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United States Patent	12389567
Kind Code	B2
Date of Patent	August 12, 2025
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Data center rack assembly and cooling fluid control method with leak alert

Abstract

A rack assembly for a data center includes: a rack frame housing at least one heat-generating component; a heat exchanger defining a first internal fluid conduit; at least one liquid cooling block connected to the at least one heat-generating component, each of the at least one liquid cooling block defining a second internal fluid conduit, the second internal fluid conduit being in thermal connection with the first internal fluid conduit; a cooling loop independent from any sources of cooling fluid external to the rack assembly and comprising the first and second internal fluid conduits, the cooling loop transferring heat from the second internal fluid conduit to the first internal fluid conduit; and a fluid compensation system comprising a reservoir fluidly connected to the cooling loop and an actuating device to force cooling fluid from the reservoir to the cooling loop to compensate for loss of cooling fluid in the cooling loop.

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Appl. No.: **17/889972**

Filed: **August 17, 2022**

Prior Publication Data

Document Identifier	Publication Date
US 20230062986 A1	Mar. 02, 2023

Foreign Application Priority Data

EP	21306176	Aug. 30, 2021

Publication Classification

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

U.S. Cl.:

CPC **H05K7/20254** (20130101); **H05K7/20272** (20130101); **H05K7/20836** (20130101);

Field of Classification Search

USPC: None

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Background/Summary

REFERENCE TO RELATED APPLICATION
(1) The present application claims priority to European Patent Application EP21306176.5, which was filed Aug. 30, 2021, the entirety of which is incorporated by reference herein.
FIELD OF TECHNOLOGY
(2) The present technology relates to rack assemblies for data centers.
BACKGROUND
(3) A data center houses many server racks that house electronic equipment such as computer systems (e.g., servers). In use, the electronic equipment generates a significant amount of heat that must be dissipated in order to ensure continued efficient operation of the electronic equipment. Many cooling solutions have been implemented to address this including the liquid cooling of heat-generating components (e.g., central processing units (CPUs)) by way of liquid cooling blocks mounted thereto (often referred to as water blocks or cold plates).
(4) Although the liquid cooling blocks can efficiently cool heat-generating components, their implementation in server racks typically requires a liquid distribution system within the data center that can continuously provide cool liquid (e.g., water) to the various server racks within the data center. This can be prohibitively costly for many data center operators. In addition, often times, the implementation of liquid cooling blocks will also over time result in leaks within the network of conduits that feed the liquid cooling blocks. For example, leaks may occur during installation or removal of servers within the server racks. Such leaks can be particularly problematic if a source of cool liquid to the liquid cooling blocks is limited.
(5) There is therefore a desire for a rack assembly for a data center which can alleviate at least some of these drawbacks.
SUMMARY
(6) It is an object of the present technology to ameliorate at least some of the inconveniences present in the prior art.
(7) According to one aspect of the present technology, there is provided a rack assembly for a data center. The rack assembly comprises: a rack frame defining at least one housing section and configured to house electronic equipment including at least one heat-generating component; a heat exchanger connected to the rack frame, the heat exchanger defining a first internal fluid conduit; at least one liquid cooling block connected to the at least one heat-generating component, each of the

at least one liquid cooling block defining a second internal fluid conduit, the second internal fluid conduit being in thermal connection with the first internal fluid conduit of the heat exchanger; a cooling loop for circulating cooling fluid therein, the cooling loop being independent from any sources of cooling fluid external to the rack assembly, the cooling loop comprising the first and second internal fluid conduits, the cooling loop being configured to transfer heat from the second internal fluid conduit to the first internal fluid conduit; and a fluid compensation system comprising: a reservoir fluidly connected to the cooling loop, the reservoir being configured to contain cooling fluid therein; and an actuating device configured to force cooling fluid from the reservoir to the cooling loop to compensate for loss of cooling fluid in the cooling loop.

(8) In some embodiments, the cooling loop fluidly connects the first internal fluid conduit to the second internal fluid conduit.

(9) In some embodiments, the heat exchanger comprises: a cooling coil defining the first internal fluid conduit; and a plurality of fins connected to the cooling coil, the fins being positioned to allow air flow therebetween.

(10) In some embodiments, the actuating device is an actuator, and the actuator is one of a mechanical actuator, an electric actuator, a pneumatic actuator and a hydraulic actuator.

(11) In some embodiments, the fluid compensation system further comprises a controller in communication with the actuator to control actuation thereof, the controller being configured to control a load applied by the actuator on the cooling fluid in the reservoir.

(12) In some embodiments, the controller controls the actuator such that the load applied by the actuator on the cooling fluid in the reservoir is generally constant.

(13) In some embodiments, the fluid compensation system further comprises at least one of a flow rate sensor, a pressure sensor and a temperature sensor configured to sense, respectively, a flow rate, a pressure, and a temperature of the cooling fluid in the cooling loop; the controller is in communication with the at least one of the flow rate sensor, the pressure sensor and the temperature sensor to receive a sensor signal therefrom; and the controller controls the load applied by the actuator on the cooling fluid in the reservoir based on the sensor signal.

(14) In some embodiments, the fluid compensation system further comprises: a sensor in communication configured to sense an operation parameter associated with the actuating device or the reservoir; and a controller in communication with the sensor, the sensor being operable to transmit a sensor signal to the controller indicative of the operation parameter, the controller being configured to transmit an alert signal based on the sensor signal received from the sensor, the alert signal being an indication of a leak in the cooling loop.

(15) In some embodiments, the actuating device is an actuator, the sensor is a position sensor, and the operation parameter is a position of the actuator.

(16) In some embodiments, the alert signal is configured to be transmitted to an external computer that monitors a status of the cooling loop of the rack assembly.

(17) In some embodiments, a volume of the reservoir is greater than a volume of the cooling loop.

(18) In some embodiments, the reservoir is a flexible reservoir; and the actuating device is configured to apply a load on the flexible reservoir in order to force cooling fluid from the flexible reservoir to the cooling loop.

(19) In some embodiments, the reservoir is replaceable with a replacement reservoir when the reservoir is empty.

(20) In some embodiments, the cooling loop comprises a bypass valve that is controllable to selectively allow cooling fluid in the cooling loop to bypass the first internal fluid conduit of the heat exchanger.

(21) According to another aspect of the present technology, there is provided a method for controlling cooling fluid in a cooling loop of a rack assembly for a data center, the rack assembly comprising a heat exchanger connected to a rack frame of the rack assembly and at least one liquid cooling block thermally connected to one another, the heat exchanger comprising a first internal

fluid conduit, the at least one liquid cooling block being connected to at least one heat-generating component housed within the rack frame, each of the at least one liquid cooling block defining a second internal fluid conduit, the cooling loop comprising the first internal fluid conduit of the heat exchanger and the second internal fluid conduit of each of the at least one liquid cooling block, the cooling loop being independent from any sources of cooling fluid external to the rack assembly, the method comprising: fluidly connecting a reservoir to the cooling loop, the reservoir containing cooling fluid therein; and forcing cooling fluid from the reservoir to the cooling loop to compensate for loss of cooling fluid in the cooling loop.

(22) In some embodiments, forcing comprises actuating an actuator to force cooling fluid from the reservoir to the cooling loop, and the method further comprises sensing an operation parameter associated with the actuator or the reservoir; comparing the sensed operation parameter to a pre-determined threshold value of the operation parameter; and based on said comparing, notifying a user of a leak in the cooling loop.

(23) In some embodiments, the operation parameter is a position of the actuator.

(24) In some embodiments, the method further comprises in response to the reservoir being empty, replacing the reservoir with a replacement reservoir that contains cooling fluid.

(25) According to yet another aspect of the present technology, there is provided a rack assembly for a data center. The rack assembly comprises a rack frame defining at least one housing section and configured to house electronic equipment including at least one heat-generating component, a heat exchanger connected to the rack frame, the heat exchanger defining a first internal fluid conduit, at least one liquid cooling block connected to the at least one heat-generating component, each of the at least one liquid cooling block defining a second internal fluid conduit, the second internal fluid conduit being in thermal connection with the first internal fluid conduit of the heat exchanger, a cooling loop for circulating cooling fluid therein, the cooling loop being independent from any sources of cooling fluid external to the rack assembly, the cooling loop comprising the first and second internal fluid conduits, the cooling loop being configured to transfer heat from the second internal fluid conduit to the first internal fluid conduit and a fluid compensation system. The fluid compensation system comprises a reservoir fluidly connected to the cooling loop, the reservoir being configured to contain cooling fluid therein and means for forcing cooling fluid from the reservoir to the cooling loop to compensate for loss of cooling fluid in the cooling loop.

(26) Implementations of the present technology each have at least one of the above-mentioned objects and/or aspects, but do not necessarily have all of them. It should be understood that some aspects of the present technology that have resulted from attempting to attain the above-mentioned object may not satisfy this object and/or may satisfy other objects not specifically recited herein.

(27) Additional and/or alternative features, aspects and advantages of implementations of the present technology will become apparent from the following description, the accompanying drawings and the appended claims.

Description

BRIEF DESCRIPTION OF THE DRAWINGS

(1) For a better understanding of the present technology, as well as other aspects and further features thereof, reference is made to the following description which is to be used in conjunction with the accompanying drawings, where:

(2) FIG. **1** is a perspective view, taken from a top, front, right side, of a rack assembly in accordance with an embodiment of the present technology;

(3) FIG. **2** is a left side elevation view of the rack assembly of FIG. **1**;

(4) FIG. **3** is a top plan view of the rack assembly of FIG. **1**;

(5) FIG. **4** is a rear elevation view of a heat exchanger of the rack assembly of FIG. **1**;

(6) FIG. **5** is a front elevation view of a liquid cooling block of the rack assembly of FIG. **1**;
(7) FIG. **6** is a schematic representation of a cooling loop of the rack assembly of FIG. **1**;
(8) FIG. **7**A is a cross-sectional view of a reservoir and an actuator of a fluid compensation system of the rack assembly of FIG. **1**, showing the reservoir in a full state;
(9) FIG. **7**B is a cross-sectional view of the reservoir and the actuator of FIG. **7**B, showing the reservoir in a half-empty state;
(10) FIG. **8** is a block diagram representation of a control scheme of the fluid compensation system; and
(11) FIG. **9** is a schematic representation of an alternative embodiment of the fluid compensation system.

DETAILED DESCRIPTION

(12) FIGS. **1** to **3** illustrate a rack assembly **100** in accordance with an embodiment of the present technology. The rack assembly **100** is configured for use in a data center which, in use, houses multiple ones of the rack assembly **100**. Notably, the rack assembly **100** is configured to house electronic equipment **125** such as servers, networking equipment, power equipment or any other suitable electronic equipment that is designed to support the function of the data center. In use, multiple such rack assemblies **100** are stacked in columns themselves and aligned in rows that are spaced from one another (forming aisles therebetween) and extend parallel to one another.
(13) As illustrated schematically in FIG. **2**, the rack assembly **100** has a cooling loop **150** that ensures cooling of the electronic equipment **125** housed by the rack assembly **100**. Particularly, as is known, the electronic equipment **125** includes heat-generating components **130** (FIG. **2**) that generate heat during use and therefore, if not properly cooled, can be subject to overheating. For instance, such heat-generating components **130** may include central processing units (CPUs), graphics processing units (GPUs), and other types of heat-generating electronic components. As will be explained in greater detail below, the rack assembly **100** is designed such that, if necessary, the cooling loop **150** can be independent from sources of cooling fluid external to the rack assembly **100**. This may facilitate installing the rack assembly **100** in a data center and also reduces requirements of the facilities at which the rack assembly **100** can be installed. For instance, the rack assembly **100** may be more easily used in facilities in which an extensive piping system to route cooling fluid therein is not provided.
(14) The general construction of the rack assembly **100** will now be described with reference to FIGS. **1** and **2**. The rack assembly **100** has a rack frame **112** defining housing units **114***a*, **114***b*, **114***c* for housing electronic equipment **125** therein. The rack assembly **100** has a front side **111** through which the electronic equipment **125** can be inserted and removed from the rack assembly **110**, and a rear side **113** opposite the front side **111**. In order to dissipate heat generated by the electronic equipment **125**, air generally enters the rack assembly **100** through the front side **111** and is discharged through the rear side **113**. The front side **111** and the rear side **113** may thus be referred to as an air inlet side and an air outlet side respectively. The rack assembly **100** could include one or more heat exchangers **165** on the rear side **113** to manage heat emitted by the electronic equipment **125**.
(15) In this embodiment, the rack frame **112** has two elongated lower support members **116** and two elongated upper support members **118** disposed vertically above and parallel to the lower support members **116**. The lower and upper support members **116**, **118** define the width of the rack frame **112**. Elongated vertical beams **120** are fastened (e.g., bolted or welded) to the lower support members **116** and the upper support members **118**. Each of the housing units **114***a*, **114***b*, **114***c* is straddled, in the lateral direction of the rack assembly **100**, by two of the vertical beams **120** such that the housing units **114***a*, **114***b*, **114***c* are arranged horizontally side-by-side. Thus, in this example of implementation, six vertical beams **120** are fastened to each of the lower support members **116** and the upper support members **118**. Each vertical beam **120** is aligned, in the lateral direction of the rack assembly **100**, with another vertical beam **120** that is affixed to an opposite

lower support member **116**. The vertical beams **120** define openings for affixing the rack-mountable electronic equipment **125** thereto.

(16) Panels **123** are affixed to the vertical beams **120** and extend laterally between adjacent ones of the vertical beams **120** (i.e., between the vertical beams **120** that are adjacent to one another in the depth direction of the rack assembly **100**) to define the housing units **114***a*, **114***b*, **114***c* therebetween. Channels **127** are formed between some of the panels **123** to accommodate cables and/or other components associated with operation of electronic equipment such as piping for conducting cooling fluid therein for cooling the electronic equipment. End panels **124** are fastened to the ends of each of the lower and upper support members **116**, **118**.

(17) In this embodiment, the rack frame **112** is horizontally-extending in that a greatest dimension thereof is defined horizontally. Notably, a width of the rack frame **112**, measured horizontally in a lateral direction of the rack **110**, is greater than a height of the rack frame **112**. The rack frame **112** may be configured differently in other embodiments.

(18) As shown in FIGS. **1** to **3**, the rack assembly **100** also includes three heat exchangers **165** configured to transfer heat with air flowing through the rack assembly **100**. In this embodiment, as best shown in FIG. **4**, the heat exchangers **165** are air-to-liquid heat exchangers such that each heat exchanger **165** has an exchanger frame **166**, a cooling coil **167** connected to the exchanger frame **166** and a plurality of fins **168** connected to the cooling coil **167**. The exchanger frame **166** is connected to the rack frame **112** and supports the components of the heat exchanger **165**. For instance, the exchanger frame **166** may be connected to the rack frame **112** via hooks engaging the rack frame **112**. In other embodiments, the exchanger frame **166** may be connected to the rack frame **112** by one or more hinges such that the exchanger frame **166**, and therefore the heat exchanger **165**, is pivotable about a hinge axis extending vertically. The cooling coil **167** is configured to circulate a cooling fluid therein. Notably, the cooling coil **167** defines an exchanger internal fluid conduit **170** which, as will be explained in more detail below, forms part of the cooling loop **150** of the rack assembly **100**. The cooling coil **167** has an inlet **182** through which, in use, cooling fluid flows into the exchanger internal fluid conduit **170** and an outlet **184** through which, in use, cooling fluid is discharged from the exchanger internal fluid conduit **170**. The fins **168** are configured to allow air flow therebetween such that air can flow through the heat exchanger **165** to exchange heat with the cooling fluid flowing in the cooling coil **167**.

(19) It is contemplated that more or fewer heat exchangers **165** may be provided in other embodiments. Furthermore, the heat exchangers **165** may be configured differently.

(20) As shown in dashed lines in FIGS. **2** and **3**, in this embodiment, the rack assembly **100** also includes a plurality of fans **180** for forcing air flow through the heat exchangers **165**. The fans **180** are supported by the rack frame **112**. For instance, in this embodiment, each fan **180** is connected to a support plate (not shown) that is connected to the rack frame **112** via hooks. In other embodiments, the support plate may be connected to the rack frame **112** via hinges (e.g., when the heat exchangers **165** are pivotably connected to the rack frame **112**). In this embodiment, at least one fan **180** is configured to force air flow through a corresponding one of the heat exchangers **165**. Each fan **180** is rotatable about a fan rotation axis **181** extending generally horizontally and more particularly in the front-to-rear direction of the rack assembly **100**. As such, as shown in FIG. **3**, the fans **180** force air flow through the respective heat exchangers **165** in the direction illustrated by air flow arrows AF. In use, the electronic equipment **125** can lack its own fans, such that the fans **180** also force air through the electronic equipment **125**.

(21) With reference to FIGS. **2** and **3**, the rack assembly **100** also includes a plurality of liquid cooling blocks **200** for cooling respective ones of the heat-generating components **130** of the electronic equipment **125** housed within the housing sections **114***a*, **114***b*, **114***c*. Notably, as shown in FIG. **5**, each liquid cooling block **200** is mounted to a corresponding one of the heat-generating components **130** to absorb heat therefrom. The liquid cooling blocks **200** are also commonly referred to as “water blocks” or “cold plates”. In this embodiment, each of the liquid cooling blocks

200 is configured identically and thus a single one of the liquid cooling blocks **200** will be described herein.

(22) With reference to FIG. **5**, in this embodiment, the liquid cooling block **200** has a base portion **202** and a cover portion **204** connected to the base portion **202**. The base portion **202** has a thermal transfer surface **205** on an underside thereof. In use, the thermal transfer surface **205** is placed in thermal contact with a corresponding heat-generating component **130** to absorb heat therefrom. Together, the base portion **202** and the cover portion **204** define a block internal fluid conduit **210** of the liquid cooling block **200**. The block internal fluid conduit **210** forms part of the cooling loop **150** of the rack assembly **100**. The liquid cooling block **200** has an inlet **206** through which cooling fluid flows into the block internal liquid conduit **210** and an outlet **208** through which cooling fluid is discharged out of the block internal liquid conduit **210** (as illustrated by the arrows in FIG. **5**). A more detailed description of an example of the liquid cooling block can be found in European Patent Application 18315027.5, filed Sep. 4, 2018, the entirety of which is incorporated by reference herein. The liquid cooling block **200** could be configured differently in other embodiments.

(23) The cooling loop **150** thermally connects the block internal fluid conduits **210** of the liquid cooling blocks **200** to the exchanger internal fluid conduits **170** of the heat exchangers **165**. In particular, in the cooling loop **150**, heat is transferred from the cooling fluid flowing in the block internal fluid conduits **210** to the cooling fluid flowing in the exchanger internal fluid conduits **170**. More specifically yet, in this embodiment, with reference to FIG. **6**, the cooling loop **150** fluidly connects the block internal fluid conduits **210** to the exchanger internal fluid conduits **170**. As such, the cooling fluid flowing in the cooling loop **150** sequentially flows in the block internal fluid conduits **210** and the exchanger internal fluid conduits **170** in a looping manner. In this embodiment, the cooling fluid flowing through the cooling loop **150** is water. However, it is contemplated that the cooling fluid could be any other suitable type of cooling fluid (e.g., a refrigerant, a two-phase dielectric solution, or others). In other embodiments where the cooling fluid is a two-phase cooling fluid, the cooling blocks **200** act like evaporators, the fluid entering the inlets **206** in liquid phase while exiting the outlets **208** totally or partially in vapour phase, and the heat exchangers **165** act like condensers returning the fluid to a liquid phase before it exits the outlets **184**.

(24) In order to promote the circulation of the cooling fluid within the cooling loop **150**, the cooling loop **150** of the rack assembly **100** includes a pump **220** which, in this embodiment, is disposed downstream of the liquid cooling blocks **200** and upstream of the heat exchangers **165**. It is contemplated that additional pumps **220** may be provided in other embodiments. Moreover, the pump **220** may be disposed at a different location within the cooling loop **150**. For instance, in embodiments where the cooling fluid is a two-phase cooling fluid, the pump **220** is installed downstream of the heat exchangers **165** and upstream the cooling blocks **200** such that the pumps **220** interact with the cooling fluid in its liquid phase. The pump **220** draws heated cooling fluid at a temperature T.sub.L1 from the liquid cooling blocks **200** and pumps it to the heat exchangers **165** where the heat from the cooling fluid is transferred to the air that flows through the heat exchangers **165**. As such, as the cooling fluid is discharged from the heat exchangers **165** within the cooling loop **150**, the cooling fluid has a temperature T.sub.L2 lower than the temperature T.sub.L1. For instance, in a non-limiting example, the temperature T.sub.L1 may be approximately 40° C. while the temperature T.sub.L2 is approximately 35° C.

(25) As such, referring to FIG. **3**, the temperature of the air flowing through the rack assembly **100** gets progressively hotter as the air traverses the rack assembly **100**. Notably, the air as it enters the rack assembly **100** has a temperature T.sub.A1 that, in a non-limiting example, may be approximately 26° C. After the air flows into the rack frame **112** and absorbs heat from the electronic equipment **125** stored within the rack frame **112**, the temperature of the air increases to a temperature T.sub.A2. For instance, in a non-limiting example, the temperature T.sub.A2 may be

approximately 30° C. Finally, as the air is discharged through the heat exchangers **165** having absorbed heat from the cooling fluid flowing in the exchanger internal fluid conduits **170**, the air has a temperature T.sub.A3 that is the highest temperature of the air in its flow through the rack assembly **100**. For instance, in a non-limiting example, the temperature T.sub.A3 may be approximately 37° C. An air conditioning system within the data center may then introduce cool air into the data center to reduce the air temperature therein which has been increased by air discharged by the rack assembly **100**. Therefore, as will be appreciated, the cooling loop **150**, which is independent of any sources of cooling fluid external to the rack assembly **100**, may facilitate the use of the rack assembly **100** in facilities that are not equipped to continuously provide cooled water (or other cooling fluid) to the rack assembly **100**. For instance, this may be useful in colocated data centers (where a company may own only one or a few rack assemblies therein) in which such cooled water provision is not guaranteed but adequate air conditioning is provided.

(26) It is to be understood that the temperature of the cooling fluid as it circulates within the cooling loop **150** can be affected by an operation configuration of the heat exchangers **165**. For instance, in this embodiment, the heat exchangers **165** operate in a counter-current flow configuration, which is generally preferred when the goal is to maximize heat transfer capacity and to lower the temperatures of the cooling fluid circulating in the cooling loop **150**, namely as this configuration allows the temperature T.sub.L2 range between T.sub.A2 and T.sub.A3. In other embodiments, the heat exchangers **165** can operate in a co-current flow configuration, at the expense of higher temperatures of the cooling fluid circulating in the cooling loop **150** as the temperature T.sub.L2 is by principle higher than the temperature T.sub.A3. Therefore, it may be preferable to operate the heat exchangers **165** in co-current flow configuration when the cooling fluid is a two-phase cooling fluid and the heat exchangers **165** act like condensers, as it could ease the choice of the two-phase cooling fluid regarding its boiling point, and ensures vaporization occurs in the cooling blocks **200**.

(27) Furthermore, as will appreciated, the temperature of the cooling fluid as it circulates within the cooling loop **150** will also be affected by the flow rate of the cooling fluid within the cooling loop **150** as well as the flow rate of air through the rack assembly **100**.

(28) As shown in FIG. **6**, the cooling loop **150** may also optionally include a bypass valve **224** that is controlled to selectively allow the cooling fluid in the cooling loop **150** to bypass the exchanger internal fluid conduits **170** of the heat exchangers **165**. Notably, when the bypass valve **224** opens, at least some part of the cooling fluid flowing through the cooling loop **150** flows into the bypass section **223**, thereby avoiding flowing into the heat exchangers **165**. This may be useful for example if the temperature of the ambient air within the data center (i.e., the temperature T.sub.A1) that enters the rack assembly **100** reaches an excessive value that would not result in cooling the cooling fluid in the heat exchangers **165**. The bypass valve **224** may close again once the situation is rectified (i.e., the temperature T.sub.A1 is no longer considered excessive). In this embodiment, the opening and closing of the bypass valve **224** is based on a temperature signal sensed by a temperature sensor **225** (FIG. **6**). Notably, if the temperature sensor **225** senses a temperature above a given pre-determined temperature threshold, a controller in communication with the bypass valve **224** could actuate the bypass valve **224** to its open position. Once the temperature sensed by the temperature sensor **225** reaches a value equal to or less than the pre-determined temperature threshold, the controller actuates the bypass valve **224** back to its closed position.

(29) In addition, with continued reference to FIG. **6**, the cooling loop **150** includes isolating valves **185** disposed near the inlets **182** and the outlets **184** of the heat exchangers **165**. Notably, as can be seen, an isolating valve **185** is disposed upstream of a corresponding inlet **182** while another isolating valve **185** is disposed downstream of the corresponding outlet **184**. The isolating valves **185** may be controlled to operate in reverse directions to the bypass valve **224**. More specifically, when the bypass valve **224** is in its open position to direct cooling fluid flow through the bypass section **223**, the isolating valves **185** are closed to impede flow into the internal fluid conduits **170**.

On the other hand, when the bypass valve **224** is closed, the isolating valves **185** are open to allow flow into the internal fluid conduits **170**. It is contemplated that only the isolating valves **185** at the inlets **182** may be controlled, or that only the isolating valve **185** at the outlets **184** may be controlled in other embodiments.

(30) Furthermore, as shown in FIG. **6**, the cooling loop **150** may also optionally include an internal heat exchanger **375** configured to cool the cooling fluid in the cooling loop **150**. Notably, the internal heat exchanger **375** defines an internal chamber (not shown) that is thermally connected to (but fluidly disconnected from) the cooling loop **150** in order to transfer heat from the cooling fluid in the cooling loop **150** to a substance contained in the internal chamber of the internal heat exchanger **375**. In particular, in this embodiment, the internal heat exchanger **375** contains a phase-change material which absorbs energy at phase transition thereof to cool the cooling fluid in the cooling loop **150**. Thus, the internal heat exchanger **375** may be useful to collaborate with the bypass valve **224** such that, when ambient air is too hot, the internal heat exchanger **375** ensures continued cooling of the cooling fluid in the cooling loop **150**. The internal heat exchanger **375** may be implemented differently in other embodiments.

(31) Referring now to FIGS. **6** to **7**B, the rack assembly **100** also has a fluid compensation system **300** configured to compensate for losses of cooling fluid within the cooling loop **150**. Notably, as shown in FIG. **7**A, the fluid compensation system **300** includes a reservoir **302** that is fluidly connected to the cooling loop **150**, and an actuating device **304** that, in use, forces cooling fluid from the reservoir **302** to the cooling loop **150** to compensate for loss of cooling fluid in the cooling loop **150**. In particular, the reservoir **302** has a reservoir outlet **307** that fluidly connects the reservoir **302** to the cooling loop **150**. The reservoir **302** contains the same type of cooling fluid therein as is contained within the cooling loop **150** (i.e., water in this embodiment). In this embodiment, the actuating device **304** is an actuator **304** having a shaft **317** and an end portion **311** connected to the shaft **317** at an end thereof. The end portion **311** of the actuator **304** exerts pressure on the cooling fluid of the reservoir **302** to force the cooling fluid into the cooling loop **150** when the cooling loop **150** requires compensation for a loss of cooling fluid.

(32) In this embodiment, the reservoir **302** is a flexible reservoir such as a pouch made of plastic, rubber, or a composite material, and is configured to be compressed by the actuator **304** to force the cooling fluid contained by the reservoir **302** into the cooling loop **150**. For instance, in this example, as shown in FIG. **7**A, the reservoir **302** is disposed within a housing **305** together with the end portion **311** of the actuator **304** which is in contact with the reservoir **302** to apply a load thereon to force the cooling fluid into the cooling loop **150**. The implementation of the reservoir **302** as a flexible reservoir may facilitate maintenance operations, namely once the reservoir **302** is empty. Notably, in this embodiment, the reservoir **302** is replaceable with a replacement reservoir (filled with cooling fluid) once the reservoir **302** is empty. For example, the reservoir **302** can be disconnected from the cooling loop **150** and the replacement reservoir is installed in its place and normal operation of the cooling fluid compensation system **300** can resume.

(33) In this embodiment, the reservoir **302** has a volume that is greater than a volume of the cooling loop **150**. In other words, the amount of cooling fluid contained within the reservoir **302** when the reservoir **302** is full is greater than the amount of cooling fluid contained within the entire cooling loop **150**. As such, the reservoir **302** may be used to fill the cooling loop **150** and subsequently to compensate losses of cooling fluid from the cooling loop **150**. That is, at installation, the reservoir **302** in its full state (i.e., filled to its maximum) can be fluidly connected to the cooling loop **150** when the cooling loop **150** is still empty in order to fill the cooling loop **150** with cooling fluid. Since the volume of the reservoir **302** is greater than that of the cooling loop **150**, a certain volume of cooling fluid would remain in the reservoir **302** which can then be used to compensate for losses of cooling fluid in the cooling loop **150**.

(34) It is contemplated that, in some embodiments, the reservoir **302** may not be a flexible reservoir and may instead consist of a volume of the cooling fluid housed in a rigid housing and under

pressure exerted by the actuator **304**.
(35) In this embodiment, the actuator **304** applies a generally constant load on the reservoir **302**. When the cooling loop **150** is full (i.e., has had no leaks), the pressure within the reservoir **302** is the same as the pressure within the cooling loop **150** at a connection point between the reservoir **302** and the cooling loop **150**. However, when there is a leak in the cooling loop **150** (i.e., a loss of cooling fluid therein), the pressure within the reservoir **302** as sustained by the actuator **304** becomes greater than the pressure within the cooling loop **150** and thus some quantity of cooling fluid flows from the reservoir **302** into the cooling loop **150** to compensate for the equivalent quantity of cooling fluid that had leaked from the cooling loop **150**.
(36) In this embodiment, the actuator **304** is an electric actuator that is powered electrically. Notably, in use, a controller is in communication with the actuator **304** to control the load applied by the actuator **304** on the reservoir **302**. For instance, the controller **310** controls the actuator **304** such that the actuator **304** applies a constant load on the reservoir **302**.
(37) In other embodiments, the controller may control the actuator **304** such that the load applied by the actuator **304** on the reservoir **302** (and thus on the cooling fluid therein) is variable. The variable load applied by the actuator **304** may be based on sensor inputs. For instance, in some embodiments, with reference to FIG. **6**, the controller is in communication with a pressure sensor **325**, a flow rate sensor **335** and a temperature sensor **345** disposed within the cooling loop **150** to receive respective sensor signals therefrom indicative of the pressure, the flow rate and the temperature of the cooling fluid in the cooling loop **150**. The controller controls the load applied by the actuator **304** on the reservoir **302** based on one or more of these sensor inputs. In some cases, the variable load applied by the actuator **304** may be based on only one of the sensor signals of the sensors **325**, **335**, **345** in which case the other ones of the sensors **325**, **335**, **345** may be omitted.
(38) The actuator **304** could alternatively be any one of a mechanical actuator, a pneumatic actuator and a hydraulic actuator. For instance, if the actuator **304** is implemented as a mechanical actuator (e.g., a spring-loaded actuator), a controller to control its actuation could be omitted. In other instances, the actuator **304** could be a pump.
(39) Furthermore, in this embodiment, as shown in FIG. **8**, the fluid compensation system **300** also includes a sensor **330** and a controller **310** in communication with the sensor **330**. The sensor **330** is configured to sense an operation parameter associated with the actuator **304** and is operable to transmit a sensor signal to the controller **310** indicative of the sensed operation parameter. More specifically, in this embodiment, the sensor **330** is a position sensor that senses a position of the actuator **304**. For instance, the sensor **330** may sense the position of the end portion **311** of the actuator **304** or of the shaft **311** and transmit this information to the controller **310**. In turn, the controller **310** processes the sensor signal transmitted thereto by the sensor **330** and can execute one or more actions based on the sensor signal. In particular, in this embodiment, based on the sensor signal, the controller **310** determines if the cooling loop **150** has lost cooling fluid and, if an important amount of cooling fluid has been lost from the cooling loop **150**, the controller **310** can notify a user in order to take corrective action (e.g., perform maintenance of the rack assembly **100**).
(40) For instance, in this example, the controller **310** stores in its memory a table including a set of values of the position of the actuator **304** and corresponding volumes of the reservoir **302** associated therewith. For example, the controller **310** may associate a position P**1** of the actuator **304** (illustrated in FIG. **7**A) with the reservoir **302** being full (i.e., 100% of its volume is full). Similarly, the controller **310** may associate a position P**2** of the actuator **304** (illustrated in FIG. **7**B) with the reservoir **302** being half empty (i.e., 50% of its volume is full). The controller **310** may thus use this stored information to determine, based on the sensed position of the actuator **304**, the current volume of the reservoir **302**. Therefore, in use, the controller **310** compares the sensed position of the actuator **304** to a pre-determined threshold position value of the actuator **304** associated with a low volume of the reservoir **302**. If the sensed position of the actuator **304** is

lower than the pre-determined threshold position value of the actuator **304**, the controller **310** transmits an alert signal that is an indication of a leak in the cooling loop **150**.

(41) In this embodiment, the alert signal is transmitted by the controller **310** to an external computer **350** (FIG. **8**) that monitors a status of the cooling loop **150**. For instance, the external computer **350** could be a computer device that is operable by an operator that is responsible for the operation of the rack assembly **100** or the data center in general. Notably, the external computer **350** is a computer within the data center in which the rack assembly **100** is located and is in communication with the controller **310** via a link **322**. The link **322** is a wireless link in this example. In other cases, the link **322** may be a wired link. In some cases, the external computer **350** may even be a computer located remotely from the data center. In other examples, the external computer **350** may be a smartphone or other handheld computer device.

(42) The controller **310** may be responsible for controlling other components associated with the fluid compensation system **300** and the rack assembly **100**. For instance, as shown in FIG. **8**, in this embodiment, the controller **310** is in communication with the actuator **304** to control actuation thereof. As such, in this embodiment, the controller **310** could also be in communication with the sensors **325**, **335**. In other embodiments, a separate controller could control the actuator **304**. Moreover, the controller **310** may also be in communication with the bypass valve **224**, the temperature sensor **225** and the isolating valves **185**.

(43) With reference to FIG. **8**, the controller **310** has a processor unit **312** for carrying out executable code, and a non-transitory memory unit **314** that stores the executable code in a non-transitory medium (not shown) included in the memory unit **314**. The processor unit **312** includes one or more processors for performing processing operations that implement functionality of the controller **310**. The processor unit **312** may be a general-purpose processor or may be a specific-purpose processor comprising one or more preprogrammed hardware or firmware elements (e.g., application-specific integrated circuits (ASICs), electrically erasable programmable read-only memories (EEPROMs), etc.) or other related elements. The non-transitory medium of the memory unit **314** may be a semiconductor memory (e.g., read-only memory (ROM) and/or random-access memory (RAM)), a magnetic storage medium, an optical storage medium, and/or any other suitable type of memory. While the controller **310** is represented as being one control unit in this implementation, it is understood that the controller **310** could comprise separate control units for controlling components separately and that at least some of these control units could communicate with each other.

(44) While the cooling loop **150** has been described as fluidly connecting the liquid cooling blocks **200** with the heat exchangers **165**, it is contemplated that, in other embodiments, the liquid cooling blocks **200** and the heat exchangers **165** may be fluidly independent from one another (i.e., fluidly disconnected) but thermally connected to one another. As such, the cooling loop **150** could include a first portion, that includes the exchanger internal fluid conduits **170** of the heat exchangers **165**, thermally connected to a second portion of the cooling loop **150** that includes the block internal fluid conduits **210** of the liquid cooling blocks **200**. For example, a plate heat exchanger could be implemented to thermally connect the first and second portions of the cooling loop. Each of the portions of the cooling loop **150** has its own pump **220**. In such embodiments, the reservoir **302** could be fluidly connected to one or both of the first and second portions of the cooling loop **150**. Alternatively, an additional reservoir could be provided in a similar manner so that each of the first and second portions of the cooling loop **150** is fluidly connected to its own reservoir **302** to compensate for losses of cooling fluid in that portion of the cooling loop **150**.

(45) In some embodiments, the actuating device **304** may not necessarily be an actuator. For instance, with reference to FIG. **9**, in an alternative embodiment, the fluid compensation system **300** has an actuating device **304′** that forces cooling fluid from the reservoir **302** to the cooling loop **150** to compensate for loss of cooling fluid in the cooling loop **150**. In particular, the actuating device **304′** is a container **315** defining an internal space **309**, and the reservoir **302** is disposed in

the internal space **309**, enclosed by the container **315**. In this alternative embodiment, the internal space **309** of the container **315** is filled with pressurized air such that the pressurized air surrounds the reservoir **302** within the container **315**. In this case, the actuating device **304′** automatically forces cooling fluid from the reservoir **302** into the cooling loop **150** when there is a loss of cooling fluid within the cooling loop **150**. Notably, when there is a loss of cooling fluid within the cooling loop **150** (e.g., a leak), the pressure within the cooling loop **150** decreases such that the pressure of the cooling fluid within the reservoir **302**, which is compressed by a load applied thereon by the pressurized air within the container **315**, becomes greater than that of the cooling loop **150**. This forces the cooling fluid within the reservoir **302** to be discharged via the reservoir outlet **307** to the cooling loop **150**, thereby compensating for the loss of cooling fluid in the cooling loop **150**. In this example, the container **305** is pre-filled with pressurize air via an inlet **313** thereof.
(46) In an alternative configuration, as shown in FIG. **9**, the container **305** may not be pre-filled and may instead be fluidly connected, via its inlet **313**, to a compressor **333** which continuously fills the container **305** with compressed air.
(47) As will be understood from the above, the fluid compensation system **300** allows for quick and easy detection of losses of cooling fluid in the cooling loop **150** and for compensation of these losses to ensure continued efficiency of the cooling of the electronic equipment **125** housed by the rack assembly **100**. Moreover, the fluid compensation system **300** can autonomously alert an operator to an excessive loss of cooling fluid in the cooling loop **150** in order for the operator to take corrective action, such as maintenance of the rack assembly **100** (e.g., fixing leaks) and/or replacement of the reservoir **302**.
(48) It is contemplated that the rack assembly **100** and a method for controlling cooling fluid in the cooling loop **150** thereof in accordance with some non-limiting implementations of the present technology can be represented as presented in the following numbered clauses.
(49) Modifications and improvements to the above-described implementations of the present technology may become apparent to those skilled in the art. The foregoing description is intended to be exemplary rather than limiting. The scope of the present technology is therefore intended to be limited solely by the scope of the appended claims.

Claims

1. A rack assembly for a data center, comprising: a rack frame defining at least one housing section and configured to house electronic equipment including at least one heat-generating component; a heat exchanger connected to the rack frame, the heat exchanger defining a first internal fluid conduit; at least one liquid cooling block connected to the at least one heat-generating component, each of the at least one liquid cooling block defining a second internal fluid conduit, the second internal fluid conduit being in thermal connection with the first internal fluid conduit of the heat exchanger; a cooling loop for circulating cooling fluid therein, the cooling loop comprising the first and second internal fluid conduits, the cooling loop being configured to transfer heat from the second internal fluid conduit to the first internal fluid conduit; and a fluid compensation system comprising: a reservoir fluidly connected to the cooling loop, the reservoir being configured to contain cooling fluid therein; an actuator configured to force cooling fluid from the reservoir to the cooling loop to compensate for loss of cooling fluid in the cooling loop; a position sensor configured to sense a position of the actuator; and a controller configured to receive the position of the actuator from the position sensor and transmit, based on the position of the actuator, an alert signal indicating a leak in the cooling loop.
2. The rack assembly of claim 1, wherein the cooling loop fluidly connects the first internal fluid conduit to the second internal fluid conduit.
3. The rack assembly of claim 1, wherein the heat exchanger comprises: a cooling coil defining the first internal fluid conduit; and a plurality of fins connected to the cooling coil, the plurality of fins

being positioned to allow air flow therebetween.

4. The rack assembly of claim 1, wherein: the actuator is one of a mechanical actuator, an electric actuator, a pneumatic actuator and a hydraulic actuator.

5. The rack assembly of claim 4, wherein the controller is in communication with the actuator to control actuation thereof, and wherein the controller is configured to control a load applied by the actuator on the cooling fluid in the reservoir.

6. The rack assembly of claim 5, wherein the controller controls the actuator such that the load applied by the actuator on the cooling fluid in the reservoir is constant.

7. The rack assembly of claim 5, wherein: the fluid compensation system further comprises at least one of a flow rate sensor, a pressure sensor and a temperature sensor configured to sense, respectively, a flow rate, a pressure, and a temperature of the cooling fluid in the cooling loop; the controller is in communication with the at least one of the flow rate sensor, the pressure sensor and the temperature sensor to receive a sensor signal therefrom; and the controller controls the load applied by the actuator on the cooling fluid in the reservoir based on the sensor signal.

8. The rack assembly of claim 1, wherein the alert signal is configured to be transmitted to a computer that monitors a status of the cooling loop of the rack assembly.

9. The rack assembly of claim 1, wherein a volume of the reservoir is greater than a volume of the cooling loop.

10. The rack assembly of claim 1, wherein: the reservoir is a flexible reservoir; and the actuator is configured to apply a load on the flexible reservoir in order to force cooling fluid from the flexible reservoir to the cooling loop.

11. The rack assembly of claim 1, wherein the reservoir is replaceable with a replacement reservoir when the reservoir is empty.

12. The rack assembly of claim 1, wherein the cooling loop comprises a bypass valve that is controllable to selectively allow cooling fluid in the cooling loop to bypass the first internal fluid conduit of the heat exchanger.

13. The rack assembly of claim 1, wherein the cooling loop is independent from any sources of cooling fluid external to the rack assembly.

14. A method for controlling cooling fluid in a cooling loop of a rack assembly for a data center, the rack assembly comprising a heat exchanger connected to a rack frame of the rack assembly and at least one liquid cooling block, the heat exchanger comprising a first internal fluid conduit, the at least one liquid cooling block being connected to at least one heat-generating component housed within the rack frame, each of the at least one liquid cooling block defining a second internal fluid conduit, the cooling loop comprising the first internal fluid conduit of the heat exchanger and the second internal fluid conduit of each of the at least one liquid cooling block, the method comprising: fluidly connecting a reservoir to the cooling loop, the reservoir containing cooling fluid therein; forcing, by an actuator, cooling fluid from the reservoir to the cooling loop to compensate for loss of cooling fluid in the cooling loop; determining, by a position sensor, a position of the actuator; receiving, by a controller, the position of the actuator; and transmitting, based on the position of the actuator, an alert signal indicating a leak in the cooling loop.

15. The method of claim 14, wherein transmitting the alert signal further comprises: comparing the position of the actuator to a pre-determined threshold value; and based on said comparing, transmitting the alert signal indicating the leak in the cooling loop.

16. The method of claim 14, further comprising controlling a load applied on the reservoir by the actuator such that the load is constant.

17. The method of claim 14, further comprising: in response to the reservoir being empty, replacing the reservoir with a replacement reservoir that contains cooling fluid.

18. The method of claim 14, wherein the cooling loop is independent from any sources of cooling fluid external to the rack assembly.