United States Patent Application Publication	20250261334
Kind Code	A1
Publication Date	August 14, 2025
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MODULAR SUPPORT ASSEMBLY FOR DATA CENTER COOLING

Abstract

A modular structure for cooling a set of servers includes a plurality of modular frame assemblies, each frame assembly including a plurality of frames affixed to one another with a plurality of longitudinal struts, assembled off-site from a data center containing the set of servers, wherein each frame assembly is independently affixed to a data center structure proximate the set of servers, and a plurality of modular fluid distribution assemblies, with each respective fluid distribution assembly affixed to a respective one of the frame assemblies, and with adjacent ones of the modular fluid distribution assemblies fluidly coupled to one another, wherein the fluid distribution assemblies are fluidly coupled with a cooling fluid source in the data center.

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Family ID: **1000008466354**

Appl. No.: **19/052916**

Filed: **February 13, 2025**

Related U.S. Application Data

us-provisional-application US 63553090 20240213

Publication Classification

Int. Cl.: **H05K7/20** (20060101)

U.S. Cl.:

CPC **H05K7/20272** (20130101); **H05K7/2079** (20130101);

Background/Summary

CROSS-REFERENCE TO RELATED APPLICATION [0001] This application claims the benefit of priority to U.S. provisional application No. 63/553,090, filed on Feb. 13, 2024, which is hereby incorporated by reference in its entirety.

BACKGROUND
[0002] Data centers require expansive cooling systems in order to operate, as the simultaneous operation of so many processors in a confined space leads to high temperatures, which-if not remediated-can degrade computing performance or otherwise interrupt data center activity.

Description

BRIEF DESCRIPTION OF THE DRAWINGS
[0003] FIG. **1** is a perspective view of a frame assembly and partial cooling fluid distribution assembly for a data center cooling system.
[0004] FIG. **2** is a process flow mounting frame assemblies according to FIG. **1** in a data center.
[0005] FIG. **3** is a perspective view of the frame assemblies of FIG. **2** deployed with a set of servers.
[0006] FIG. **4** is a schematic front view of the assemblies and set of servers of FIG. **3**.
[0007] FIG. **5** is a perspective view of a cooling assembly portion.
[0008] FIG. **6** is a flow chart illustrating an example method of assembling a cooling assembly for one or more servers.
DETAILED DESCRIPTION
[0009] Various embodiments of this disclosure include a modular system for providing cooling to computing equipment, including but not limited to servers in a data center. Because servers generate an immense amount of radiative heat during operation, it is crucial to provide sufficient cooling to regulate the servers' temperature. While many different methods of cooling have been utilized—including forced air or the use of cool water-filled piping—each cooling system faces a similar issue: on-site construction of cooling systems must compete for time, space, and resources with the construction of the rest of the data center. In particular, certain skilled labor, such as welding, may be in high demand in the construction process at the time that cooling assembly supports are typically installed. Further, installation of cooling infrastructure relies on the building itself having been completed, and thus an extended time period of building and installation of cooling infrastructure can delay the installation and ultimate operation of the servers for which the data center is being built. Accordingly, it is advantageous for a cooling system to be able to be built and assembled off-site, transported to the data center as constructed modular assemblies, and then installed and connected to in-building infrastructure (rather than completely constructed) on-site in the data center in order to advance the operations of the data center and improve its time to being online. The system as described herein accomplishes this by providing a modular frame unit that may be used to build a cooling assembly of a desired size by coupling a chosen quantity of identical modular frame units. The assembled frame units are then attached to a ceiling of the data center. In addition, the modular frame unit may include structural support for both cooling assemblies (e.g., piping) and for electrical assemblies (e.g., wiring harnesses) so that installation and connection of both cooling and electrical hardware is simplified on-site.
[0010] In some embodiments, the modular frame assemblies may be assembled offsite in conjunction with cooling fluid distribution assemblies. That is, inflow and outflow piping, taps to connect those inflows and outflows to server cooling devices, and other distribution components may be assembled and affixed to the frame assemblies offsite. Those fluid distribution assemblies

may then be connected to each other (e.g., for continuity of inflow and outflow through a server row) and to a fluid source on site in the data center. Like assembling the frame assemblies offsite, assembling the cooling fluid distribution assemblies offsite permits the separation of labor needs between the assemblies (which can be built at a convenient time before their installation) and the construction of the data center itself.

[0011] FIG. **1** is a perspective view of a frame unit **100**. As shown, the frame unit **100** may include a central support body **110**, at least one water pipe **120**, and a plurality of side support extensions **130**. The central support body **110** may be substantially rectangular (e.g., in a cross-section taken across any of the Z-axis, Y-axis, or X-axis), and may be formed of interconnected struts, which may offer high strength at relatively low weight. Specifically, the support body **110** may be formed of a rectangular frame of a lower horizontal strut **112** and an upper horizontal strut **114** coupled to each other by two vertical struts **116**, **118**. The struts **112**, **114**, **116**, **118** may surround and may define a central gap **122** through which a desired number of water pipes **120** may extend and which may be sized to support a needed quantity of pipes **120**. The support body **110** may further include one or more (e.g., two) additional horizontal struts **124**, **126** extending between the vertical struts **116**, **118**, and diagonal struts **128**, **136** that each extends between a respective set of horizontal struts **124**, **126**, **114**.

[0012] A set of connected struts **112**, **114**, **116**, **118**, **124**, **126**, **128**, **136** may define a single frame, and a plurality of frames may be coupled together via longitudinal struts. For example, longitudinal struts **140**, **142**, **144**, **146** may extend from each corner of the rectangular frames. Accordingly, the frame unit **100** may comprise a plurality of rectangular frames coupled together by a plurality of longitudinal struts.

[0013] The at least one pipe **120** may be structured to carry a liquid (e.g., water), and may be positioned within and extend longitudinally (e.g., along a Y-axis that is parallel with the ground when the frame unit **100** is installed in a building) through the central gap **122**. Although the frame unit **100** of FIG. **1** is shown to include four pipes **120**, this disclosure should not be read as limited to only four pipes **120** and should be read as inclusive of any number of desired pipes **120**. During installation of a modular frame assembly **100** at a data center, each pipe **120** may be connected to one or more cooling units on one or more servers or server racks. Accordingly, as will be shown in FIGS. **4** and **5**, each pipe **120** may include one or more vertical taps, each used for exchange of liquid with the pipe, and each of which may terminate in a valve. In some embodiments, one pipe **120** may serve as a cooling intake and another pipe **120** as a cooling output, such that the liquid flowing through the cooling units serves as a heat sink and is recooled before being recirculated to the cooling units.

[0014] In some embodiments, each pipe **120** may rest on top of a horizontal strut **112**, **114**, **124**, **126**, or may rest under and be supported by a horizontal strut **112**, **114**, **124**, **126**. A pipe **120** may be secured to a horizontal strut **112**, **114**, **124**, **126** via a band, clamp, or tie made of metal, nylon, or another appropriate material that is wrapped around the pipe **120** and secured to the strut **112**, **114**, **124**, **126** via one or more fasteners.

[0015] A plurality of side extensions **130** may protrude from the central body **110** along the X-axis, which may be parallel to the ground once the frame unit is installed in a building. In some embodiments, each side extension **130** may be monolithically-formed with the central frame (e.g., such as by welding). As shown, four side extensions **130** protrude from each vertical beam of the central body **110**. The lower two side extensions **130** on each side may hold a trough **132** shaped to hold cables, wires, or other accessories associated with the servers **300**. A suspension wire **134** may be fixed to each third side extension **130** and fed through the fourth side extension **130** before being fixed to a ceiling (e.g., ceiling frame **150**).

[0016] In some embodiments, struts **112**, **114**, **116**, **118**, **124**, **126**, **128**, **136** may be affixed to one another by welding, metal fasteners (e.g., bolts with angle joints, etc.), or other appropriate affixation techniques. In some embodiments, the techniques used to assemble a frame **150** (e.g., used to affix struts **112**, **114**, **116**, **118**, **124**, **126**, **128**, **136** to one another) may be different from the affixation techniques used to affix the frame assembly **100** to a building. For example, welding may be employed when assembling the frame unit **100**, whereas only fasteners may be needed to affix the frame unit **100** to a building.

[0017] As shown in FIG. **2**, a first frame unit **100**A may be attached to a second frame unit **100**B end-to-end along the Z-axis to form a frame assembly **200**. In some embodiments, the trough **132** may be attached to the frame unit **100** prior to connecting the multiple frame units. In some embodiments, the trough **132** may be attached to the frame assembly **200** following assembly of multiple frame units **100** together. Like the trough **132**, the pipes **120** may be installed within the frame unit **100** prior to full assembly, or within the frame assembly **200** once assembled. Once the frame units **100** are assembled at floor level, the frame assembly **200** may be elevated and attached to ceiling **150** via the suspension wires **134** and/or by fastening top struts **114**, **140**, **142** to the building structure. Alternatively, an individual frame unit **100** may be attached to ceiling **150** before being coupled to another frame unit **100**, i.e., frame units **100** may be suspended before being attached to each other. Still further, in some embodiments, frame units **100** may be independently suspended from ceiling **150** and may not be mechanically coupled to other frame units **100** other than by virtue of continuity of pipes **120** and/or other non-structural components. FIG. **3** shows the elevated frame assembly **200** in position above the server racks **300** (which may be filled with servers after assembly of the frame assembly **200**), with the troughs **132** and pipes **120** omitted for clarity. As shown, electrical equipment **136** may be further coupled to the central body **110**.

[0018] FIG. **4** is a schematic end view of the frame unit **100** in elevated position above the server racks **300**. The frame unit may further include a plurality of valves **410** (e.g., one or more valves **410** per pipe **120**) for fluidly coupling the pipes **120** to cooling units (not shown) installed on the server racks **300** for cooling servers and other computing equipment. The valves **410** may be provided at the end of cooling fluid supply or return taps **420**.

[0019] FIG. **5** is a perspective view of a cooling assembly portion **500** that may find use with the frame unit **100**. The cooling assembly portion **500** includes a main pipe **120** and a plurality of cooling fluid supply or return taps **420**, each terminating in a valve **410**. The cooling assembly portion **500** may further includes a water-resistant sheath **502** that may cover all pipe headers (including main pipe **120**) and supply/return taps **420**. The sheath **502** may prevent significant leaks and indiscriminate spraying in the event of a leak or excess condensation, instead containing, and directing the disposition of any such moisture to a desired location, such as a floor portion with a drain or water collection recess.

[0020] The sheath **502** may be or may include a waterproof or water-resistant material that contains leaks and condensation from the pipe **120** and funnels any such leaks and condensation to a location where liquid can safely drip down from the pipe. In some embodiments, the sheath may be or may include a polymer material, such as neoprene rubber or other rubber, treated nylon, rubberized cotton or other rubberized material, a polyethylene wrap, a polyvinyl chloride (PVC) coating or wrap, a thermal shrink sleeve such as polyethylene shrink, a fiberglass wrap, and/or another appropriate material.

[0021] The sheath **502** may be circumferentially sealed around each pipe **120**, in some embodiments. For example, a longitudinal portion of the sheath **502** may be wrapped around the pipe **120**, and a slit in the sheath **502** that permitted it to be placed on the pipe **120** may be sealed with adhesive, tape, heat, or another sealant.

[0022] The sheath **502** may include portions **504** for a pipe **120** and portions **506** for taps **420** that are assembled to the piping separately. In some embodiments, seams between portions **504**, **506** may be sealed with adhesive, heat, or another sealant. The seams between portions **504**, **506** may be sealed at the same time as, or separately from, slits in the portions themselves.

[0023] One or more moisture sensor assemblies **508** may be provided in the sheath **502** for detection of leaks and/or excess condensation. A moisture sensor may be or may include, for example, a resistive moisture sensor, capacitive moisture sensor, infrared moisture sensor, and/or any other appropriate type of sensor. The assembly portion **500** (or, more broadly, the assembly **100** of FIG. **1**) may include a plurality of moisture sensor assemblies spaced throughout the assembly **100** or assembly portion **500**. For example, a moisture sensor assembly may be provided at three-foot intervals, five-foot intervals, ten-foot intervals, or another interval, along the pipe **120**.

[0024] Each moisture sensor assembly **508** may include the sensor itself as well as a circuit board and one or more output devices. An output device may include, for example, one or more of a buzzer, speaker, or other audio output, an LED or other light, and/or a wireless transmitter that transmits a status of the moisture sensor to an external controller. For example, a moisture sensor assembly may transmit its status and identifier to a central controller for the broader infrastructure of a data center, and the central controller may determine the location of a leak or other excess moisture based on transmissions received from one or more sensors and known locations of those sensors based on their identifiers.

[0025] In some embodiments, where the moisture sensor includes an audio output or visual output, an aperture may be provided in the sheath **502** for passage of wiring for the audio and/or visual output through the sheath wall, or for the audio and/or visual output mechanism itself to protrude through the sheath wall. Any such aperture may be sealed around the passed wiring, audio output mechanism, and/or visual output mechanism. For example, the sealant may include a silicone sealant, caulk, epoxy, and/or another appropriate sealant given the material of the sheath **502**.

[0026] Moisture sensor assemblies **508** may be used even in embodiments without a sheath **502**. For example, one or more moisture sensor assemblies may be coupled directly to the pipe **120** and/or all pipes of an assembly **100**.

[0027] Portions of the sheath **502** are cut away in FIG. **5** for visual clarity. It should be understood that any and/or all pipes **120** and/or taps **420** may be enveloped by the sheath **502**, in embodiments.

[0028] FIG. **6** is a flow chart illustrating an example method **600** of assembling and installing a colling assembly for a set of servers. The method **600** may improve the efficiency of data center construction. In embodiments, by separating the construction of the cooling assembly from the construction of the larger data center, construction of both the cooling assembly and the data center can be completed more efficiently. Accordingly, as will be described in detail below, certain assembly aspects may be performed at a first location, separate from the data center, and other assembly aspects may be performed at a second location (the data center itself).

[0029] The method **600** may include, at block **602**, receiving a plurality of struts (e.g., struts **112**, **114**, **116**, **118**, **124**, **126**, **128**, **136**). The struts may all be identical to one another in size, or may be a variety of sizes (e.g., widths, thicknesses, and lengths). The structs may all be identical to one another in cross-sectional shape, or may be a variety of shapes (e.g., I-beam, box construction, etc.). The dimensions of the struts (e.g., material thickness) may be determined according to an anticipated load to be borne by cooling and other infrastructure supported by the struts.

[0030] The method **600** may further include, at block **604**, assembling a plurality of struts into a plurality of frames. Each frame may include, for example, an upper horizontal strut, a lower horizontal strut, a left vertical strut, and a right vertical strut defining a rectangular frame outline. A frame may further include one or more additional horizontal struts extending from the left vertical strut to the right vertical strut and/or one or more additional vertical struts extending from the lower horizontal strut to the upper horizontal strut.

[0031] Assembling struts into a frame may include affixing each strut to one or more other struts. Struts may be affixed to one another by welding, in some embodiments.

[0032] The method **600** may further include, at block **606**, assembling a plurality of frames into one or more (e.g., a plurality of) frame assemblies. Block **606** may include, for example, affixing adjacent frames to one another via a plurality of longitudinal struts. Frames may be affixed to longitudinal struts (that is, horizontal and/or vertical struts may be affixed to longitudinal struts) by welding, in some embodiments.

[0033] Block **608** may further include, in some embodiments, affixing one or more eye bolts or other structures that can be used to attach the completed frame assembly to a data center structure, as described below in block **618**. For example, block **608** may include affixing a plurality of eye bolts to the upper struts of the frame assembly, for example. The eye bolts may be affixed by welding, in some embodiments.
[0034] In addition to or instead of eye bolts or separate structures, block **608** may include forming loops or other receiving structures in the struts themselves.
[0035] In some embodiments, blocks **604**, **606** may be performed in conjunction, rather than sequentially, to assemble a frame assembly.
[0036] A frame assembly that is assembled at blocks **604**, **606** may be of a size so as to fit on a standard flatbed truck (that is, a truck bed intended to accommodate a standard shipping container) or in a standard shipping container, in some embodiments. That is, a frame assembly may fit within dimensions of 20 feet in length, 8 feet in width, and 8.5 feet in height. Alternatively, a frame assembly may fit within dimensions of 40 feet in length, 8 feet in width, and 8.5 feet in height. Alternatively, a frame assembly may fit within a height dimension of 9.5 feet, with a length and width as noted above.
[0037] The method **600** may further include, at block **608**, receiving a plurality of fluid conduits (e.g., pipes **120**, taps **420**, valves **410**, and the like). The quantity and dimensions of fluid conduit may be determined according to an anticipated cooling need of the set of servers or other computing devices to be cooled using infrastructure supported by the frame assembly.
[0038] The method **600** may further include, at block **610**, assembling a cooling fluid distribution assembly comprised of the received fluid conduit. The cooling fluid distribution assembly may include, for example, inflow pipes, outflow pipes, and taps. The quantity of taps may be determined according to an arrangement of a cooling device or arrangement for the intended set of servers or other computing devices. Block **610** may include affixing the cooling fluid distribution assembly to the frame assembly. For example, pipes may be affixed to struts with bands, clamps, ties, etc. Block **610** may further include coupling one or more moisture sensors to the cooling fluid distribution assembly, such as coupling sensor assemblies at predetermined intervals along the inflow and/or outflow pipes. Where such moisture sensor assemblies are provided, block **610** may further include routing power wiring for the sensor assemblies along the cooling fluid distribution assembly, terminating in ported electrical connectors for connection to a power supply and/or to other cooling fluid distribution assembly moisture sensors, for example.
[0039] The method **600** may further include, at block **612**, covering one or more portions of the cooling fluid distribution assembly with a liquid containment sheath. As described above with respect to FIG. **5**, the sheath may include a waterproof or water-resistant material that contains leaks and excess condensation from the cooling fluid distribution assembly and directs any such moisture to a safe location for its exit.
[0040] Block **612** may include inserting cooling pipes, taps, and/or other aspects of the cooling fluid distribution assembly through respective sheath portions. Block **612** may further include sealing junctions of sheath portions in a watertight manner, such as with adhesive, heat, tape (e.g., where the sheath comprises heat shrink or another heat-deformable material), and/or another sealant. Block **612** may further include sealing longitudinal slits that were utilized to place sheath portions in a similar manner.
[0041] In some embodiments, block **612** may include forming one or more apertures in the sheath for the passage of moisture sensor assemblies, or portions of such assemblies, such as wiring, audio or visual outputs, and the like. When such apertures are formed, block **612** may further include sealing those apertures about the devices that are passed through the apertures, such as with epoxy, adhesive, etc.
[0042] The method **600** may further include, at block **614**, affixing one or more support accessories to the frame assembly and/or cooling fluid distribution assembly. The support accessories may

include, for example, one or more longitudinal trays, troughs, and/or other multi-use support infrastructure.

[0043] Blocks **602**, **604**, **606**, **608**, **610**, **612**, **614** may be performed at a first location, in some embodiments, such as a location different from a data center in which the frame assembly and cooling fluid distribution assembly are to be deployed.

[0044] The method **600** may further include, at block **616**, transporting the assembled frame assembly and cooling fluid distribution assembly from the first location to a data center. Block **616** may include, for example, loading the assembled frame assembly and cooling fluid distribution assembly into a shipping container and/or onto a truck for transport and transporting the assembled frame assembly and cooling fluid distribution assembly to the data center for it to be deployed.

[0045] The method **600** may further include, at block **618**, affixing a plurality of frame assemblies to the data center structure. Block **618** may include, for example, affixing each frame assembly to a ceiling of the data center above locations where associated servers are to be disposed. A frame assembly may be affixed to a ceiling via a plurality of cables and associated fasteners to fasten the cable to the ceiling and to the frame assembly. In some embodiments, the cables may be attached to the data center structure before the frame assemblies are introduced, and block **618** may include simply coupling the cables to the frame assembly. Block **618** may include coupling the cables to eye bolts, loops, or similar structures of the frame assembly.

[0046] The method **600** may further include, at block **620**, fluidly coupling adjacent fluid distribution assemblies to each other in the data center. For example, inflow pipes of each fluid distribution assembly may be fluidly coupled to the inflow pipes of one or two adjacent fluid distribution assemblies (e.g., one assembly upstream and one assembly downstream). Similarly, outflow pipes of each fluid distribution assembly may be fluidly coupled to the outflow pipes of one or two adjacent distribution assemblies. Adjacent fluid pipes may be coupled together via threaded fittings, crimp fittings, and/or another fluid coupling approach.

[0047] The method **600** may further include, at block **622**, fluidly coupling the fluid distribution assemblies to one or more server cooling apparatus (e.g., via the taps) and/or fluidly coupling the fluid distribution assemblies to one or more fluid sources (e.g., pumps).

[0048] In a first aspect of the present disclosure, a method for assembling a server cooling assembly is provided. The method includes assembling, offsite from a data center, a plurality of frame assemblies, each frame assembly including a plurality of frames affixed to one another with a plurality of longitudinal struts, coupling a respective fluid distribution assembly to each of the frame assemblies, offsite from the data center, transporting the plurality of frame assemblies, with coupled fluid distribution assemblies, to the data center, affixing the frame assemblies to a structure of the data center, and fluidly coupling the plurality of fluid distribution assemblies to one another within the data center.

[0049] In an embodiment of the first aspect, assembling the plurality of frame assemblies includes welding a plurality of struts together. In a further embodiment of the first aspect, the frame assemblies and fluid distribution assemblies do not require welding at the data center.

[0050] In an embodiment of the first aspect, the method further includes fluidly coupling the plurality of fluid distribution assemblies to a cooling fluid source within the data center.

[0051] In an embodiment of the first aspect, the method further includes placing a water-resistant sheath about each fluid distribution assembly, the sheath configured to contain and direct the flow of leaks from the fluid distribution assembly. In a further embodiment of the first aspect, the method further includes coupling a respective moisture sensor assembly to each of the fluid distribution assemblies, wherein each moisture sensor assembly comprises a moisture sensor configured to detect moisture within the sheath and an output device.

[0052] In an embodiment of the first aspect, affixing the frame assemblies to a structure of the data center includes suspending each frame assembly from the data center ceiling with one or more cables.

[0053] In an embodiment of the first aspect, each frame includes an upper strut, lower strut, left strut, and right strut forming a generally rectangular body that defines a central gap, and at least one additional horizontal strut or at least one additional vertical strut disposed within the gap, wherein the respective fluid distribution assembly is affixed to the at least one additional horizontal strut or at least one additional vertical strut.

[0054] In a second aspect of the present disclosure, a cooling system for a set of servers is provided. The system includes a plurality of identical frame assemblies, each frame assembly including a plurality of frames affixed to one another with a plurality of longitudinal struts, assembled off-site from a data center containing the set of servers, a plurality of identical fluid distribution assemblies, with each respective fluid distribution assembly affixed to a respective one of the frame assemblies, wherein the frame assemblies are configured to be independently affixed to a data center structure proximate a set of servers, and wherein the plurality of fluid distribution assemblies are configured to be fluidly coupled to one another on-site at the data center.

[0055] In an embodiment of the second aspect, each of the plurality of frame assemblies includes a plurality of welded struts. In a further embodiment of the second aspect, the frame assemblies and fluid distribution assemblies do not require welding at the data center.

[0056] In an embodiment of the second aspect, the plurality of fluid distribution assemblies are fluidly coupled to a cooling fluid source within the data center.

[0057] In an embodiment of the second aspect, the cooling system further includes a water-resistant sheath disposed about each fluid distribution assembly, the sheath configured to contain and direct the flow of leaks from the fluid distribution assembly. In a further embodiment of the second aspect, the cooling system further includes a respective moisture sensor assembly coupled to each of the fluid distribution assemblies, wherein each moisture sensor assembly comprises a moisture sensor configured to detect moisture within the sheath and an output device.

[0058] In an embodiment of the second aspect, the frame assemblies are suspended from the data center ceiling with one or more cables.

[0059] The cooling system of claim **9**, wherein each frame comprises an upper strut, lower strut, left strut, and right strut forming a generally rectangular body that defines a central gap, and at least one additional horizontal strut or at least one additional vertical strut disposed within the gap, wherein the respective fluid distribution assembly is affixed to the at least one additional horizontal strut or at least one additional vertical strut.

[0060] In a third aspect of the present disclosure, a modular structure for cooling a set of servers is provided. The modular structure includes a plurality of modular frame assemblies, each frame assembly comprising a plurality of frames affixed to one another with a plurality of longitudinal struts, assembled off-site from a data center containing the set of servers, wherein each frame assembly is independently affixed to a data center structure proximate the set of servers, and a plurality of modular fluid distribution assemblies, with each respective fluid distribution assembly affixed to a respective one of the frame assemblies, and with adjacent ones of the modular fluid distribution assemblies fluidly coupled to one another, wherein the fluid distribution assemblies are fluidly coupled with a cooling fluid source in the data center.

[0061] In an embodiment of the third aspect, each modular frame assembly is 40 feet in length or less, 8 feet in width or less, and 9.5 feet in height or less.

[0062] In an embodiment of the third aspect, the modular structure further includes a water-resistant sheath disposed about each fluid distribution assembly, the sheath configured to contain and direct the flow of leaks from the fluid distribution assembly, wherein sheath portions disposed on adjacent fluid distribution assemblies are sealed together.

[0063] In an embodiment of the third aspect, the modular structure further includes a respective moisture sensor assembly coupled to each of the fluid distribution assemblies, wherein each moisture sensor assembly comprises a moisture sensor configured to detect moisture within the sheath and an output device.

[0064] The previous description of the disclosed embodiments is provided to enable any person skilled in the art to make or use the present invention. Various modifications to these embodiments will be readily apparent to those skilled in the art, and the generic principles defined herein may be applied to other embodiments without departing from the spirit or scope of the invention. Thus, the present invention is not intended to be limited to the embodiments shown herein but is to be accorded the widest scope consistent with the principles and novel features disclosed herein.

Claims

1. A method for assembling a server cooling assembly, the method comprising: assembling, offsite from a data center, a plurality of frame assemblies, each frame assembly comprising: a plurality of frames affixed to one another with a plurality of longitudinal struts; coupling a respective fluid distribution assembly to each of the frame assemblies, offsite from the data center; transporting the plurality of frame assemblies, with coupled fluid distribution assemblies, to the data center; affixing the frame assemblies to a structure of the data center; and fluidly coupling the plurality of fluid distribution assemblies to one another within the data center.
2. The method of claim 1, wherein assembling the plurality of frame assemblies comprises welding a plurality of struts together.
3. The method of claim 2, wherein the frame assemblies and fluid distribution assemblies do not require welding at the data center.
4. The method of claim 1, further comprising: fluidly coupling the plurality of fluid distribution assemblies to a cooling fluid source within the data center.
5. The method of claim 1, further comprising placing a water-resistant sheath about each fluid distribution assembly, the sheath configured to contain and direct the flow of leaks from the fluid distribution assembly.
6. The method of claim 5, further comprising: coupling a respective moisture sensor assembly to each of the fluid distribution assemblies, wherein each moisture sensor assembly comprises a moisture sensor configured to detect moisture within the sheath and an output device.
7. The method of claim 1, wherein affixing the frame assemblies to a structure of the data center comprises suspending each frame assembly from the data center ceiling with one or more cables.
8. The method of claim 1, wherein each frame comprises an upper strut, lower strut, left strut, and right strut forming a generally rectangular body that defines a central gap, and at least one additional horizontal strut or at least one additional vertical strut disposed within the gap, wherein the respective fluid distribution assembly is affixed to the at least one additional horizontal strut or at least one additional vertical strut.
9. A cooling system for a set of servers, the system comprising: a plurality of identical frame assemblies, each frame assembly comprising a plurality of frames affixed to one another with a plurality of longitudinal struts, assembled off-site from a data center containing the set of servers; a plurality of identical fluid distribution assemblies, with each respective fluid distribution assembly affixed to a respective one of the frame assemblies; wherein the frame assemblies are configured to be independently affixed to a data center structure proximate a set of servers; and wherein the plurality of fluid distribution assemblies are configured to be fluidly coupled to one another on-site at the data center.
10. The cooling system of claim 9, wherein each of the plurality of frame assemblies comprises a plurality of welded struts.
11. The cooling system of claim 10, wherein the frame assemblies and fluid distribution assemblies do not require welding at the data center.
12. The cooling system of claim 9, wherein the plurality of fluid distribution assemblies are fluidly coupled to a cooling fluid source within the data center.
13. The cooling system of claim 9, further comprising a water-resistant sheath disposed about each

fluid distribution assembly, the sheath configured to contain and direct the flow of leaks from the fluid distribution assembly.

14. The cooling system of claim 13, further comprising a respective moisture sensor assembly coupled to each of the fluid distribution assemblies, wherein each moisture sensor assembly comprises a moisture sensor configured to detect moisture within the sheath and an output device.

15. The cooling system of claim 9, wherein the frame assemblies are suspended from the data center ceiling with one or more cables.

16. The cooling system of claim 9, wherein each frame comprises an upper strut, lower strut, left strut, and right strut forming a generally rectangular body that defines a central gap, and at least one additional horizontal strut or at least one additional vertical strut disposed within the gap, wherein the respective fluid distribution assembly is affixed to the at least one additional horizontal strut or at least one additional vertical strut.

17. A modular structure for cooling a set of servers, the modular structure comprising: a plurality of modular frame assemblies, each frame assembly comprising a plurality of frames affixed to one another with a plurality of longitudinal struts, assembled off-site from a data center containing the set of servers, wherein each frame assembly is independently affixed to a data center structure proximate the set of servers; and a plurality of modular fluid distribution assemblies, with each respective fluid distribution assembly affixed to a respective one of the frame assemblies, and with adjacent ones of the modular fluid distribution assemblies fluidly coupled to one another; wherein the fluid distribution assemblies are fluidly coupled with a cooling fluid source in the data center.

18. The modular structure of claim 17, wherein each modular frame assembly is 40 feet in length or less, 8 feet in width or less, and 9.5 feet in height or less.

19. The modular structure of claim 17, further comprising a water-resistant sheath disposed about each fluid distribution assembly, the sheath configured to contain and direct the flow of leaks from the fluid distribution assembly, wherein sheath portions disposed on adjacent fluid distribution assemblies are sealed together.

20. The modular structure of claim 19, further comprising a respective moisture sensor assembly coupled to each of the fluid distribution assemblies, wherein each moisture sensor assembly comprises a moisture sensor configured to detect moisture within the sheath and an output device.