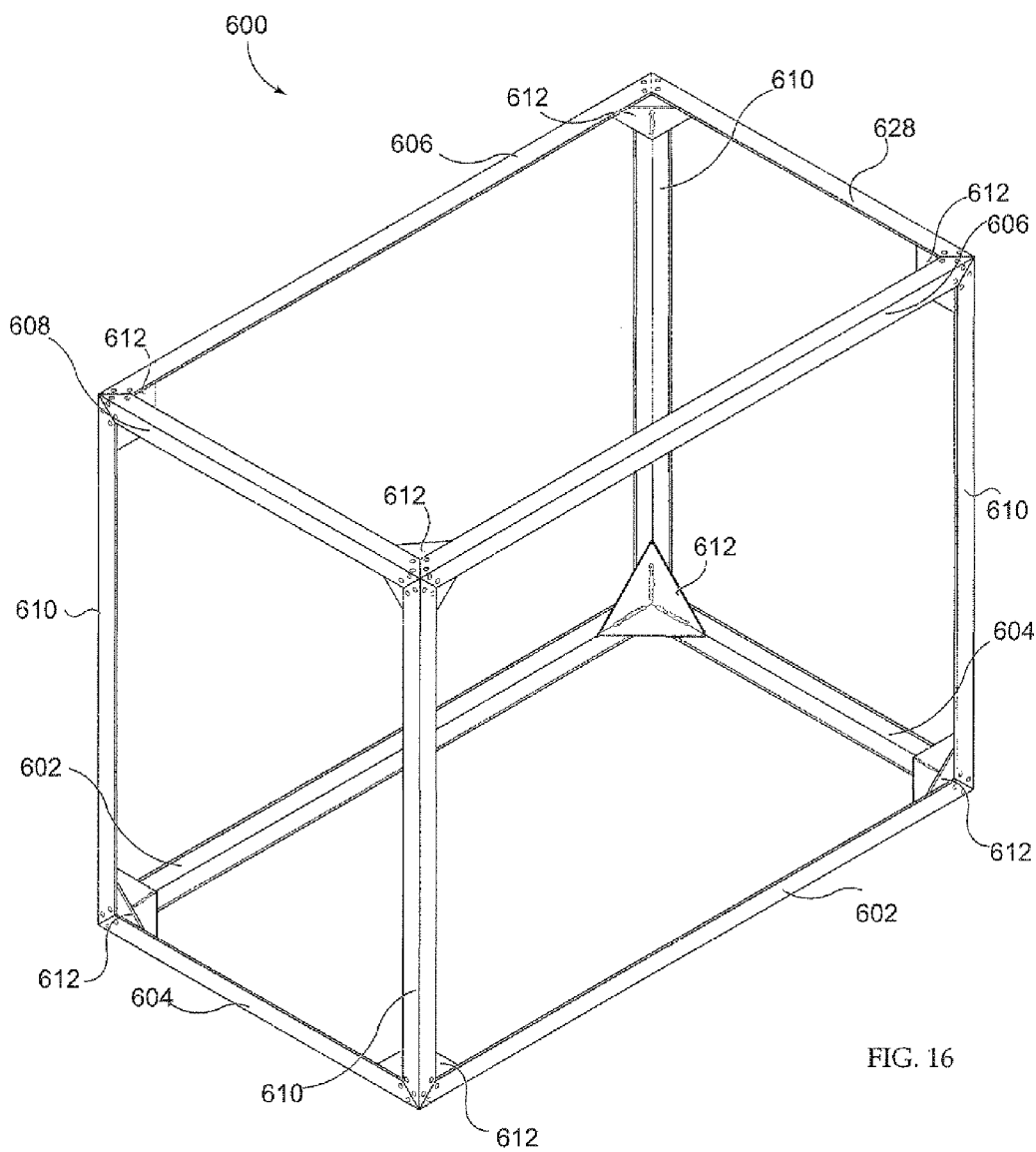


FIG. 16

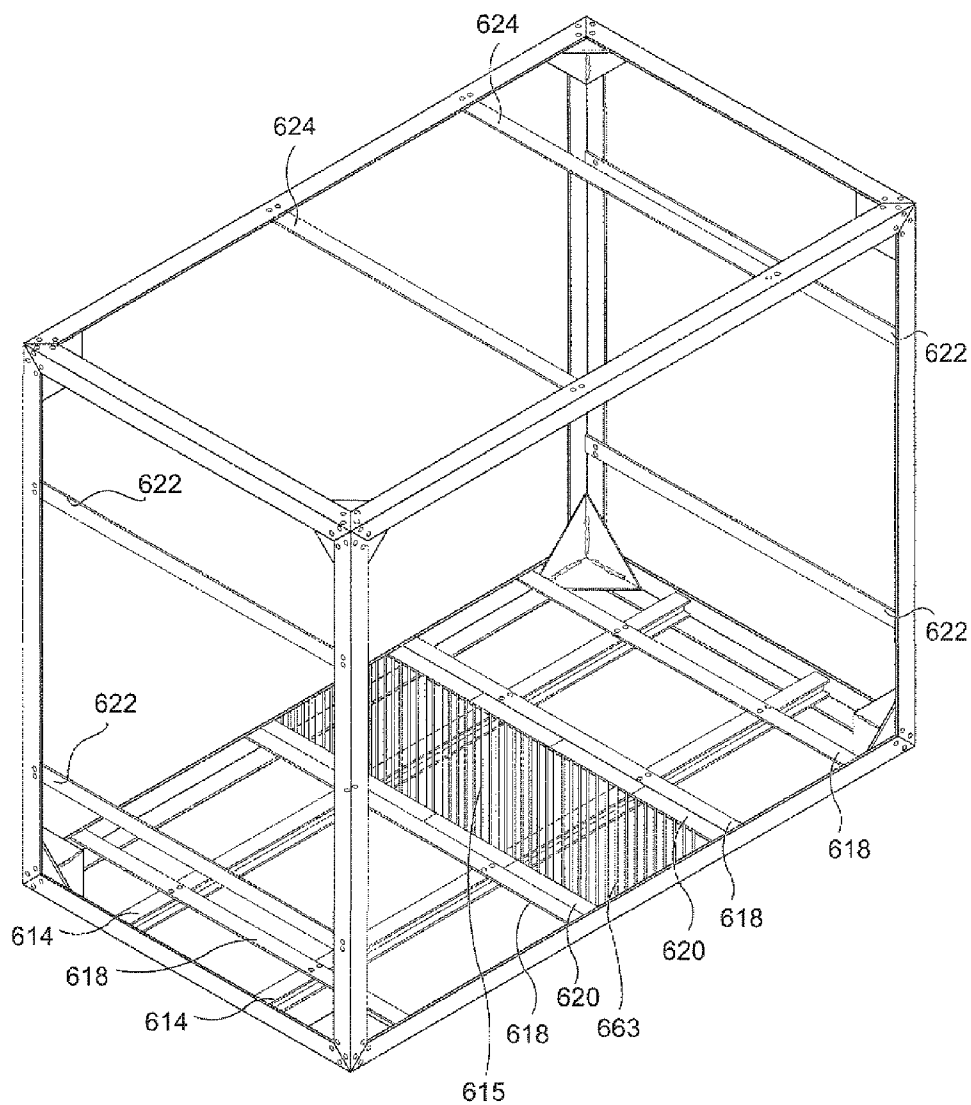


FIG. 17

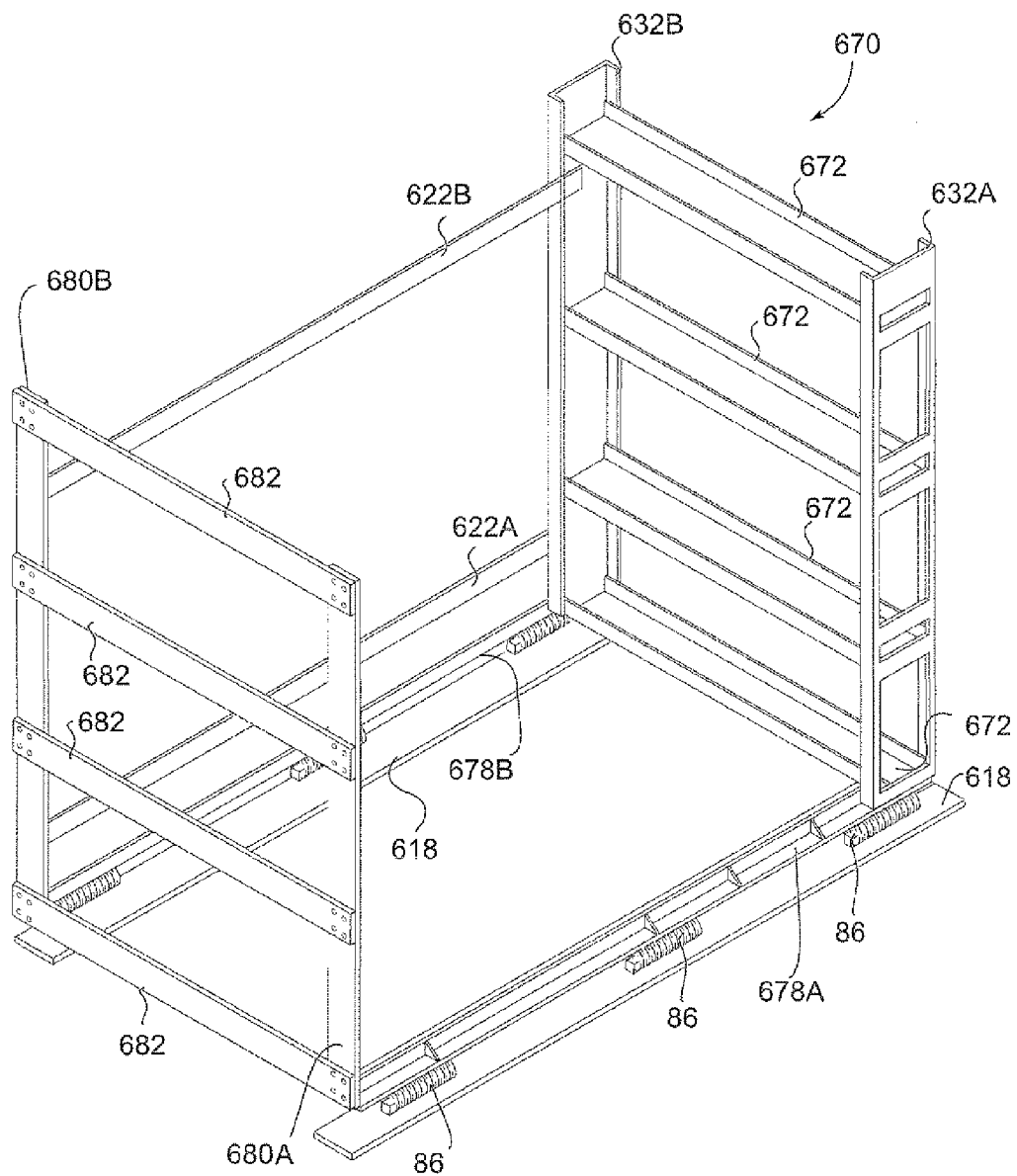


FIG. 18

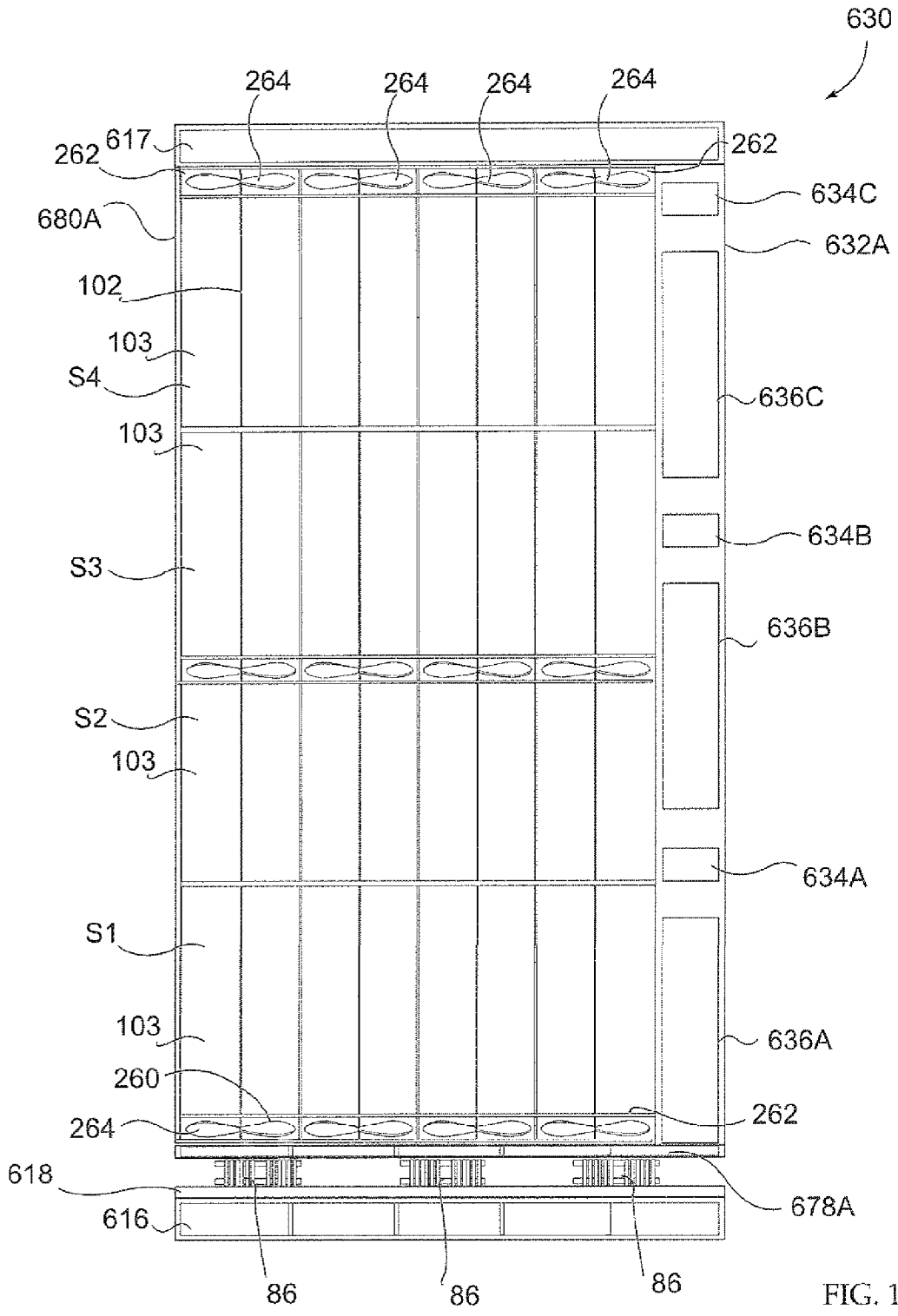
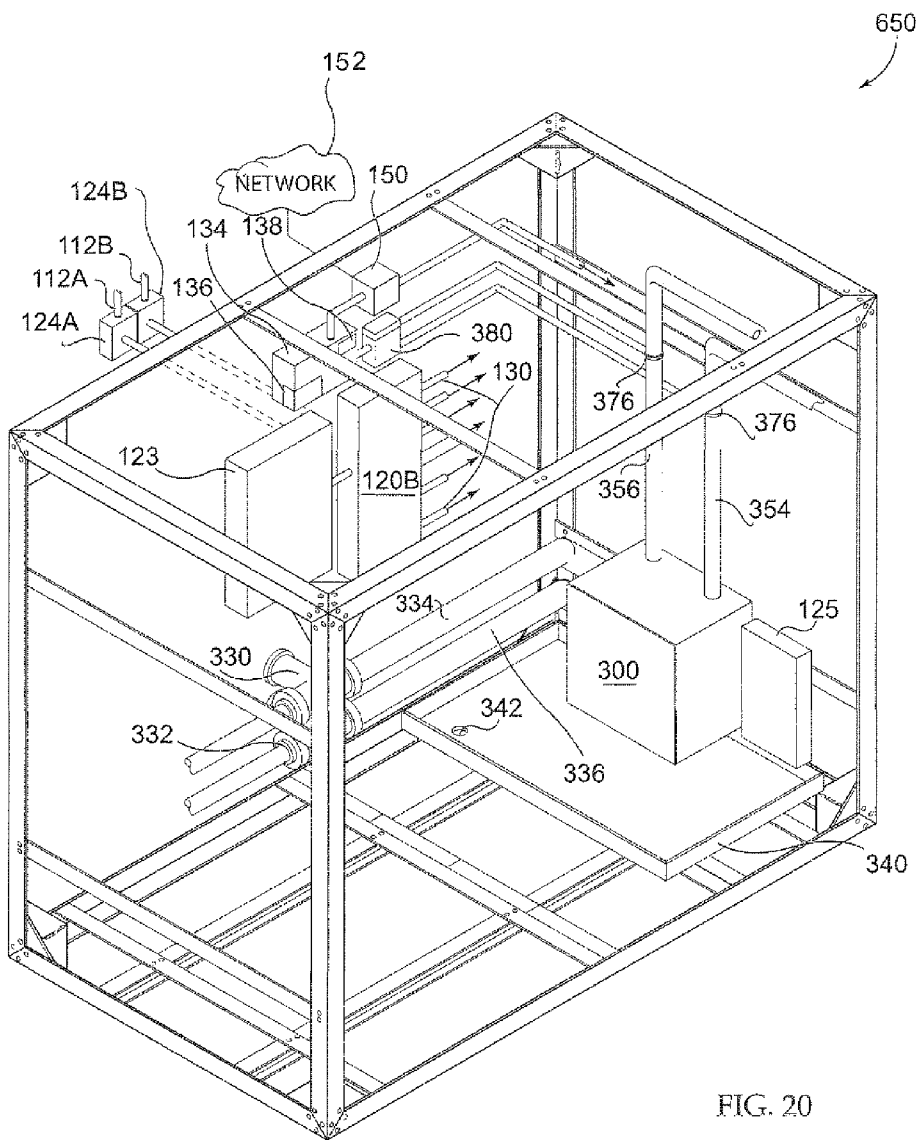
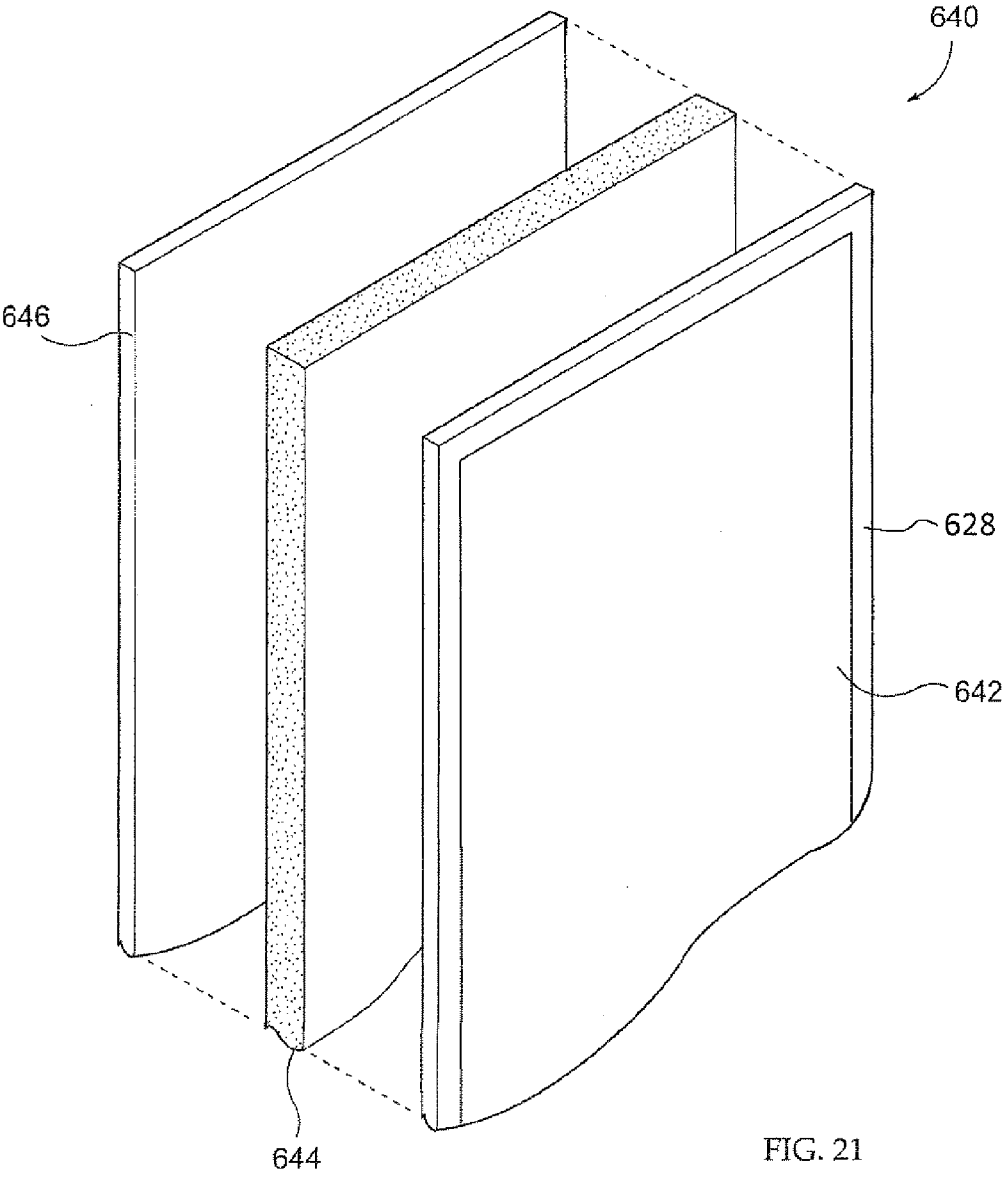


FIG. 19





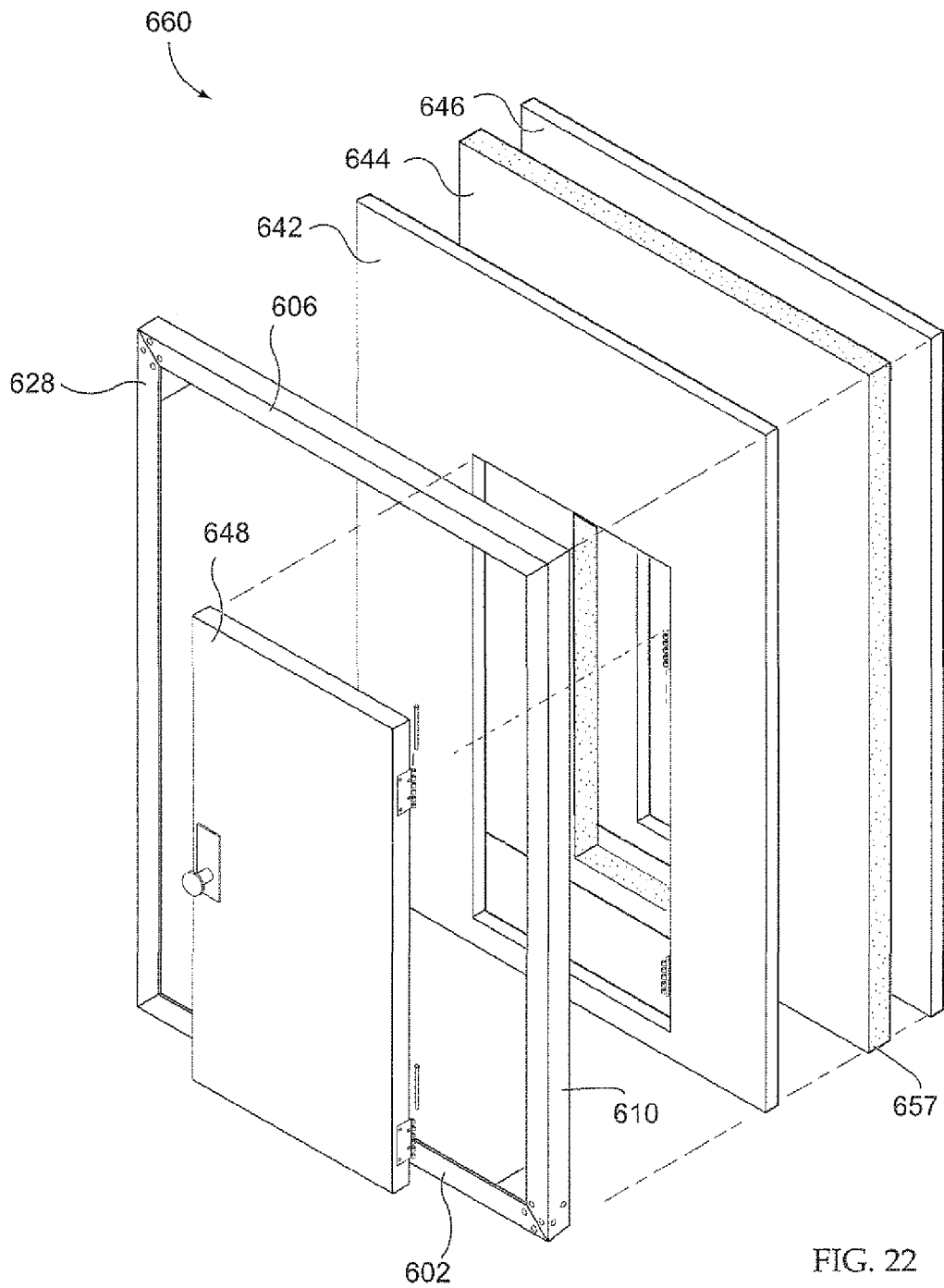


FIG. 22

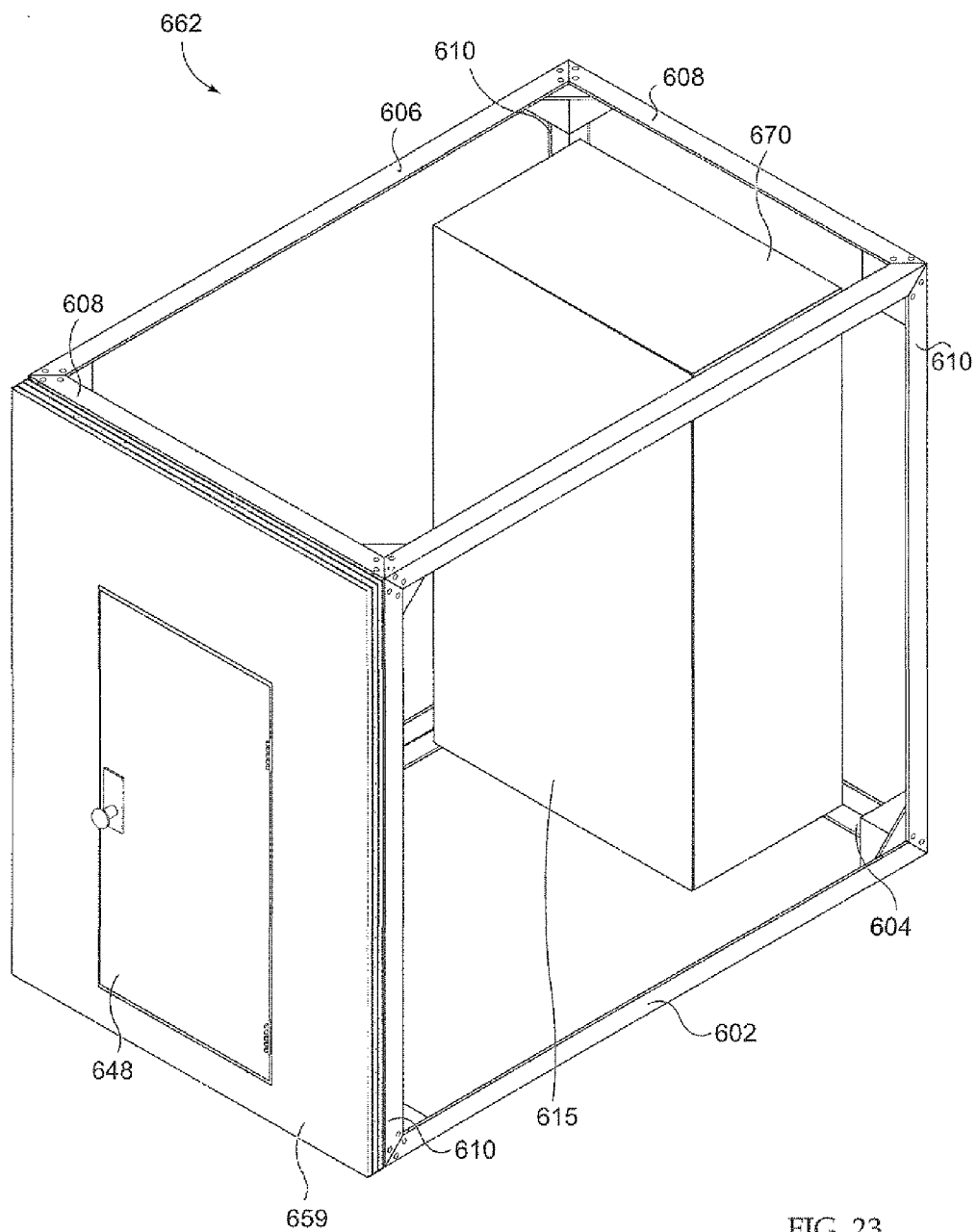


FIG. 23

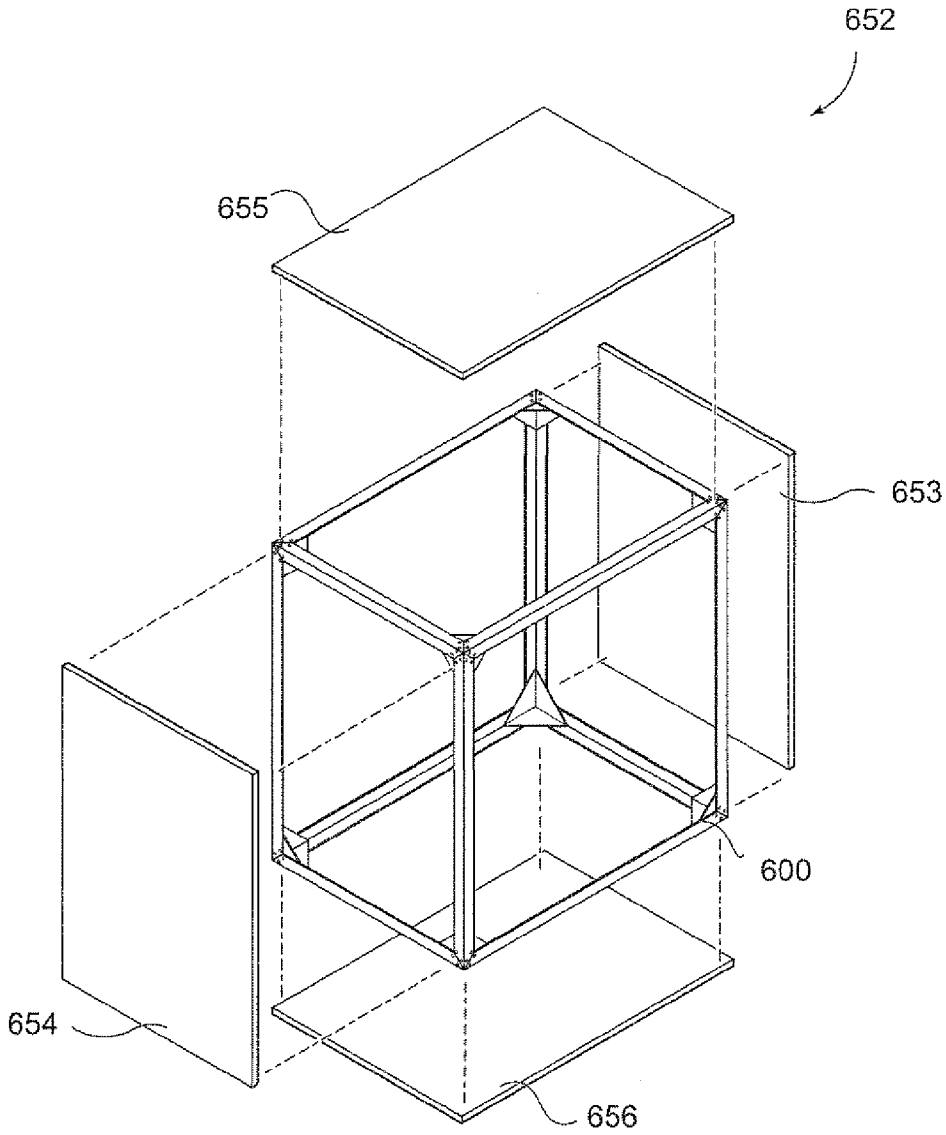


FIG. 24

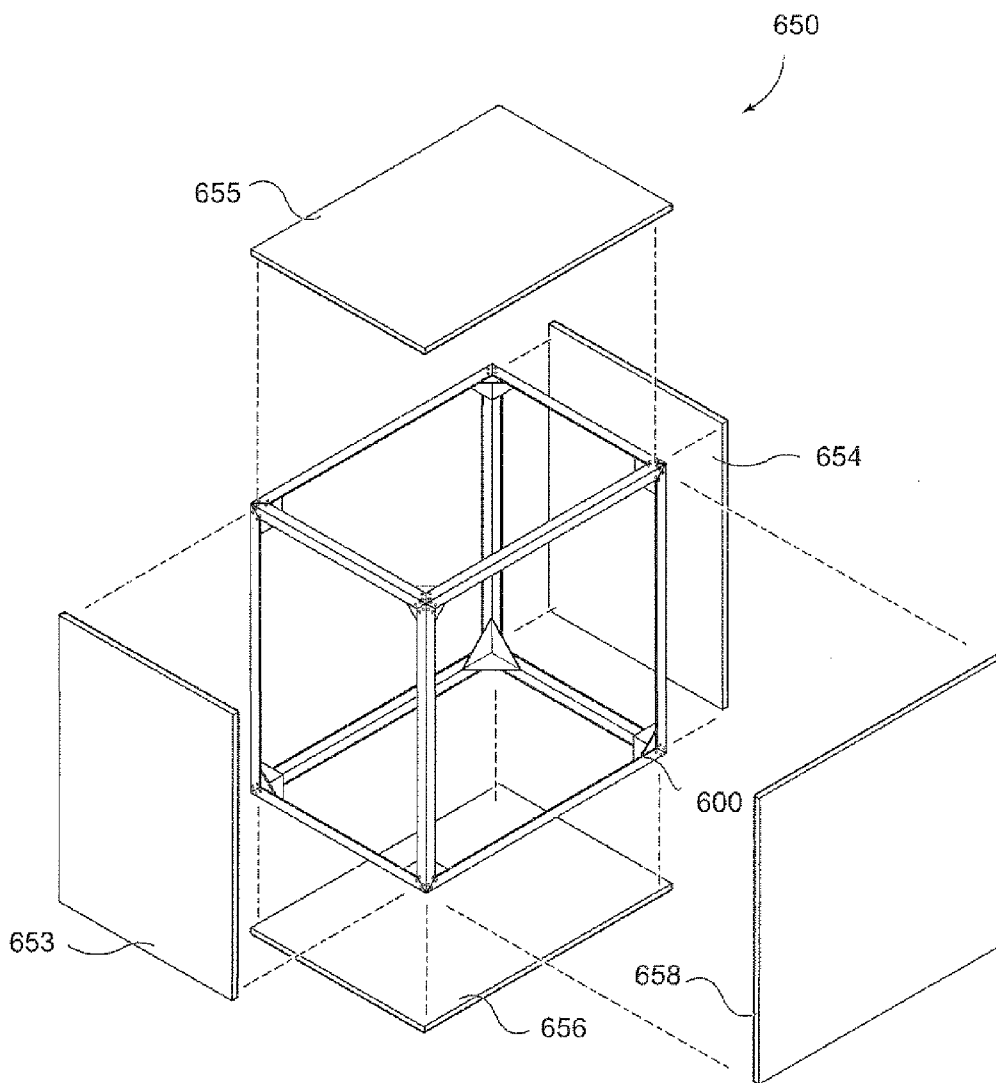


FIG. 25

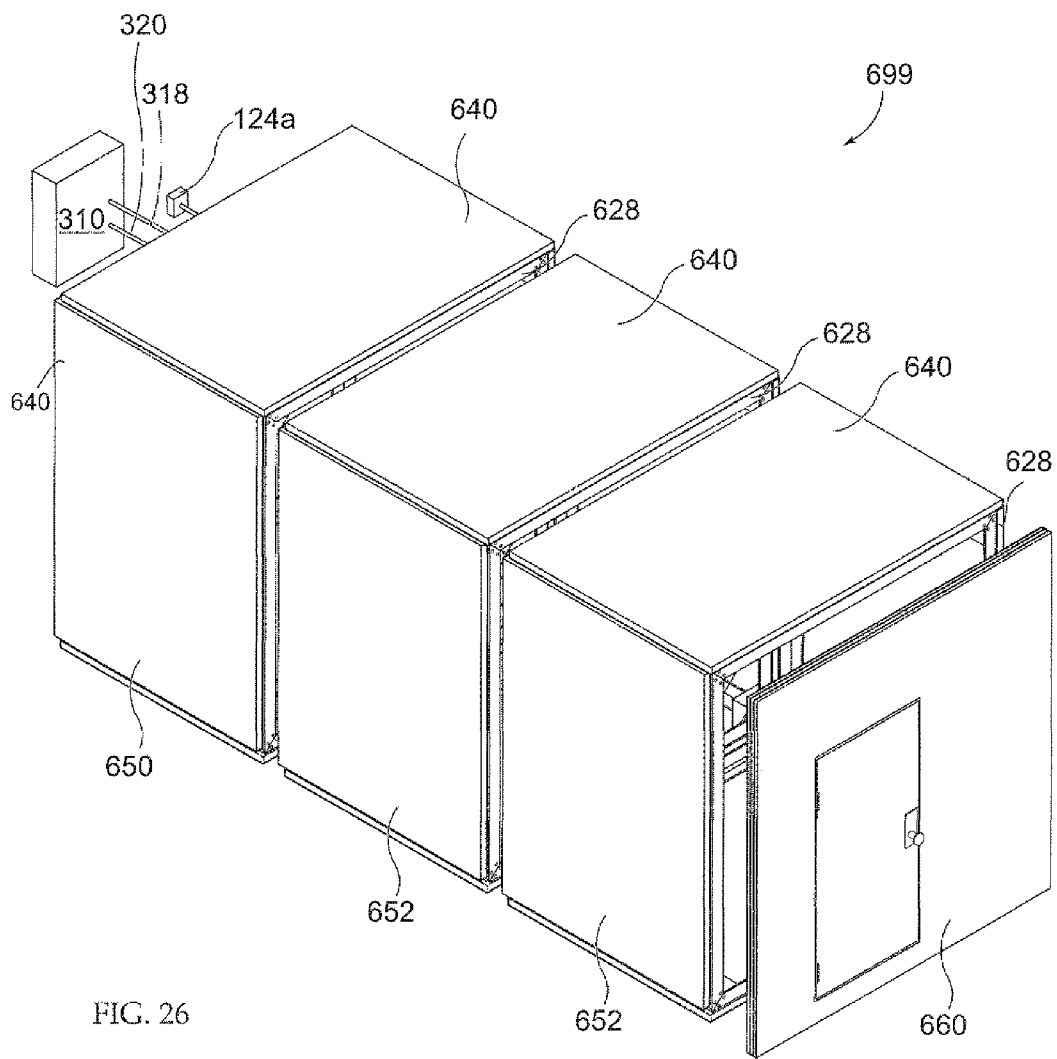


FIG. 26

DATA CENTER

RELATED APPLICATIONS

[0001] This application is a Continuation in Part of, and claims the benefit of priority to, United States Utility patent application Ser. No. 12/347,415 entitled "Data Center", filed Dec. 31, 2008.

BACKGROUND OF THE INVENTION

[0002] 1. Field of the Invention

[0003] The present invention is directed generally to a data center and more particularly to a modular data center.

[0004] 2. Description of the Related Art

[0005] Planning and constructing a traditional data center requires substantial capital, planning, and time. The challenges of planning a traditional data center include maximizing computing density (i.e., providing a maximum amount of computing capacity within a given physical space). Further, it may be difficult, if not impossible, to use the space available efficiently enough to provide adequate computing capacity.

[0006] Once a data center is constructed, it can be difficult to upgrade to keep up with current technologies. For example, it may be difficult, if not impossible, to expand an existing data center operating at full capacity because the expansion may require additional power and cooling resources, which simply are not available or would be costly to install.

[0007] Therefore, a need exists for a means of reducing the capital, planning, and/or time required to implement a data center. A further need exists for a data center that requires less capital, planning, and/or time than a traditional data center. A customizable data center configurable for a particular user's needs is also desirable. A data center capable of integration with an already existing data center is also advantageous. A further need also exists for a data center that requires less time and effort during set up and installation. The present application provides these and other advantages as will be apparent from the following detailed description and accompanying figures.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWING(S)

[0008] FIG. 1 is a perspective view of a data center housed inside a container.

[0009] FIG. 2 is an enlarged fragmentary perspective view of the container of FIG. 1 omitting its first longitudinal side portion, front portion, and personnel door to provide a view of its interior portion.

[0010] FIG. 3 is an enlarged fragmentary cross-sectional perspective view of the data center of FIG. 1 taken laterally through the container and omitting its first longitudinal side portion, and second longitudinal side portion.

[0011] FIG. 4 is an enlarged fragmentary cross-sectional perspective view of the data center of FIG. 1 omitting its electrical system and taken longitudinally through the container.

[0012] FIG. 5 is an enlarged fragmentary cross-sectional view of the data center of FIG. 1 omitting its electrical system and taken laterally through the container.

[0013] FIG. 6 is a front view of a carriage of the data center of FIG. 1 housing exemplary computing equipment.

[0014] FIG. 7A is an enlarged fragmentary cross-sectional perspective view of the data center of FIG. 1 omitting portions of its vertical cooling system and taken longitudinally through the container.

[0015] FIG. 7B is an electrical schematic of the electrical system of the data center of FIG. 1.

[0016] FIG. 8A is an enlarged fragmentary cross-sectional perspective view of an embodiment of the data center of FIG. 1 including an uninterruptible power supply ("UPS") omitting its vertical cooling system and taken longitudinally through the container.

[0017] FIGS. 8B and 8C are an electrical schematic of the electrical system of the data center of FIG. 1 including a UPS.

[0018] FIG. 9 is a perspective view of the carriage of FIG. 5 omitting the exemplary computing equipment.

[0019] FIG. 10 is an enlarged fragmentary cross-sectional perspective view of the data center of FIG. 1 omitting its electrical system and taken longitudinally through the container.

[0020] FIG. 11 is an enlarged fragmentary cross-sectional view of an alternate embodiment of a data center including openings and louvers along its roof and floor portions, omitting its electrical system, and taken laterally through the container.

[0021] FIG. 12 is an enlarged fragmentary cross-sectional perspective view of the data center of FIG. 11 including alternate louvers along its roof and floor portions and, omitting its electrical system and portions of its vertical cooling systems, and taken longitudinally through the container.

[0022] FIG. 13 is an enlarged fragmentary perspective view of alternate embodiment of a data center including openings and louvers along its roof portion and side portions.

[0023] FIG. 14 is an enlarged fragmentary perspective view of the data center of FIG. 13 omitting louvers along its roof portion and including louver assemblies along its side portions.

[0024] FIG. 15 is an enlarged fragmentary cross-sectional view of the insulated wall of the data center of FIG. 1 showing the outer container wall, a middle insulating layer, and an inner protective layer.

[0025] FIG. 16 is a perspective view of the base frame of the modular data center, including corner support braces.

[0026] FIG. 17 is a perspective view of the base frame with bottom, side and top supports used to mount and support internal equipment.

[0027] FIG. 18 is a perspective view of a carriage assembly for receiving computing equipment.

[0028] FIG. 19 is a front view of a carriage assembly showing air moving devices and designated spaces for computing equipment.

[0029] FIG. 20 is a perspective view of a facilities module showing a heat exchanger, cooling water pipes, humidifier, dehumidifier, electrical panels and conduits, external connections, a controller, and sensors. The internal components of the module are redundant on both sides therefore only one side is shown for clarity.

[0030] FIG. 21 is a fragmentary view of a modular wall showing an inner wall, an insulating layer, and an outer wall.

[0031] FIG. 22 is a fragmentary view of an end cap showing an outer wall, insulating layer, inner wall, frame, and personnel door.

[0032] FIG. 23 is a perspective view of an alternative embodiment of a computing module showing a personnel door replacing a carriage.

[0033] FIG. 24 is a fragmentary view of a computing equipment module showing the frame, two side walls, a bottom wall, and a top wall.

[0034] FIG. 25 is a fragmentary view of a facilities module showing the frame, two side walls, one end wall, one bottom wall, and one top wall.

[0035] FIG. 26 is a perspective view of an embodiment of the modular data center showing one facilities module, two computing equipment modules, one end cap with personnel door, and external support connections.

DETAILED DESCRIPTION OF THE INVENTION

[0036] Referring to FIG. 1, aspects of the present invention relate to a data center 10 housed inside a container 12. The container 12 may be a conventional shipping container of the type typically used to ship goods via a cargo ship, railcar, semi-tractor, and the like. The container 12 is portable and may be delivered to a use site substantially ready for use with minimal set up required. As will be described in detail below, the data center 10 may be preconfigured with desired computer hardware, data storage capacity, and interface electronics. For example, the data center 10 may be configured according to customer requirements and/or specifications.

[0037] The data center 10 is completely self contained in the container 12 and may be substantially ready for use immediately following delivery thus reducing the need for on-site technical staff, and in particular embodiments, reducing the need to install and setup computing hardware, route data cables, route power cables, and the like.

[0038] As described in detail below, the environment inside the container 12 may be climate controlled to provide a suitable environment for the operation of computing equipment and hardware. For example, the environment inside the container 12 may provide optimal power consumption (including adequate power for lighting), cooling, ventilation, and space utilization. The data center 10 may be configured to provide an efficient self-contained computing solution suitable for applications in remote locations, temporary locations, and the like.

[0039] The container 12 has a first longitudinal side portion 14 opposite a second longitudinal side portion 16. The container 12 also includes a first end portion 18 extending transversely between the first and second longitudinal side portions 14 and 16 and a second end portion 20 extending transversely between the first and second side portions 14 and 16. By way of a non-limiting example, each of the first and second longitudinal side portions 14 and 16 may be about 40 feet long and about 9.5 feet tall. By way of an alternative non-limiting example, each of the first and second longitudinal side portions 14 and 16 may be about 20 feet long and about 9.5 feet tall. The first and second end portions 18 and 20 may be about 8 feet wide and about 9.5 feet tall. One of the first and second end portions 18 and 20 may include a personnel door 24. The container 12 also includes a top or roof portion 30 extending transversely between the first and second side portions 14 and 16 and longitudinally between the first and second end portions 18 and 20. The container 12 also includes a bottom or floor portion 32 extending transversely between the first and second side portions 14 and 16 and longitudinally between the first and second end portions 18 and 20. The container 12 may be mounted on pillars 33, blocks, or the like to be elevated above the ground.

[0040] To minimize or prevent condensation build up on the inside of the container 12, and to minimize the required

amount of cool water from the cooled water supply or source 310, insulation may be applied to the inside of the container 12, covering the longitudinal side portions 14 and 16, the end portions 18 and 20, the top or roof portion 30 and the bottom or floor portion 32. A steel panel (not shown) is then applied to cover the insulation, providing protection for the insulation. The steel panel may be attached to the container 12 side portions 14 and 16, end portions 18 and 20, top or roof portion 30, and bottom or floor portion 32 by way of, for example, spot welds numerous enough to provide adequate mechanical support for the steel panels and applied insulation. By way of non-limiting example, the insulation may be pre-formed foam panels of polyisocyanurate.

[0041] As illustrated in FIG. 2 and appreciated by those of ordinary skill in the art, the floor portion 32 includes a support frame 40 having a first longitudinally extending framing member 42A spaced laterally from a second longitudinally extending framing member 42B. The first and second longitudinally extending framing members 42A and 42B extend along and support the first and second longitudinal side portions 14 and 16 (see FIG. 1), respectively.

[0042] The floor portion 32 also includes a plurality of laterally extending framing members 44 that extend transversely between the first and second longitudinally extending framing members 42A and 42B. A plurality of laterally extending interstices or lower plenums 46 are defined between the laterally extending framing members 44. If as illustrated in the embodiment depicted in FIG. 3, the laterally extending framing members 44 have a C-shaped cross-sectional shape having an open inside portion 47, the lower plenums 46 may each include the open inside portions 47 of the C-shaped laterally extending framing members 44. Air may flow laterally within the floor portion 32 inside the lower plenums 46, which include the open inside portion 47 of the C-shaped laterally extending framing members 44. The laterally extending framing members 44 may help guide or direct this lateral airflow.

[0043] Each of the laterally extending framing members 44 may be constructed from a single elongated member having a C-shaped cross-sectional shape. However, each of the laterally extending framing members 44 may include three laterally extending portions: a first portion 50, a second portion 52, and a third portion 54. The first portion 50 is adjacent the first longitudinal side portion 14, the second portion 52 is adjacent the second longitudinal side portion 16, and the third portion 54 is located between the first and second portions 50 and 52.

[0044] A first pair of spaced apart longitudinally extending support surfaces 56A and 56B are supported by the first portion 50 of the laterally extending framing members 44. A second pair of spaced apart longitudinally extending support surfaces 58A and 58B are supported by the second portion 52 of the laterally extending framing members 44. In the embodiment illustrated, the third portion 54 of the laterally extending framing members 44 is flanked by the longitudinally extending support surfaces 56B and 58B.

[0045] FIG. 4 provides a longitudinal cross-section of the data center 10. For illustrative purposes, the first end portion 18 and the personnel door 24 have been omitted to provide a better view of the components inside the container 12. The first longitudinal side portion 14, the second longitudinal side portion 16, the first end portion 18 (see FIG. 1), the second end portion 20, the roof portion 30, and the floor portion 32

define an enclosed hollow interior portion 60 accessible to a user (such as a technician) via the personnel door 24 (see FIG. 1).

[0046] Turning to FIGS. 3 and 5, inside the interior portion 60, a plurality of racks or carriages 70 are arranged along each of the first and second longitudinal side portions 14 and 16. The first pair of spaced apart longitudinally extending support surfaces 56A and 56B (see FIGS. 2 and 3) supported by the first portions 50 of the laterally extending framing members 44 support the plurality of carriages 70 (see FIG. 3) extending along the first longitudinal side portion 14. The second pair of spaced apart longitudinally extending support surfaces 58A and 58B supported by the second portions 52 of the laterally extending framing members 44 support the plurality of carriages 70 (see FIGS. 3 and 4) extending along the second longitudinal side portion 16.

[0047] A central aisle portion 72 is defined between the carriages 70 and above the third portions 54 of the laterally extending framing members 44. In the central aisle portion 72, the third portions 54 of the laterally extending framing members 44 support a walkway 74. Optionally, the walkway 74 may include a perforated portion 76 and one or more raceways or wire management channels 78A and 78B extending longitudinally alongside the perforated portion 76. Optionally, one or more raceways or wire management channels (not shown) may extend along the roof portion 30 in the central aisle portion 72.

[0048] The perforated portion 76 may be constructed using a gas permeable, porous, or perforated material. For example, the perforated portion 76 may be constructed using perforated tiles 80 that permit air to flow through the tiles, from above the tiles to below the tiles and into the lower plenums 46. The perforated tiles 80 may be any standard perforated computer room tiles known in the art. For example, suitable tiles include manufacturing part number 20-0357 sold by Tate Access Floors, Inc. of Jessup, Md.

[0049] Each of the wire management channels 78A and 78B has an open top portion 82 and one or more removable cover 84 affixed thereupon. Each of the covers 84 is coupleable to the open top portion 82 of each of the wire management channels 78A and 78B. By way of a non-limiting example, the covers 84 may couple to the open top portion 82 of the channels 78A and 78B via a friction connection, snap fit connection, and the like.

[0050] Optionally, the carriages 70 may be coupled to the first pair of spaced apart longitudinally extending support surfaces 56A and 56B and the second pair of spaced apart longitudinally extending support surfaces 58A and 58B by isolators or isolating couplers 86 configured to absorb movement of the container 12 relative to the carriages 70. The isolating couplers 86 help prevent damage to any computing equipment mounted to the carriages 70 that may be caused by the movement of the container 12 occurring when the container is moved to a use location, during a seismic event (e.g., an earthquake), and the like. As illustrated in FIG. 5, each of the carriages 70 may also be coupled to one of the first and second longitudinal side portions 14 and 16 by isolating couplers 86 to prevent the carriages from toppling over or bumping into the first and second longitudinal side portions 14 and 16 of the container 12 during transport, a seismic event, and the like.

[0051] In the embodiment illustrated in FIG. 4, five carriages 70 are arranged along each of the first and second longitudinal side portions 14 and 16. However, this is not a

requirement and different numbers of carriages 70 may be arranged along the first and/or second longitudinal side portions 14 and 16 depending upon the dimensions used to construct both the carriages 70 and the container 12. By way of a non-limiting example, five carriages 70 may be arranged along each of the first and second longitudinal side portions 14 and 16 when the container 12 side portions 14 and 16 are each 40 feet long. By way of an additional non-limiting example, two carriages 70 may be arranged along each of the first and second longitudinal side portions 14 and 16 when the container 12 side portions 14 and 16 are each 20 feet long.

[0052] As may best be viewed in FIG. 5, a first upper plenum 90A is provided adjacent to the first longitudinal side portion 14 and the roof portion 30 and a second upper plenum 90B is provided adjacent to the second longitudinal side portion 16 and the roof portion 30. Air disposed in the first upper plenum 90A is cooled by a vertical cooling system 100A (described in greater detail below). Air disposed in the second upper plenum 90B is cooled by a vertical cooling system 100B substantially similar to the vertical cooling system 100A. The cooled air flows downwardly from the first and second upper plenums 90A and 90B into the central aisle portion 72 of the interior portion 60 of the container 12 and toward the walkway 74. The central aisle portion 72 essentially serves as a duct to receive and combine the cooled air from both of the vertical cooling systems 100A and 100B. In other words, the vertical cooling systems 100A and 1008 floor with cooled air the central aisle portion 72 of the interior portion 60 of the container 12 between the carriages 70. By way of a non-limiting example, the air in the central aisle portion 72 of the interior portion 60 of the container 12 may have a temperature of about 75 degrees F. to about 79 degrees F., and in some implementations about 77 degrees F.

[0053] The combined cooled air passes through the perforated portion 76 of the walkway 74 and into the laterally extending lower plenums 46. The cooled air inside the lower plenums 46 flows laterally along the laterally extending framing members 44 toward both the first and second longitudinal side portions 14 and 16. As described below, the cooled air is drawn up into the carriages 70, flows upwardly therethrough, and returns to the first and second upper plenums 90A and 90B above the carriages 70 whereat it is cooled again by the vertical cooling systems 100A and 100B, respectively.

[0054] The vertical cooling systems 100A and 1008 are mechanically separate and operate independently of one another. If one of the vertical cooling systems 100A and 100B is not functioning, the other functional vertical cooling system continues to cool the air flowing into the central aisle portion 72 and hence into the lower plenums 46 for distribution to both the carriages 70 at the first longitudinal side portion 14 and the carriages at the second longitudinal side portion 16 without regard to which vertical cooling system is not functioning. In this manner, the data center 10 may be cooled by one of the vertical cooling systems 100A and 1008 alone. Both of the vertical cooling systems 100A and 100B may be coupled to a common power source or separate power sources. Further, the vertical cooling systems 100A and 100B may be coupled to a common cooled water supply or source 310 (see FIG. 10).

Electrical System

[0055] FIG. 6 provides a front view of one of the carriages 70 storing computing equipment 102. The particular computing equipment 102 received inside the carriage 70 may

include any computing devices (e.g., blade-type servers, backplanes therefore, and the like) as well as any other type of rack mounted electronic equipment known in the art. The structure of the carriages 70 is described in detail below.

[0056] Turning to FIGS. 7A, 7B and 8A, an electrical system 110 supplies electric power to the computing equipment 102 (see FIG. 6) housed by the carriages 70. For ease of illustration, the computing equipment 102 has been omitted from FIGS. 7A and 7B. One or more electric utility lines 112A and 1128 (see FIG. 8A) supply power to the electrical system 110. By way of a non-limiting example, each of the electric utility lines 112A and 1128 may provide about 600 Amperes WYE of power to the electrical system 110. A WYE power system will allow for the implementation of standard voltages used in the computing equipment industry like, for example, 110 VAC and 208 VAC. In a preferred embodiment, 208 VAC is supplied to a plurality of power receptacles 132 to allow for increased efficiency of the internal power supplies of the individual pieces of computing equipment thereby reducing overall power consumption of the data center. Additionally, 110 VAC is supplied to a plurality of power receptacles to support computing equipment that cannot accept 208 VAC power input.

[0057] The electrical system 110 includes one or more power distribution panels 120A and 120B each having a plurality of circuit breakers 122A-M, and 122A-N, respectively, that protect the various powered components (including the vertical cooling systems 100A and 100B, the computing equipment 102, and the like) within the container 12 from power surges, such as an excess in current draw due to low voltage, a power cable interconnect fault, or any other condition that causes an excess current draw. By way of a non-limiting example, the circuit breakers 122A-M of the power distribution panel 120A and the circuit breakers 122A-N of the power distribution panel 120B may have a fault rating of less than 22 KAIC (Thousand Ampere Interrupting Capacity).

[0058] The utility line 112A is coupled to the electrical system 110 through a disconnect switch 124A configured to selectively disconnect the flow of current from the utility line 112A to the power distribution panels 120A and 120B. For example, the disconnect switch may be configured for 600 Amps AC. The utility line 112B may be coupled to a separate disconnect switch 124B configured to selectively disconnect the flow of current from the utility line 112B.

[0059] In the embodiment depicted, the power distribution panel 120A provides power to the vertical cooling system 100A and the power distribution panel 120B provides power to the vertical cooling system 100B. Each of the power distribution panels 120A and 120B also provides power to the carriages 70 along both the first and second longitudinal side portions 14 and 16 of the container 12. In FIG. 7B, the five carriages 70 extending along the first longitudinal side portion 14 of the container 12 have been labeled "CARR. #9," "CARR. #7," "CARR. #5," "CARR. #3," and "CARR. #1," and the five carriages 70 extending along the second longitudinal side portion 16 of the container 12 have been labeled "CARR. #8," "CARR. #6," "CARR. #4," "CARR. #2," and "CARR. #0."

[0060] A plurality of electrical conductors 130 are connected to the circuit breakers 122A-M of the power distribution panel 120A and the circuit breakers 122A-N of the power distribution panel 120B. Each of the electrical conductors 130 coupled to the circuit breakers 122C-G and 1221-M of the

power distribution panel 120A extend along the first longitudinal side portion 14 behind the carriages 70 and each of the electrical conductors 130 coupled to the circuit breakers 122C-G and 1221-M of the power distribution panel 120B extend along the second longitudinal side portion 16 behind the carriages 70. The electrical conductors 130 extending along the first and second longitudinal side portions 14 and 16 transport electricity to a plurality of power receptacles 132, which may be mounted to the first and second longitudinal side portions 14 and 16, or the carriages 70. For ease of illustration, in FIG. 7A, electrical conductors 130 conducting electricity to selected power receptacles 132 have been omitted.

[0061] Depending upon the implementation details and as appropriate to satisfy power needs, two or more power receptacles 132 may be included for each carriage 70. For ease of illustration, two power receptacles 132 have been illustrated in FIG. 7B for each carriage 70. In the embodiment illustrated, the power receptacles 132 for the carriage "CARR. #8" are coupled one each (via a pair of electrical conductors 130) to the circuit breakers 122C of the power distribution panels 120A and 1206. The power receptacles 132 for the carriage "CARR. #6" are coupled one each (via a pair of electrical conductors 130) to the circuit breakers 122D of the power distribution panels 120A and 120B. The power receptacles 132 for the carriage "CARR. #4" are coupled one each (via a pair of electrical conductors 130) to the circuit breakers 122E of the power distribution panels 120A and 120B. The power receptacles 132 for the carriage "CARR. #2" are coupled one each (via a pair of electrical conductors 130) to the circuit breakers 122F of the power distribution panels 120A and 120B. The power receptacles 132 for the carriage "CARR. #0" are coupled one each (via a pair of electrical conductors 130) to the circuit breakers 122G of the power distribution panels 120A and 120B.

[0062] Turning to the carriages 70 along the second longitudinal side portion 16, the power receptacles 132 for the carriage "CARR. #9" are coupled one each (via a pair of electrical conductors 130) to the circuit breakers 1221 of the power distribution panels 120A and 120B. The power receptacles 132 for the carriage "CARR. #7" are coupled one each (via a pair of electrical conductors 130) to the circuit breakers 122J of the power distribution panels 120A and 120B. The power receptacles 132 for the carriage "CARR. #5" are coupled one each (via a pair of electrical conductors 130) to the circuit breakers 122K of the power distribution panels 120A and 120B. The power receptacles 132 for the carriage "CARR. #3" are coupled one each (via a pair of electrical conductors 130) to the circuit breakers 122L of the power distribution panels 120A and 120B. The power receptacles 132 for the carriage "CARR. #1" are coupled one each (via a pair of electrical conductors 130) to the circuit breakers 122M of the power distribution panels 120A and 120B.

[0063] The electrical system 110 may include a separate power supply 133 (e.g., a 480 VAC power supply) for each of the power receptacles 132. Each of the power supplies 133 may be coupled between one of the circuit breakers 122C-G and 1221-M of the power distribution panels 120A and 120B and the power receptacles 132. The power supplies 133 are coupled to a controller 134 (described below). The controller 134 sends instructions to the power supplies 133 instructing them to provide power to one or more of their respective power receptacles 132 or discontinue sending power to one or more of their respective power receptacles 132. In this man-

ner, the controller 134 controls which of the power receptacles 132 are powered and which are not.

[0064] Further, the circuit breaker 122A of the power distribution panel 120A is coupled by an electrical conductor 130 to the vertical cooling systems 100A and the circuit breaker 122B of the power distribution panel 120B is coupled by an electrical conductor 130 to the vertical cooling systems 100B. Optionally, the circuit breaker 122B of the power distribution panel 120A may be coupled to the vertical cooling systems 1008 and the circuit breaker 122N of the power distribution panel 120B may be coupled to the vertical cooling systems 100A.

[0065] The circuit breaker 122H of the power distribution panel 120B may be coupled by an electrical conductor 130 to an optional humidifier 123. Additionally, the circuit breaker 122B of power distribution panel 120A may be coupled by an electrical conductor 130 to an optional dehumidifier 125. The optional humidifier 123 and dehumidifier 125 may include a humidity sensor (not shown) configured to generate a humidity signal indicating the humidity inside the container 12. The controller 134 may be coupled to the optional humidifier 123 and dehumidifier 125 and configured to receive the humidity signal and interpret it to determine the humidity inside the container 12. The controller 134 may send instructions to the humidifier 123 and dehumidifier 125 instructing them to increase or decrease the humidity inside the container 12 based on the humidity signal. In response to the instructions from the controller 134, the humidifier 123 may increase its water vapor output to increase the humidity in the air inside the container 12 or the dehumidifier may increase its dry air output to decrease the humidity inside the air inside the container 12. Optionally, the functions of the humidifier 123 and dehumidifier 125 may be combined into a single humidity control unit (not shown). The controller 134 may be coupled to the humidity control unit. The controller 134 may send instructions to the humidity control unit instructing it to increase or decrease humidity inside the container 12 based on the humidity signal.

[0066] Referring to FIGS. 8A-8C, optionally, the electrical system 110 may include one or more uninterruptible power supplies (“UPS”) 114, continuous power supplies (“CPS”), backup batteries, and the like. The UPS 114 provides power to the various powered components of the data center 10, including the vertical cooling systems 100A and 100B, the computing equipment 102, and the like when power to the utility line 112B is interrupted. In the embodiment illustrated, the electrical system 110 includes a single UPS 114 configured to provide power to all of the carriages 70 and other electrical equipment (e.g., the cooling systems 100A and 100B) located inside of the data center 10. The UPS 114 may include one or more batteries 115.

[0067] One or more carriages 70 may be omitted from the data center 10 to provide physical space inside the container 12 for the UPS 114. By way of a non-limiting example, a single UPS 114 may fit within the same footprint or spatial envelope occupied by one of the carriages 70. By way of another non-limiting example, a single UPS 114 may fit within the same footprint or spatial envelope occupied by a pair of laterally adjacent carriages 70. In such embodiments, the UPS 114 may fit within the spatial envelope of a first one of the carriages 70 and the batteries 115 of the UPS 114 may occupy the same spatial envelope as a second one of the carriages 70 laterally adjacent to the first. Thus, the data center 10 may be configured based on the user’s desires with

respect to computing equipment 102 and the number of carriages 70 required thereby versus reliability (i.e., the inclusion or exclusion of one or more optional UPS 114).

[0068] The UPS 114 may receive electricity from the utility line 112B and/or the utility line 112A. The UPS 114 is coupled to the power distribution panels 120A and 120B through a disconnect switch 124C. In the implementation illustrated, a UPS bypass switch 124D is provided. During normal operations, the switches 124A, 124B, and 124C are closed and the UPS bypass switch 124D is open. The UPS 114 may be bypassed by opening switches 124A, 1248, and 124C and closing the UPS bypass switch 124D. The controller 134 may be coupled to the switches 124A, 124B, 124C, and 124D and configured to open them to cut off power to the power distribution panels 120A and 120B. The dashed lines in FIG. 8B illustrate control lines coupling the controller 134 to the switches 124A, 124C, and 124D. The control lines carry instructions from the controller instructing the switches 124A, 124C, and 124D to open to cut all power to the power distribution panels 120A and 120B. Another control line (not shown) may be used to connect the controller 134 to the disconnect switch 124B.

[0069] The UPS 114 is configured to detect when power to the power distribution panels 120A and 120B has been interrupted and begin discharging power thereto to avoid or reduce the duration of any loss of power to the other components of the electrical system 110. In the embodiment depicted, power received from the utility line 112B (through the disconnect switch 124B) is routed by the UPS 114 through the disconnect switch 124C to the power distribution panels 120A and 120B. When the UPS 114 detects the utility line 112B is no longer carrying an electrical current, the UPS 114 may be configured to begin discharging electricity from the batteries 115 to the power distribution panels 120A and 1208 or alternatively, to route power from the utility line 112A to the power distribution panels 120A and 120B.

[0070] In the embodiment illustrated in FIGS. 8A-8C, the UPS 114 includes a static switch 116. Upon loss of power in the utility line 112B, the static switch 116 may transfer the load (e.g., the computing equipment 102) to the utility line 112A. If the utility line 112A is also not providing power, the UPS 114 will discharge electricity from the batteries 115 to the power distribution panels 120A and 120B of the electrical system 110. Alternatively, upon loss of power in the utility line 112B, the UPS 114 may begin discharging electricity from the batteries 115 to the power distribution panels 120A and 1208 of the electrical system 110. When the UPS 114 has discharged all of its stored energy, the static switch 116 will transfer the load (e.g., the computing equipment 102) to the utility line 112A. Coupling the static switch 116 of the UPS 114 to the utility line 112A provides greater fault tolerance than coupling the UPS 114 to the utility line 112B alone.

[0071] Tables A and B below provide a pair of non-limiting examples of from which power source, the utility line 112A, the utility line 112B, and the batteries 115, the static switch 116 may direct power to the power distribution panels 120A and 120B. In Tables A and B, the term “YES” indicates the power source is providing power at the static switch 116 and the term “NO” indicates the power source is not providing power at the static switch 116.

TABLE A

Utility Line 112A	Utility Line 112B	Batteries 115	Supplies power to power distribution panels 120A and 120B
YES	YES	YES	Utility Line 112B
YES	YES	NO	Utility Line 112B
YES	NO	YES	Utility Line 112A
YES	NO	NO	Utility Line 112A
NO	YES	YES	Utility Line 112B
NO	YES	NO	Utility Line 112B
NO	NO	YES	Batteries 115
NO	NO	NO	None

TABLE B

Utility Line 112A	Utility Line 112B	Batteries 115	Supplies power to power distribution panels 120A and 120B
YES	YES	YES	Utility Line 112A
YES	YES	NO	Utility Line 112A
YES	NO	YES	Utility Line 112A
YES	NO	NO	Utility Line 112A
NO	YES	YES	Batteries 115
NO	YES	NO	Utility Line 112B
NO	NO	YES	Batteries 115
NO	NO	NO	None

[0072] Referring to FIG. 5, the electrical system 110 also provides power to a lighting system 140. The lighting system 140 may include a plurality of light emitting diodes (“LEDs”) 142 installed inside the interior portion 60 of the container 12 on the roof portion 30 within the central aisle portion 72 above the walkway 74 and between the upper plenums 90A and 90B. The LEDs 142 may provide power and/or space efficiency over other types of light emitting devices. Alternatively, the lighting system 140 may include fluorescent lights (not shown) installed in the central aisle portion 72 above the walkway 74. In such embodiments, the electrical system 110 may include a 2 KVA lighting transformer (not shown). The lighting system 140 may include emergency lights (not shown) located over the personnel door 24 for emergency egress upon loss of power. The controller 134 may be coupled to the lighting system 140 and configured to turn the LEDs 142 on and off. The lighting system 140 may also include a motion sensing unit 153 installed inside the interior portion 60 of the container 12. The motion sensing unit may generate a motion signal indicating the presence of motion inside the container 12. The controller 134 may be coupled to the optional motion sensing unit 153 and configured to receive the motion signal and interpret it to determine the presence of motion inside the container 12. The controller 134 may send instructions to the lighting system 140 and configured the turn the LEDs 142 on. The controller 134 may send instructions to the lighting system 140 and configured to turn the LEDs 142 off after a pre-determined time from the cessation of the presence of motion inside the container 12. By way of a non-limiting example, the controller 134 may instruct the lighting system 140 to turn the LEDs 142 off after the presence of motion inside the container 12 has not been detected for 10 minutes. The motion signal may also be communicated to an intrusion detection system 196.

[0073] Referring to FIG. 8D, to support various management functions within the container 12, a 24 VDC system 180 may be implemented. The 24 VDC system may provide

power to various controllers associated with the data center. By way of non-limiting examples, the controller functions may be for power monitoring and management 190 such as voltage and current, water supply monitoring 192 such as pressure, temperature and flow rate, various system alarms such as fire detection 184, fire suppression 186 such as DuPont’s FM200 Fire Suppression System, flood detection 188, as well as motion sensing 153, lighting 140, intrusion detection 196, and personnel door 24 control. The 24 VDC system may use a dedicated UPS 194 to allow for continued monitoring and management in the event that AC input power to the container 12 is lost or interrupted. In a preferred embodiment, the UPS 194 will have enough capacity to provide power to the 24 VDC system 180 for a minimum of 1 hour. It is to be appreciated that multiple DC systems, each outputting a different DC voltage such as, for example, 12 VDC or 48 VDC, may be implemented to accomplish all management and control functions. It is also to be appreciated that each DC system may use a single dedicated UPS, a single UPS may be used to supply power to all DC systems, or multiple DC systems may be provided with power from one of a plurality of DC system UPSs.

Communication Network

[0074] Returning to FIGS. 7A and 8A, the container 12 may include a network connection 150, such as a modem, router, and the like, coupled to an external network 152, such as the Internet. The network connection 150 may be connected to the external network 152 by any suitable connection known in the art, including a wireless connection, a segment of copper cable, a segment of fiber optic cable, and the like. For example, the container 12 may be coupled to an external network implemented in a neighboring building by one or more network cable connections (e.g., 48 CAT6 GigE network connections).

[0075] The container 12 may also include an internal or private network 154, such as a local area network (“LAN”), used to route data within the data center 10 between the various pieces of computing equipment 102. By way of a non-limiting example, the private network 154 may be implemented as an Ethernet network.

[0076] Network cabling (not shown) may couple the computing equipment 102 in the carriages 70 to the various network components of the private network 154. The network cabling may include any suitable cables known in the art, including copper cables, fiber optic cables, and the like. The network cabling may be coupled along the first and second longitudinal side portions 14 and 16 as appropriate to effect a connection with the computing equipment 102 residing in the carriages 70. Further, the network cabling may reside inside the wire management channels 78A and 78B. Alternatively, the computing equipment 102 in the carriages 70 may be coupled to the various components of the private network 154 via wireless connections.

[0077] The controller 134 is also coupled to the private network 154. The electrical system 110 may also be connected to the private network 154. For example, each of the power sources 133 (coupled to the power receptacles 132) may be coupled to the private network 154. In such embodiments, the controller 134 may send instructions to the power sources 133 over the private network 154. Further, the lighting system 140 may be coupled to the private network 154 and the controller 134 may send instructions to the lighting system 140 over the private network 154. Other components,

such as the optional humidifier 123, dehumidifier 125, and the vertical cooling systems 100A and 100B may be coupled to the private network 154 for the purposes of communicating with the controller 134 and/or receiving instructions therefrom.

[0078] The network connection 150 may be coupled to the private network 154 for the purposes of providing communication between the private network 154 and the external network 152. Methods and devices for implementing the private network 154, coupling the computing equipment 102 to the private network 154, and coupling the private network 154 to the external network 152 are well-known in the art and will not be described in detail herein.

Controller

[0079] As is appreciated by those of ordinary skill in the art, the controller 134 is coupled to and/or includes a memory 136. The memory 136 includes instructions executable by the controller 134. The controller 134 may also be optionally coupled to one or more temperature sensors 137 disposed inside the interior portion 60 of the container 12 each configured to send a temperature signal to the controller 134. The memory 136 may include instructions that when executed by the controller 134 instruct the controller to interpret the temperature signal received from each of the temperature sensors 137 to obtain a temperature measurement. The memory 136 may also store the temperature measurement(s) obtained from the temperature signal(s), the temperature signal received from each of the temperature sensors 137, and the like.

[0080] The controller 134 may control both the computing equipment 102 (see FIG. 6) and the environment inside the container 12 over the private network 154. In embodiments in which the controller 134 is coupled to the network connection 150 to the external network 152, one or more remote computing devices (not shown) coupled to the external network 152 may communicate with the controller 134. For example, the remote computing devices may receive temperature information from the controller 134. Similarly, the remote computing devices may receive humidity information from the controller 134 that the controller received from the optional humidifier 123 and dehumidifier 125. Further, the remote computing devices may send instructions to the controller 134 instructing it to send instructions to the optional humidifier 123 and dehumidifier 125 to increase or decrease the humidity inside the container 12. The remote computing devices may also instruct the controller 134 to send instructions powering up or powering down selected power sources 133 (coupled to selected power receptacles 132). Further, the remote computing devices may also instruct the controller 134 to turn on or off the LEDs 142 of the lighting system 140.

[0081] The controller 134 may monitor environmental systems inside the container 12. For example, the vertical cooling systems 100A and 1408 may each include a cooling system processor or controller 380 (described below). The controller 134 may be coupled to the cooling system controller 380 for the purposes of receiving information (e.g., alerts, warnings, system faults, and the like) therefrom. The controller 134 may send the information it receives to the remote computing device(s). For example, the controller 134 may transmit an alert to the remote computing device(s) indicating a problem has occurred (e.g., the flow of cooled water has stopped, the temperature of the flow of refrigerant is too high to adequately cool the computing equipment 102, and the

like). Further, the controller 134 may send instructions to the cooling system controller 380 instructing it to operate or not operate based on the temperature inside the container 12.

[0082] The memory 136 may include instructions for monitoring the electrical system 110 and instructing the controller 134 to report information related to power availability and consumption to the remote computing device(s) (not shown) coupled to the external network 152. Further, the controller 134 may receive instructions from the remote computing device(s), such as an instruction to power down the electrical system 110 (e.g., open switches 124A, 124B, 124C, and 124D), power selected power sources 133 (coupled to one or more power receptacles 132), turn off the power to selected power sources 133 (coupled to one or more power receptacles 132) and the like.

[0083] The controller 134 may monitor and/or control the computing equipment 102 (see FIG. 6). For example, the memory 136 may include instructions for monitoring the UPS 114, individual pieces of computing equipment 102 (e.g., individual blade servers), and the like. Further, the controller 134 may receive instructions from the remote computing device(s), instructing the controller to turn individual pieces of computing equipment 102 on or off, provide data thereto, and the like.

[0084] The controller 134 may include a user interface 138 configured to display the temperature measurement(s) obtained from the temperature signal received from each of the temperature sensors 137, and any data received from other systems inside the container 12.

Carriage

[0085] An exemplary embodiment of the carriage 70 is provided in FIGS. 5, 6, and 9. As mentioned above, the carriage 70 is configured to store computing equipment 102, which may include a plurality of computing devices (e.g., blade-type servers) as well as any other type of rack mounted electronic equipment known in the art. The carriage 70 has a substantially open base portion 210 opposite a substantially open top portion 212. The carriage 70 also has a substantially open front portion 214 into which computing equipment 102, fans, cabling, rack mountable equipment, accessories, and the like are received for storage and use therein. Opposite the open front portion 214, the carriage 70 has a back portion 216.

[0086] Cabling and wiring, such as electrical wiring, communication cables, and the like, may enter the carriage 70 through the back portion 216, which may be open and/or may include one or more apertures 215 configured to permit one or more cables or wires to pass therethrough. As mentioned above, the electrical conductors 130 and optional communication cabling (not shown) may extend along the first and second longitudinal side portions 14 and 16. Further, the power receptacles 132 (see FIG. 7) are positioned adjacent to the back portions 216 of the carriages 70 along the first and second longitudinal side portions 14 and 16. Such power receptacles 132 and communication cabling may be coupled to the computing equipment 102 in the carriage 70 through its back portion 216.

[0087] As is appreciated by those of ordinary skill in the art, an amount of computing equipment 102 housed in the interior portion 60 of the container 12 is determined at least in part by the number of carriages 70 and the capacity of each to house computing equipment 102. The carriage 70 includes a frame 220 to which computing equipment 102, fans, cabling, rack mountable equipment, accessories, and the like may be

mounted or otherwise attached. The frame 220 is configured to permit air to flow into the open base portion 210, up through the carriage 70, through and around the computing equipment 102 and other items therein, and out the open top portion 212.

[0088] The frame 220 includes a plurality of spaced apart upright support members 222A-H, defining one or more upright equipment receiving areas 224A-C. The embodiment depicted has three equipment receiving areas 224A-C, defined by four upright support members 222A-D arranged along the front portion 214 of the carriage 70 and four upright support members 222E-H arranged along the back portion 216 of the carriage 70. Upright support member 222C may be removable, as opposed to support members 222A-B and 222D-H which are fixed in place. The removal of upright support member 222C and the associated front to back extending members 236 may allow for the installation of any configuration of computer equipment spanning equipment receiving areas 224B and 224C without any modification. By way of a non-limiting example, upright support member 222C and the associated front to back extending members 236 may be removed to allow the installation of a custom designed server chassis oriented longitudinally along side portion 14 and 16. Also, removing upright support member 222C and the associated front to back extending members 236 may allow for the onsite installation of customer equipment without any modification of the carriage 70. Those of ordinary skill in the art appreciate that carriages having a different number of upright equipment receiving areas may be constructed by applying ordinary skill in the art to the present teachings and such embodiments are within the scope of the present teachings.

[0089] The upright support members 222A-H are coupled together at the open top portion 212 of the carriage 70 by a vented top plate 226 having apertures 228A-F in communication with the equipment receiving areas 224A-C through which heated air may exit the equipment receiving areas 224A-C and be passed to the corresponding first or second upper plenum 90A or 90B positioned thereabove. Apertures 228A-B may be joined together to create one large aperture. Similarly, apertures 228C-D and 228E-F may be joined together. Joining the apertures together may be done to support some HVAC devices. The upright support members 222A-H are coupled together at the open base portion 210 along the front portion 214 of the carriage 70 by a front rail 230 and at the open base portion 210 along the back portion 216 of the carriage 70 by a back rail 232.

[0090] The four upright support members 222A-D aligned along the front portion 214 of the carriage 70 may be coupled to the four upright support members 222E-H aligned along the back portion 216 of the carriage 70 by any desired number of front-to-back extending members 236. The members 236 may provide structural stability to the carriage 70. Further, the members 236 may provide attachment points to which computing equipment 102, fans, cabling, rack mountable equipment, accessories, and the like may be coupled. Further, the upright support members 222E-H along the back portion 216 may be coupled together by any number of members 238 extending therebetween. The members 238 may provide stability and/or attachment points to which computing equipment 102, fans, cabling, rack mountable equipment, accessories, and the like may be coupled. Optionally, apertures 239 in the members 238 are configured to provide throughways for wiring, cabling, and the like.

[0091] The upright support members 222A-D along the front portion 214 of the carriage 70 may include openings 240A-F each configured to receive computing equipment, such as a rectifier, network switching device (e.g., routers), and the like. In the embodiment illustrated in FIG. 6, two of the openings 240E and 240F each house a rectifier 242 and four of the openings 240A-D each house a network switching device 244. By way of an example, the rectifier 242 may be configured to rectify from about 480 VAC to about 48 VDC. Referring to FIG. 7B, the power receptacle 132 coupled to the power distribution panel 120A may be coupled to one of the rectifiers 242 and the power receptacle 132 coupled to the other power distribution panel 120B may be coupled to the other of the rectifiers 242. In this manner, each of the rectifiers 242 receives power from a different power distribution panel 120A or 120B.

[0092] Turning to FIG. 9, optionally, the upright support members 222E-H along the back portion 216 of the carriage 70 may include one or more openings 241 substantially similar to the openings 240A-F and aligned with one or more corresponding opening 240A-F of the upright support members 222A-D.

[0093] One or more open-ended conduits 250A-F may extend between the upright support members 222A-D along the front portion 214 and the upright support members 222E-H along the back portion 216. Each of these conduits 250A-F has an open front end portion 251 opposite and open back end portion 253 (see FIG. 3). Each conduit 250A-F may be configured to provide a throughway for cabling (not shown) from the front portion 214 of the carriage 70 to the back portion 216 of the carriage 70. By way of a non-limiting example, the cabling may include Category 6 ("Cat-6") cable for Ethernet connections. Turning to FIG. 6, one or more network connections 252A-F, such as an Ethernet jack, may be located adjacent the front portion 214 of the carriage 70 and coupled to a cables (not shown) extending through the conduits 250A-F.

[0094] As illustrated in FIG. 6, the equipment receiving areas 224A-C may each be divided into four sections "S1-S4" (for a total of 12 sections per carriage 70). Each section "S1-S4" may use twenty-four Ethernet connections; however, this is not a requirement. Alternatively, the equipment receiving areas 224A-C may each be divided into five sections "S1-S5" (for a total of 15 sections per carriage 70), where section S5 (not shown) may be used to implement a multiport networking device. By way of non-limiting example, the networking device may contain twenty four Ethernet ports or other suitable type of communication ports. By way of a non-limiting example, each blade slot may have two Ethernet ports. However, as is appreciated by those of ordinary skill in the art, each blade slot may include more than two Ethernet ports. For example, more than one Ethernet port may be located in a front portion of a blade server and more than one Ethernet port may be located in a back portion of a blade server. The equipment receiving areas 224A-C are not limited to use with blade servers having a particular number of Ethernet ports. Further, the equipment receiving areas 224A-C are not limited to use with blade servers having Ethernet ports and may be used with blade servers having other types of communication ports.

[0095] As illustrated in FIGS. 5 and 6, a plurality of air moving assemblies 260 each having a plurality of air moving devices 264 (e.g., fans) oriented to blow air upwardly through the equipment receiving areas 224A-C, are mounted therein

between the upright support members 222A-H of the carriage 70. Each of the air moving assemblies 260 includes a frame 262 configured to be mounted inside one of the equipment receiving areas 224A-C. The frame 262 houses the plurality of air moving devices 264, each of which is oriented to flow air in substantially the same upward direction. In the embodiment depicted in FIGS. 5 and 6, the carriage 70 includes nine air moving assemblies 260. However, this is not a requirement. The number of air moving assemblies mounted inside each of the equipment receiving areas 224A-C may be determined based at least in part on the amount of air circulation required to cool the computing equipment received therein. The air moving assemblies 260 each receive power from the power conductors 130 (see FIG. 7) carrying power to the carriages 70 and powering the computing equipment 102 housed therein.

[0096] Computing equipment, or the like, that is mounted in the region between upright support members 222B and 222F, or 222C and 222G may not receive adequate air flow due to the front to back extending members 236 blocking the path for air flow through the region. When equipment is installed in these regions, one or more air moving assemblies 260 may be installed transversely between the upright support members 222 associated with the equipment to allow for the heated air produced by the equipment to be moved longitudinally into an upright equipment receiving area 224A-C where it will mix with the air flow created by the vertical cooling system.

[0097] The upright equipment receiving areas 224A-C may be customized to receive a predetermined collection of computing equipment (e.g., a predetermined number of blade servers). For example, the upright equipment receiving areas 224A-C may be configured to receive blade servers 103 in an upright orientation. Alternatively, the upright equipment receiving areas 224A-C may be configured to receive blade servers in a horizontal orientation. Additionally, the upright equipment receiving areas 224A-C may be configured to receive computing equipment in a longitudinal orientation. When computing equipment is to be installed longitudinally, it may be necessary to remove upright support member 222C and the associated front to back extending members 236 to create the required spatial envelope for the computing equipment to occupy.

[0098] In some embodiments, standard 19" rack mount computer gear (not shown) may be mounted inside the upright equipment receiving areas 224A-C. The fans inside the rack mount computer gear will draw air into the upright equipment receiving areas 224A-C from the central aisle portion 72 of the interior portion 60 of the container 12. This air will pass through the rack mount computer gear, be heated thereby, and exit from the rack mount computer gear adjacent to the back portion 216 of the carriage 70. The heated air may exit the rack mount computer gear inside the carriage 70 or between the back portion 216 of the carriage 70 and an adjacent one of the first and second longitudinal side portions 14 and 16. In such embodiments, the air moving assemblies 260 will direct the heated air inside the carriage 70 upwardly toward the open top portion 212 of the carriage 70. Further, the air moving assemblies 260 will help draw heated air outside the carriage 70 into the upright equipment receiving areas 224A-C whereat the air moving assemblies 260 will direct the heated air upwardly toward the open top portion 212 of the carriage 70. The rack mount computer gear may be mounted inside the upright equipment receiving areas

224A-C in any orientation. For example, the rack mount computer gear may be mounted inside the upright equipment receiving areas 224A-C in a manner resembling blade servers. Furthermore, an alternate embodiment of the carriage 70 may be used, in which the rack mount computer gear may be mounted to extend longitudinally inside the container 12.

[0099] The rack mount computer gear may be mounted inside the equipment receiving areas 224A-C using a slide-out rail system (not shown). The use of a slide-out rail system may allow for any manufacturer's computer hardware to be adapted for use in the data center 10. The slide-out rail system will allow for the computer gear to be pulled out from the equipment receiving areas 224A-C to a distance of, for example, 6 inches past the front portion 214 of the carriages 70. This will allow for unrestricted service access to all areas of that individual piece of computing equipment and associated external connections. To support the use of a slide-out rail system, an articulated cable management tray system (not shown) may be used to manage and control the movement of the various cables (e.g., data, power) associated with an individual piece of computing equipment when the piece of computing equipment is pulled out of and pushed into the equipment receiving areas 224A-C. One or more power strips may be attached to the slide-out rail system to provide electrical power to the computing equipment associated with the rail system. The power strip input is connected to one of the plurality of power receptacles 132. By way of a non-limiting example, the power strip may be supplied with 208 VAC single phase power. When a plurality of power strips are attached to a rail system, at least one power strip is connected to a power receptacle 132 receiving power from power distribution panel 120A, and at least one power strip is connected to a power receptacle 132 receiving power from power distribution panel 120B. This allows for the computing equipment to be supplied with power from redundant sources.

[0100] The isolating couplers 86 may be coupled to the upright support members 222A-H along the base portion 210 of the carriage 70. Alternatively, the isolating couplers 86 may be mounted to the front rail 230, the back rail 232, and/or the front to back extending members 236 located along the base portion 210 of the carriage 70. As may best be viewed in FIG. 5, the isolating couplers 86 may also couple one or more of the upright support members 222F-G to one of the first and second longitudinal side portions 14 and 16 of the container 12.

Vertical Cooling System

[0101] Referring to FIG. 5, as mentioned above, the vertical cooling system 100A cools air flowing up through the carriages 70 arranged along the first longitudinal side portion 14 and the vertical cooling system 100B cools air flowing up through the carriages 70 arranged along the second longitudinal side portion 16. The vertical cooling system 100B is substantially identical to the vertical cooling system 100A. Therefore, for illustrative purposes, only the vertical cooling system 100B will be described in detail.

[0102] Turning to FIG. 10, the vertical cooling system 100B includes two fluid flows: a flow of refrigerant and a flow of chilled or cooled water. Within the vertical cooling system 100B, the flow of refrigerant is cooled by transferring its heat to the flow of cooled water. The vertical cooling system 100B includes a water/refrigerant heat exchanger 300 configured to transfer heat from the flow of refrigerant to the flow of cooled water. The water/refrigerant heat exchanger 300 may be

implemented using any heat exchanger known in the art. By way of a non-limiting example, a suitable heat exchanger includes a Liebert XDP Water-Based Coolant Pumping Unit, which may be purchased from Directnet, Inc. doing business as 42U of Broomfield, Colo.

[0103] The flow of cooled water is received from an external supply or source **310** of cooled water as a continuous flow of cooled water. By way of a non-limiting example, the flow of cooled water received may have a temperature of about 45 degrees Fahrenheit to about 55 degrees Fahrenheit. Optionally, the flow of cooled water may reside in a closed loop **312** that returns the heated previously cooled water to the external source **310** of cooled water to be cooled again. The closed loop **312** and the water/refrigerant heat exchanger **300** are spaced apart from the carriages **70** and the refrigerant is brought thereto. Thus, the closed loop **312** flow of cooled water and the water/refrigerant heat exchanger **300** are segregated from the computing equipment **102** of the data center **10**.

[0104] The flow of cooled water is transported to the container **12** by a first water line **318** and is transported away from the container **12** by a second water line **320**. The container **12** includes a T-shaped inlet valve **330** that directs a portion of the flow of cooled water received from the first water line **318** to each of the vertical cooling systems **100A** and **100B** (see FIG. 5). The container **12** includes a T-shaped outlet valve **332** that directs the flow of return water received from both of the vertical cooling systems **100A** and **1008** (see FIG. 5) to the second water line **320**.

[0105] An inlet pipe **334** is coupled between one outlet port of the inlet valve **330** and the water/refrigerant heat exchanger **300** of the vertical cooling system **1008**. The inlet pipe **334** carries a portion of the flow of cooled water to the water/refrigerant heat exchanger **300**. A similar inlet pipe (not shown) is coupled between the other outlet port of the inlet valve **330** and the water/refrigerant heat exchanger **300** of the vertical cooling system **100A**.

[0106] An outlet pipe **336** is coupled between the water/refrigerant heat exchanger **300** of the vertical cooling system **100B** and one inlet port of the outlet valve **332**. The outlet pipe **336** carries the flow of return water from the water/refrigerant heat exchanger **300** to the outlet valve **332**. A similar outlet pipe (not shown) is coupled between the water/refrigerant heat exchanger **300** of the vertical cooling system **100A** and the other inlet port of the outlet valve **332**.

[0107] The flow of cooled water flowing within the inlet pipe **334** may cool the inlet pipe below the condensation temperature of moisture in the air within the interior portion **60** of the container **12**. Thus, water may condense on the inlet pipe **334** and drip therefrom. Similarly, the flow of return water flowing within the outlet pipe **336** may cool the outlet pipe below the condensation temperature of moisture in the air within the interior portion **60** of the container **12** causing water to condense on the outlet pipe and drip therefrom.

[0108] A basin or drip pan **340** may be positioned below the inlet and outlet pipes **334** and **336**. Any condensed water dripping from the inlet and outlet pipes **334** and **336** may drip into the drip pan **340**. The drip pan **340** includes an outlet or drain **342** through which condensed water exits the drip pan **340**. The drain **342** may extend through the floor portion **32** of the container **12** and may be in open communication with the environment outside the container **12**. As is appreciated by those of ordinary skill in the art, external piping, hoses, and

the like may be coupled to the drain for the purposes of directing the condensed water away from the container **12**.

[0109] Together the inlet pipe **334** and drip pan **340** form a passive dehumidification system **350** that limits the humidity inside the container **12** without consuming any additional electrical power beyond that consumed by the vertical cooling systems **100A** and **1008** (see FIG. 5). In some implementations, the passive dehumidification system **350** includes the outlet pipe **336**. The amount of dehumidification provided by the passive dehumidification system **350** may be determined at least in part by the surface area of the components (e.g., the inlet pipe **334**, the outlet pipe **336**, the water/refrigerant heat exchanger **300**, the inlet valve **330**, the outlet valve **332**, and the like) upon which water condenses.

[0110] Within the vertical cooling system **1008**, the flow of refrigerant flows through a closed loop **352**. The closed loop **352** includes a refrigerant supply manifold **354** which is thermally insulated and a refrigerant return manifold **356** which is thermally insulated. The refrigerant supply manifold **354** carries cooled refrigerant to a plurality of supply conduits **360** which are thermally insulated, each coupled to one of a plurality of refrigerant/air heat exchangers **370**. In the embodiment illustrated, two heat exchangers **370** are provided for each carriage **70**. However, this is not a requirement. A plurality of return conduits **372** which are thermally insulated, each coupled to one of the plurality of heat exchangers **370**, carry heated refrigerant from the plurality of heat exchangers **370** to the refrigerant return manifold **356**. The thermal insulation that is applied to the supply manifold, return manifold, supply conduits, and return conduits will prevent any condensation from dripping onto the servers located below the manifolds and conduits. Because the embodiment illustrated includes two heat exchangers **370** for each carriage **70**, the plurality of supply conduits **360** and the plurality of return conduits **372** each include ten conduits. The refrigerant return manifold **356** carries heated refrigerant received from the heat exchangers **370** back to the water/refrigerant heat exchanger **300** to be cooled again by the flow of cooled water therein.

[0111] The refrigerant supply manifold **354**, supply conduits **360**, the refrigerant return manifold **356**, and return conduits **372** may include one or more flow regulators or valves **358** configured to control or restrict the flow of the refrigerant therethrough. In the embodiment depicted in FIG. 10, the refrigerant supply manifold **354** includes one valve **358** before the first supply conduit **360** regulating the flow of refrigerant into the supply conduits **360**. In the embodiment depicted in FIG. 10, the supply conduits **360** each include one valve **358** regulating the flow of refrigerant to each of the heat exchangers **370**. By selectively adjusting the flow of refrigerant through the valves **358**, the amount of cooling supplied to each of the heat exchangers **370** may be adjusted.

[0112] The vertical cooling system **100B** may include one or more temperature sensors **376** coupled to refrigerant supply manifold **354**, supply conduits **360**, the refrigerant return manifold **356**, and/or return conduits **372**. Each of the temperature sensors **376** may be used to monitor the temperature of the flow of refrigerant and generate a temperature signal. As mentioned above, the vertical cooling system **1008** may include the cooling system controller **380**, which may be located inside cooling unit **300**. The cooling system controller may be coupled to the inlet valve **330** and the temperature sensor(s) **376**. In such embodiments, the cooling system controller **380** is configured to increase or decrease a flow rate of the cooled water through the first water line **318** and the inlet

valve 330 based upon the temperature signal(s) received from the temperature sensor(s) 376 for the purpose of decreasing or increasing the temperature of the flow of refrigerant within the closed loop 352 of the vertical cooling system 100B. In this manner, the temperature of the flow of refrigerant within the closed loop 352 may be adjusted by modifying the flow rate of the cooled water used to cool the flow of refrigerant.

[0113] If any of the refrigerant leaks from the vertical cooling system 100B, it does so in a gas or vapor form. Thus, even if a refrigerant leak occurs, it does not leak or drip onto the computing equipment 102. The refrigerant supply manifold 354, supply conduits 360, the refrigerant return manifold 356, and return conduits 372 in which the refrigerant circulates have a temperature above the condensation temperature of the moisture in the air within the interior portion 60 of the container 12. Thus, water does not condense on the refrigerant supply manifold 354, supply conduits 360, the refrigerant return manifold 356, and return conduits 372. As a result, the flow of refrigerant does not expose the computing equipment 102 to dripping water (from condensation).

[0114] Referring to FIG. 4, each of the heat exchangers 370 has a coil assembly 373. The refrigerant flows from the supply conduits 360 into each of the heat exchangers 370 and circulates through its coil assembly 373. The air above the carriages 70 is warm, having been heated by the computing equipment 102. The heated air travels upward through the heat exchangers 370 and is cooled by the refrigerant. As may best be viewed in FIGS. 4 and 5, each of the heat exchangers 370 is implemented as a radiator style evaporator with its coil assembly 373 arranged at an angle relative to the front portion 214 and the open top portion 212 of the carriages 70. As is appreciated by those of ordinary skill in the art, the coil assembly 373 has one or more cooling surfaces (not shown) whereat heat is exchanged between the air external to the coil assembly 373 and the refrigerant flowing inside the coil assembly 373. The coil assembly 373 of the heat exchangers 370 may be angled to maximize an amount of cooling surface for the space available for positioning of the heat exchangers, thereby providing a maximum amount of cooling capacity. For example, an inside angle "A" defined between the front portion 214 of the carriages 70 and the coil assembly 373 may range from about 144 degrees to about 158 degrees. Thus, an angle of about 144 degrees to about 158 degrees may be defined between the coil assembly 373 and the open top portions 212 of the carriages 70.

[0115] The cooling capacity of the heat exchanger 370 may also depend at least in part on the amount of refrigerant flowing in its coil assembly 373. As mentioned above, by adjusting the valves 358, the amount of refrigerant flowing from each of the supply conduits 360 into each of the heat exchangers 370 may be adjusted. In this manner, the cooling capacity of the vertical cooling system 100B may be customized for each carriage 70, a portion of each carriage, and the like. Further, the cooling capacity may be determined at least in part based on the amount of heat expected to be produced by the computing equipment 102 mounted within each of the carriages, portions of the carriages, and the like. By way of a non-limiting example, the flow of refrigerant from the supply conduits 360 into the heat exchangers 370 may be customized for a particular distribution of computing equipment 102 (e.g., blade servers) within the container 12. Further, the valves 358 in the refrigerant supply manifold 354 may be used to control the flow of refrigerant to all of the heat exchangers 370 of the vertical cool system 100B. Similarly, a

valve (not shown) in the refrigerant return manifold 356 may be used to restrict the flow of refrigerant from all of the heat exchangers 370 of the vertical cool system 100B.

[0116] A plurality of bent ducts or conduits 390 may be coupled between each of the heat exchangers 370 and at least a portion of the open top portion 212 of an adjacent carriage 70 to direct heated air rising from the carriage 70 into the heat exchanger 370. In the embodiment illustrated, one bent conduit 390 is coupled between a single heat exchanger 370 and a portion (e.g., approximately half) of the open top portion 212 of an adjacent carriage 70. Each bent conduit 390 has a bent portion 392 and defines a bent travel path for the heated air expelled from the carriage 70 into the heat exchanger 370. By directing the heated air rising from the carriage 70 along the roof portion 30 of the container 12, the bent portions 392 help prevent the formation of a back pressure in the upper plenums 90A and 90B along the roof portion 30 that could push the heated air back into the open top portions 212 of the carriages 70. In the embodiment depicted, the bent conduit 390 includes an internal baffle 394 that bifurcates the bent conduit 390 along the bent travel path.

[0117] A sealing member 396 is positioned between the back portions 216 of the carriages 70 and the first and second longitudinal side portions 14 and 16. Similarly, a sealing member 397 is positioned between the front portions 214 of the carriages 70 and the heat exchangers 370. The sealing members 396 and 397 help seal the upper plenums 90A and 90B from the remainder of the interior portion 60 of the container 12. The sealing members 396 and 397 may be constructed from any suitable material known in the art including foam.

[0118] The air cooled by the heat exchangers 370 is pushed therefrom by the air moving assemblies 260 and flows downwardly from the angled heat exchangers 370 toward the walkway 74 on the floor portion 32 of the container 12. As discussed above, the walkway 74 includes the perforated portion 76 that permits air to flow therethrough and into the lower plenums 46. If the laterally extending framing members 44 are implemented with a C-shaped cross-sectional shape, air may flow laterally inside the open inside portion 47 of the laterally extending framing members 44. In other words, the open inside portion 47 of the C-shaped laterally extending framing members 44 may be considered part of an adjacent lower plenum 46.

[0119] Once inside one of the lower plenums 46, the air may flow beneath the carriages 70. Because the laterally extending framing members 44 extend from the beneath the walkway 74 to beneath the carriages 70 arranged along both the first and second longitudinal side portions 14 and 16, air is directed laterally by the laterally extending framing members 44 from beneath the walkway 74 toward and below the carriages 70. Once beneath the carriages 70, the air is drawn upward by the air moving assemblies 260 of the carriages and into the carriages 70, and through and around the computing equipment 102. As the air is heated by the computing equipment 102, the heated air rises up through the carriage 70, and into the bent conduit 390, which directs the heated air into the heat exchangers 370 associated with the carriage to be cooled again.

[0120] As mentioned above, each of the carriages 70 includes air moving devices 264 (see FIG. 5). An amount of power consumed by the air moving devices 264 to adequately cool the computing equipment 102 may be determined at least in part by how well air flows from the carriages 70 and

into the heat exchangers 370. Thus, the shape of the bent conduits 390 in the upper plenums 90A and 90B may determine at least in part the amount of power consumed by the air moving devices 264. Thus, the bent conduits 390 may be configured to reduce or minimize the amount of power consumed by the air moving devices 264.

[0121] If the container 12 is located in an environment in which the air outside the container has a temperature suitable for cooling the computing equipment 102 (see FIG. 6) mounted inside the carriages 70, the container may include openings through which air from the outside environment may flow into the container to cool the computing equipment 102. The container may also include openings through which air heated by the computing equipment 102 may exit the container into the outside environment. In such embodiments, some of the air cooling components of the vertical cooling systems 100A and 100B (see FIG. 5) may be omitted from the data center 10.

[0122] FIG. 11 provides a data center 400 for use in an environment having a temperature suitable for cooling the computing equipment 102 (see FIG. 6) mounted inside the carriages 70. For ease of illustration, like reference numerals have been used to identify like components of the data center 400 and the data center 10 (see FIG. 5). The data center 400 includes a container 402, substantially similar to the container 12 (see FIG. 5). For ease of illustration, only aspects of the container 402 that differ from those of container 12 will be described in detail.

[0123] The container 402 includes a first plurality of upper openings 410A, a second plurality of upper openings 410B, a first plurality of lower openings 412A, and a second plurality of lower openings 412B. The first plurality of upper openings 410A and the first plurality of lower openings 412A extend along the first longitudinal side portion 14 of the container 402. The second plurality of upper openings 410B and the second plurality of lower openings 412B extend along the second longitudinal side portion 16 of the container 402. The first and second plurality of upper openings 410A and 410B provide open communication between the upper plenums 90A and 90B, respectively, and the environment outside the container 402. The first and second plurality of lower openings 412A and 412B provide open communication between the lower plenums 46 and the environment outside the container 402.

[0124] Cool air is drawn into the lower plenums 46 by the air moving assemblies 260 mounted inside the carriages 70 through the first and second plurality of lower openings 412A and 412B. Air heated by the computing equipment 102 (see FIG. 6) is pushed from the upper plenums 90A and 90B by the air moving assemblies 260 through the first and second plurality of upper openings 410A and 410B, respectively. In this embodiment, the humidity of the air inside the container 402 is controlled by controlling the humidity of the air outside the container 402.

[0125] Optionally, the data center 400 includes louvers 420. In the embodiment illustrated in FIG. 11, a single louver 420 is received inside each of the first and second plurality of upper openings 410A and 410B and a single louver 420 is received inside each of the first and second plurality of lower openings 412A and 412B. However, this is not a requirement.

[0126] In alternate implementations discussed below, the louvers 420 may cover the first and second plurality of upper openings 410A and 410B and the first and second plurality of lower openings 412A and 412B. By way of a non-limiting

example, a first louver may cover a single one of the first plurality of upper openings 410A and a second different louver may cover a single one of the second plurality of upper openings 410B. Similarly, a third louver may cover a single one of the first plurality of lower openings 412A and a fourth louver may cover a single one of the second plurality of lower openings 412B. By way of another non-limiting example, a single louver may cover more than one of the first plurality of upper openings 410A, more than one of the second plurality of upper openings 410B, more than one of the first plurality of lower openings 412A, or more than one of the second plurality of lower openings 412B.

[0127] The louvers 420 may be selectively opened and closed to selectively transition the data center 400 between an open system state in which at least one of the louvers 420 is open and a closed system state in which all of the louvers 420 are closed. Based on the external environmental factors, the data center 400 may operate in the open system state to exploit “free air” cooling when appropriate and switch to the closed system state when necessary (e.g., the temperature of the air in the outside environment is too hot or too cold, the air in the outside environment is too humid, the air in the outside environment includes too many contaminants, and the like).

[0128] Optionally, as illustrated in FIGS. 11 and 12, the data center 400 may omit the source 310 of cooled water, the chilled water/refrigerant heat exchanger 300, the refrigerant supply manifold 354, the refrigerant return manifold 356, the supply conduits 360, the return conduits 372, the refrigerant/air heat exchangers 370, the bent conduits 390, the T-shaped inlet valve 330, the T-shaped outlet valve 332, the first water line 318, the second water line 320, the inlet pipe 334, and the outlet pipe 336. In such embodiments, the data center 400 may remain in the open system state during operation and transition to a closed system state only when the computing equipment 102 (see FIG. 6) is powered down.

[0129] In some implementations, the louvers 420 are configured such that all of the louvers 420 are either open or closed at the same time. For example, each of the louvers 420 may include a plurality of blades 422 (illustrated in an open position) selectively openable and closable by a control switch (not shown). When the switch is placed in the closed position, all of the blades 422 of the louvers 420 are closed and when the switch is in the open position all of the blades 422 of the louvers 420 are open.

[0130] Optionally, the data center 400 includes one or more covers, chimneys, or similar structures (not shown) configured to allow air to flow from the first and second plurality of upper openings 410A and 410B and at the same time, prevent precipitation (rain, snow, etc) from entering the container 402 through the first and second plurality of upper openings 410A and 410B.

[0131] Referring to FIG. 12, an alternate embodiment of the louvers 420 is provided. Louvers 430 are configured to be coupled to the roof portion 30 of the container 402 adjacent the second plurality of upper openings 410B and to extend outwardly away from the roof portion 30 of the container 402. The louvers 430 are further configured to be coupled to the roof portion 30 of the container 402 adjacent the first plurality of upper openings 410A (see FIG. 11) and to extend outwardly away from the roof portion 30 of the container 402. The louvers 430 are also configured to be coupled to the floor portion 32 of the container 402 adjacent one or more of the second plurality of lower openings 412B and to extend outwardly away from the floor portion 32 of the container 402.

The louvers **430** are further configured to be coupled to the floor portion **32** of the container **402** adjacent one or more of the first plurality of lower openings **412A** (see FIG. **11**) and to extend outwardly away from the floor portion **32** of the container **402**.

[0132] Each of the louvers **430** include an assembly (not shown) configured to selectively open to provide air flow between the interior portion **60** of the container **402** and the outside environment and to selectively close to cutoff air flow between the interior portion **60** of the container **402** and the outside environment. The louvers **430** may be configured to be opened and closed at the same time using any method known in the art. Further, each of the louvers **430** may include a filter (not shown) configured to prevent contaminants and particulate matter (e.g., dust, insects, and the like) from entering the interior portion **60** of the container **402**.

[0133] FIGS. **13** and **14** provide a data center **450** for use in an environment having a temperature suitable for cooling the computing equipment **102** (see FIG. **6**) mounted inside the carriages **70**. For ease of illustration, like reference numerals have been used to identify like components of the data center **450** and the data centers **10** and **400**. The data center **450** includes a container **452**, substantially similar to the container **12** (see FIG. **1**). For ease of illustration, only aspects of the container **452** that differ from those of container **12** will be described in detail.

[0134] Like the data center **400** (see FIGS. **11** and **12**), the data center **450** includes the first and second plurality of upper openings **410A** and **410B**. However, the data center **450** omits the first and second plurality of lower openings **412A** and **412B**. Instead, the data center **450** includes a first plurality of side openings **456A** and a second plurality of side openings **456B**. The first plurality of side openings **456A** extends along the first longitudinal side portion **14** of the container **452** and the second plurality of side openings **456B** extends along the second longitudinal side portion **16** of the container **452**.

[0135] The first and second plurality of side openings **456A** and **456B** provide open communication between the environment outside the container **452** and the lower plenums **46** (see FIG. **11**). Cool air is drawn into lower plenums **46** by the air moving assemblies **260** (see FIG. **11**) through the first and second plurality of side openings **456A** and **456B**. Air heated by the computing equipment **102** (see FIG. **6**) is pushed from the upper plenums **90A** and **90B** (see FIG. **11**) by the air moving assemblies **260** through the first and second plurality of upper openings **410A** and **412B**. In this embodiment, the humidity of the air inside the container **452** is controlled by controlling the humidity of the air outside the container **452**.

[0136] In FIG. **13**, a louver **420** is received inside each of the first and second plurality of upper openings **410A** and **412B** and the first and second plurality of side openings **456A** and **456B** are covered by louvers **560** substantially similar to the louvers **420**. In FIG. **14**, the first and second plurality of upper openings **410A** and **412B** are illustrated without louvers and the first and second plurality of side openings **456A** and **456B** are covered by louver assemblies **562** that extend outwardly away from the container **452**.

[0137] Instead of blades, the louver assemblies **562** include openings or slots **564**. Each of the louver assemblies **562** includes an assembly (not shown) configured to selectively open to provide air flow between the interior portion **60** of the container **452** and the outside environment and to selectively close to cutoff air flow between the interior portion **60** of the container **452** and the outside environment. The louver

assemblies **562** may be configured to be opened and closed at the same time using any method known in the art. Further, each of the louver assemblies **562** may include a filter (not shown) configured to prevent particulate matter (e.g., dust, insects, and the like) from entering the interior portion **60** of the container **452**.

[0138] The foregoing described embodiments depict different components contained within, or connected with, different other components. It is to be understood that such depicted architectures are merely exemplary, and that in fact many other architectures can be implemented which achieve the same functionality. In a conceptual sense, any arrangement of components to achieve the same functionality is effectively "associated" such that the desired functionality is achieved. Hence, any two components herein combined to achieve a particular functionality can be seen as "associated with" each other such that the desired functionality is achieved, irrespective of architectures or intermedial components. Likewise, any two components so associated can also be viewed as being "operably connected," or "operably coupled," to each other to achieve the desired functionality.

Modular Embodiment

[0139] Aspects of the modular embodiment relate to a data center, comprising modules that perform specific functions associated with the operation of a data center, where the modules can be connected together to form a functional data center to satisfy specific use requirements. Many of the functions and individual components used in the data center contained within a container are used in the modular embodiment and function in an identical or similar manner. Only the differences between the two embodiments will be addressed in the following description.

[0140] In a typical embodiment, the modular data center will consist of at least one facilities module **650**, at least one computing equipment module **652**, and one end cap with personnel door **660**. A complete modular data center of a preferred embodiment will function identical to a data center contained within a container. The environment inside the data center will be climate controlled to provide a suitable environment for the operation of computing equipment and associated hardware. The external support services may include at least one data connection **152**, at least one power connection **112A**, and at least one supply of cool water **310**. The data center modules may be preconfigured with the desired computing equipment and support interfaces to minimize set up time, cost, and technical knowledge. The modular data center may provide an efficient self-contained solution suitable for applications in standard office spaces and other work environments where the availability of space and support services to implement a standard data center may be limited or not available.

[0141] The facilities module **650**, computing equipment modules **652**, and end caps **660** and **661** are designed to be connected together to form a continuous barrier allowing the interior environment to be separate from the exterior environment. This will allow for the interior temperature, humidity, and air flow to be maintained at the optimum levels required for the efficient operation of the computing equipment. The outward facing portions of the frame members **602**, **604**, **606**, **608**, and **610** provide an exterior mating surface **628** which is used to mate the modules together or mount modular walls **640**. An exterior mating surface **628** is smooth, straight, and uniform which will allow for pairs of exterior mating surfaces

628 to come into full contact along the length of the mating surfaces **628**. The exterior mating surfaces **628** of a facilities module **650**, a computing equipment module **652**, end cap **660**, or modular wall **640**, when in full contact, will form a continuous barrier between the external environment and internal environment. A gasket like device, or other similar device known in the industry, may be inserted between the external mating surfaces **628** to facilitate the forming of a barrier between the interior and exterior environment. After the modules are set in place and mated together such that a barrier is formed, a 'C' style clamp may be applied to a plurality of locations around the mating surfaces to hold the modules in place and maintain continuity between the mating surfaces **628**. It is to be appreciated that any method known in the industry may be used to hold the modules together in close proximity thereby maintaining continuity between the sealing surfaces thereby maintaining the environmental barrier. By way of non-limiting example, standard nuts, bolts, and washers may be used in conjunction with matching pre-drilled holes through the mating surfaces to hold the modules and/or end cap together.

Modular Wall and Base Frame Design

[0142] The modular walls **640** of the modular data center consist of three layers. The layers consist of an inner wall **642**, and an outer wall **646**, and an insulation layer **644** that is located between the inner wall **642** and the outer wall **646**. The three layers are connected together, by any method known in the industry, to form the modular wall **640**. The inner wall **642** has a mating surface **628** located around the outside perimeter. The mating surface is of a width that allows for a modular wall **640** to fully engage the exterior mating surface **628** of the modules. By way of non-limiting example, the width of the modular wall's mating surface **628** is 2 inches wide.

[0143] A modular wall **640** is connected to the exterior mating surface **628** of a module frame whereby a continuous barrier is formed between the internal and external environments. The modular wall **640** is connected to the external mating surface **628** of a module by any method generally known in the industry. By way of non-limiting example, the modular wall **640** may be connected to the exterior surface **628** by way of screws, washers, and threaded inserts that use predrilled holes through the exterior mating surface **628** of the basic frame **600** and in the modular wall **640**.

[0144] The facilities module and the computing equipment module each comprise a base frame **600**. The frame consists of two lower longitudinally extending frame members **604**, two lower transversely extending frame members **602**, two upper longitudinally extending frame members **608**, and two upper transversely extending frame members **606**. The frame also consists of four vertically extending frame members **610**. The twelve extending frame members, when combined together, form the base frame **600** provide the necessary structural support required by the additional interior frame members, computing equipment and other hardware. Corner support braces **612** may be used to provide additional structural support for the base frame **600**. Each intersection of frame members may contain up to three corner braces **612**. The base frame **600** will have additional support members **618**, **622** and **624** added to it as necessary depending on the type of module to be built and the use requirements associated with the module.

Facilities Module

[0145] Referring to FIGS. **20** and **25**, the facilities module **650** consists of a base frame **600**. Connected to the base frame

600 is a first side modular wall **653**, opposite a second side modular wall **654**. The module also contains an upper modular wall **655** and a lower modular wall **656**. Also connected to the base frame **600** is an end modular wall **658**. The side opposite the end modular wall **658** is open and contains the external mating surface **628** (not shown) allow for the connection to a computing equipment module **652**.

[0146] Similar to the data center contained within a container, the facilities module may contain one or more of the following: water/refrigerant heat exchanger **300**, inlet T-shaped valve **330**, outlet T-shaped valve **332**, a basin or drip pan **340**, power distribution panel **1208**, disconnect switch, humidifier **123**, dehumidifier **125**, humidity control unit, controller unit **134**, power supplies, lighting system, internal private network, UPS, and DC control system. It is to be appreciated that the UPS may be located in the computing equipment module depending on the operational requirements of the modular data center. The functions performed by the above mentioned components in a modular data center are similar, if not identical, to the functions performed by the components in a data center contained within a container.

[0147] As an alternative to refrigerant being circulated to individual refrigerant/air heat exchangers located above each of the upright equipment receiving areas of each module, all cooled air is generated within the facilities module which is then supplied to each module to remove heat generated from the computing equipment and associated hardware.

[0148] An additional alternative to the above mentioned cooling system is a water/refrigerant heat exchanger located within each computing equipment module. The cooled water will be supplied to the computing equipment module's **652** water/refrigerant heat exchanger via the facilities module **650**. The refrigerant will circulate within a closed loop that includes a refrigerant/air heat exchanger. The complete refrigerant loop will be contained within each module for ease of modular data center **699** assembly and maintenance.

Computing Equipment Module

[0149] Referring to FIGS. **17**, **19**, **23** and **24**, the computing equipment module consists of a base frame **600**. Connected to the base frame **600** is a first side modular wall **653**, opposite a second side modular wall **654**. The module also contains an upper modular wall **655** and a lower modular wall **656**. The ends of the module are open to allow for the module to be connected to another computing equipment module **652**, a facilities module **650**, or an end cap **660** or **661**.

[0150] The computing equipment module contains transversely extending C-shaped frame members **614** that are laterally spaced apart to form a series of lower air plenums **616**. The lower air plenums **616** allow for air flow from the center aisle **615**, down through the perforated floor **663**, flow transversely through the lower air plenums **616**, upward into and through the equipment receiving area **670**, into the upper air plenum **617**, then back into the center aisle **615**. Above the transversely extending C-shaped frame members **614** are located four longitudinally extending floor support members **618**, laterally spaced apart, which are supported by the transversely extending C-shaped frame members **614**. Four longitudinally extending side support members **622**, two on each side and laterally spaced apart, are mounted to the base frame **600**. Two longitudinally extending top support members **624**, laterally spaced apart, are mounted to the base frame **600**. The computing equipment receiving areas **670**, or other module hardware, will be mounted to, or supported by, the longitudi-

nally extending frame members **618**, **622** and **624**. Also mounted above the transversely extending frame members **614**, adjacent to the perforated floor **663** and in front of the equipment receiving areas **670** are cable conduits with covers **620** to allow for the efficient and manageable routing of various cables between modules.

[0151] The module may also contain four vertically extending support members (not shown), two on each side, which are laterally spaced apart and mounted adjacent to the first and second side portions, to provide additional support for the equipment receiving area or other module hardware. Additionally, the module may contain two transversely extending frame members (not shown), laterally spaced apart and mounted adjacent to the upper or roof portion of the module, which can be used to provide additional support for the vertical cooling system or other module hardware.

[0152] Referring to FIGS. **18** and **19**, the equipment receiving area **670** may consist of an equipment receiving carriage **630**. Similar to the data center within a data center **10**, the function of the equipment receiving area is to store computing equipment **102** or other associated hardware to support data center functions such as air moving assemblies **260**. The design of the carriage is very similar to the carriage **70** described above. The equipment receiving carriage **630** of the modular data center **699** consists of a front upright support **632A**, a rear upright support **632B**, front to back extending members **672** that are connected between the front and rear upright supports **632A-B**, front carriage vertical support **680A**, rear carriage vertical support **680B**, carriage front to rear extending members **682**, front carriage rail **678A**, and a rear carriage rail **678B**. The front and rear carriage rails **678A-B** of the equipment receiving carriage **630** may be mounted to isolators **86** or directly to longitudinally extending floor support members **618**. The back of the equipment receiving carriage **630** may be mounted to isolators **86** or directly to longitudinally extending side support members **622A-B**.

[0153] The front upright support **632A** may contain openings **636A-C**, which allow for the mounting of networking equipment **244** or other computing hardware to support the computing equipment **103** located in areas **S1-S4**. The front to rear extending members **672** form transverse cable conduits **634A-C** that may be used to route and manage the various cables associated with connecting computing and networking equipment.

[0154] Each computing equipment module may contain a center aisle portion **615** which exists between the front edges of the equipment receiving areas **670**. The center aisle portion **615** will be wide enough to allow for the computing equipment **102**, which is mounted within the equipment receiving carriage **630**, to be “racked” out to allow for inspection and maintenance.

[0155] Referring to FIG. **23**, an alternative embodiment of the computing equipment module contains an insulated personnel door **648** and is generally designated **662**. The personnel door **648** will allow access to the center aisle portion **615**. In this embodiment, only one equipment receiving area **670** is located within the module space and the personnel door **648** is located opposite of equipment receiving area **670**. This module embodiment may be used when the space where the modular data center **699** is to be located is not sufficient to allow for personnel access to the outside end areas. This

module may replace any regular computing equipment module **652** that is part of the modular data center.

End Cap

[0156] Referring to FIG. **22**, the end cap with personnel door is similar in construction to the end portion of the facilities module and is generally designated **660**. The end cap **660** consists of a lower transversely extending member **602**, an upper transversely extending member **606**, and two vertically extending frame members **610**. Additionally, the frame contains corner braces **612** at the intersection of the transversely extending frame members **602** and **606**, and the vertically extending frame members **610**. The end cap **660** has an exterior mating surface **628** and is used to mate the end cap **660** to the external mating surface **628** of a facilities module **650** thereby forming a continuous barrier between the inside and outside environment. An end modular wall with personnel door **657** is connected exterior mating surface **628** to the outside of the end cap frame to create a continuous barrier between the inside and outside environment.

[0157] If the alternative embodiment of the computing module **663**, where an equipment receiving area **670** is removed to allow for a personnel door **648**, is implemented, the end cap may not include a personnel door and is generally designated **661**. In this implementation, the end modular wall with personnel door **657** is replaced by end modular wall **658**.

Split Module

[0158] To support the need to locate a modular data center **699** where access to the area for installation is supported by a standard freight elevator of limited size or is limited by other factors that will prevent the delivery of standard size modules, the modules may be manufactured such that the modules can be separated along the longitudinal centerline. Allowing for longitudinal separation would enable the individual modules to be separated prior to loading them onto an elevator or moving them through a space of restricted size, and then reassembled in the designated data center space. The functionality of the modular data center **699** would not be limited by the split module design.

[0159] While particular embodiments of the present invention have been shown and described, it will be obvious to those skilled in the art that, based upon the teachings herein, changes and modifications may be made without departing from this invention and its broader aspects and, therefore, the appended claims are to encompass within their scope all such changes and modifications as are within the true spirit and scope of this invention. Furthermore, it is to be understood that the invention is solely defined by the appended claims. It will be understood by those within the art that, in general, terms used herein, and especially in the appended claims (e.g., bodies of the appended claims) are generally intended as “open” terms (e.g., the term “including” should be interpreted as “including but not limited to,” the term “having” should be interpreted as “having at least,” the term “includes” should be interpreted as “includes but is not limited to,” etc.). It will be further understood by those within the art that if a specific number of an introduced claim recitation is intended, such an intent will be explicitly recited in the claim, and in the absence of such recitation no such intent is present. For example, as an aid to understanding, the following appended claims may contain usage of the introductory phrases “at least one” and “one or more” to introduce claim recitations. How-

ever, the use of such phrases should not be construed to imply that the introduction of a claim recitation by the indefinite articles “a” or “an” limits any particular claim containing such introduced claim recitation to inventions containing only one such recitation, even when the same claim includes the introductory phrases “one or more” or “at least one” and indefinite articles such as “a” or “an” (e.g., “a” and/or “an” should typically be interpreted to mean “at least one” or “one or more”); the same holds true for the use of definite articles used to introduce claim recitations. In addition, even if a specific number of an introduced claim recitation is explicitly recited, those skilled in the art will recognize that such recitation should typically be interpreted to mean at least the recited number (e.g., the bare recitation of “two recitations,” without other modifiers, typically means at least two recitations, or two or more recitations).

[0160] Accordingly, the invention is not limited except as by the appended claims.

The invention claimed is:

1. A modular data center comprising:

a facilities module having a base frame of longitudinal, vertical, and transverse frame members which form a rectangular shaped volume and define two side portions, two end portions, a top portion and a bottom portion wherein said frame members have external mating surfaces, a chilled water inlet connection for receiving chilled water from an external source, a chilled water outlet connection for exiting the chilled water from the interior portion of the modular data center, one or more water/refrigerant heat exchangers that receive said chilled water from said chilled water inlet and returns said chilled water to said chilled water outlet, said water/refrigerant heat exchangers also receiving refrigerant from and returning refrigerant to air/refrigerant heat exchangers located internally to the modular data center, a power connection to receive power from an external source, a power distribution system consisting of said power connection, switches, breakers, and electrical panels which control and distribute power to the equipment located internally to the modular data center, an environment control system for sensing and controlling the environmental conditions internal to the modular

data center, a network connection, a controller for controlling and modifying conditions internal to the modular data center, modular walls comprising an outer layer, a middle insulation layer, and an inner layer having a mating surface which is in direct communication with said side portions, one said end portion, said top portion, and said bottom portion;

a computing equipment module having a base frame of longitudinal, vertical and transverse frame members which form a rectangular shaped volume and define two side portions, two end portions, a top portion and a bottom portion wherein said frame members have external mating surfaces, modular walls comprising an outer layer, a middle insulation layer, and an inner layer having a mating surface, where said mating surfaces of said modular walls are in direct communication with said side portions, said top portion, and said bottom portion, an upper plenum, a lower plenum, one or more equipment receiving areas located between said upper and said lower plenum and adjacent to said side portions, a center aisle section located between said equipment receiving areas, a floor section located at the bottom of said center aisle section and above said lower plenum, a lighting system, a carriage located in the equipment receiving areas and having a plurality of upwardly and longitudinally directed air moving devices, a cable tray system for routing cables between modules, one or more air/refrigerant heat exchangers where the refrigerant lines of said air/refrigerant heat exchangers are in communication with one of said water/refrigerant heat exchangers; and

an end cap having a frame consisting of two vertically extending frame members and two transversely extending frame members wherein said frame members have external mating surfaces, a modular wall comprising an outer layer, a middle insulation layer, and an inner layer having a mating surface, wherein said mating surfaces of said modular wall are in direct communication with said frame, and a door located integrally to said modular wall for personnel access.

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