US 20250267820A1

(19) United States
(12) Patent Application Publication
WELTSCH et al.

(10) Pub. No.: US 2025/0267820 A1
(43) Pub. Date: Aug. 21, 2025

(54) DEVICE WITH INTEGRATED LIQUID COOLING SYSTEM

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(21) Appl. No.: **19/184,039**

(22) Filed: **Apr. 21, 2025**

Related U.S. Application Data

(63) Continuation-in-part of application No. 17/534,645, filed on Nov. 24, 2021, now Pat. No. 12,284,783.

Publication Classification

(51) **Int. Cl.**
H05K 7/20 (2006.01)

(52) **U.S. Cl.**
CPC ***H05K 7/20263*** (2013.01); ***H05K 7/20154*** (2013.01); ***H05K 7/20272*** (2013.01)

(57) **ABSTRACT**

A device may include: a frame having an interior; an electronic component; a heat conducting body in thermal contact with the electronic component; a conduit containing a liquid coolant, the conduit being coupled to the heat conducting body to deliver the liquid coolant to and from the heat conducting body; and a pump positioned within the interior of the frame, the pump being removably insertable into the interior of the frame and being removably couplable to the conduit to circulate the liquid coolant through the conduit.

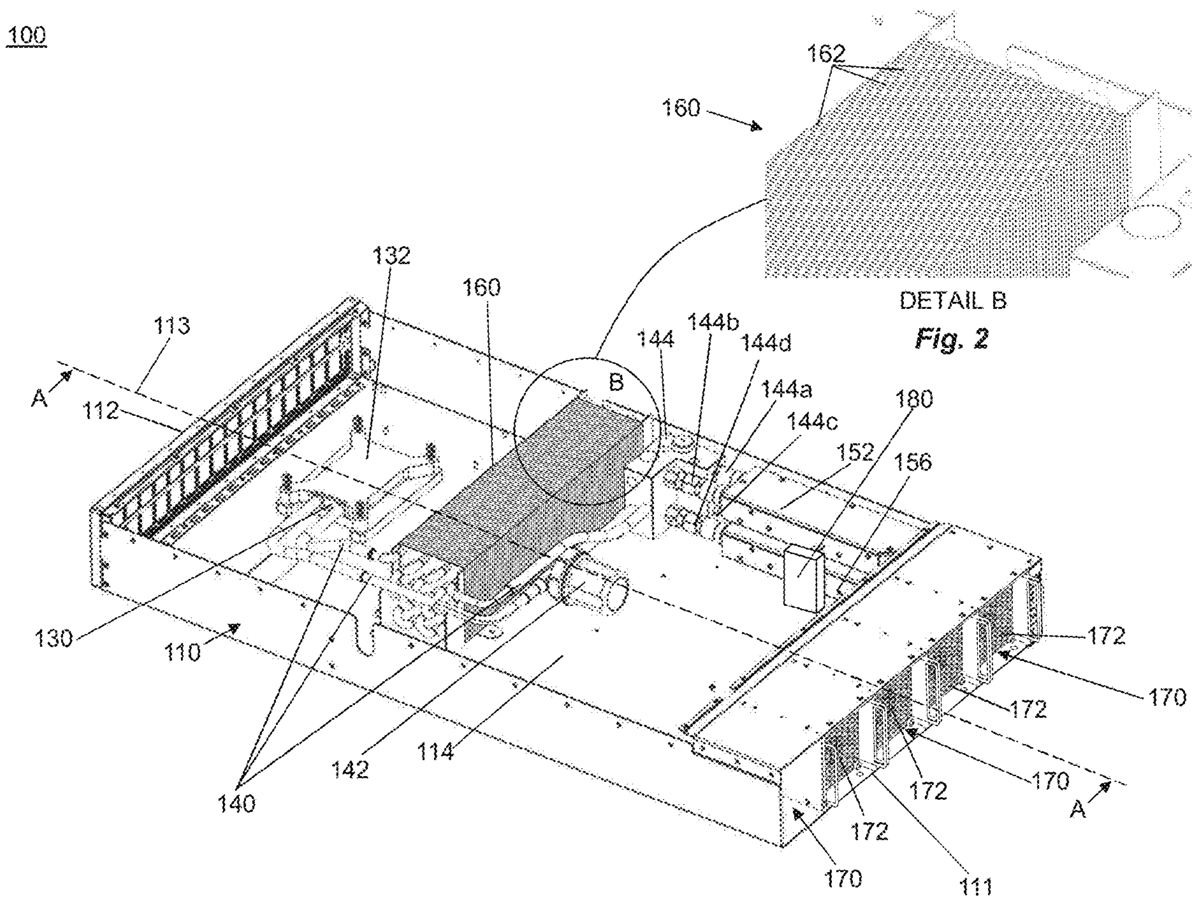
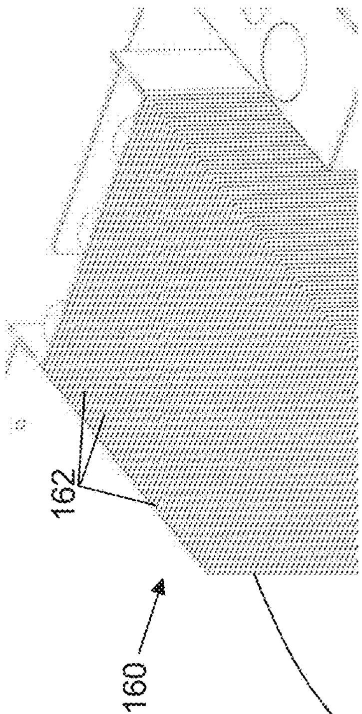


Fig. 2

100



DETAIL B

Fig. 2

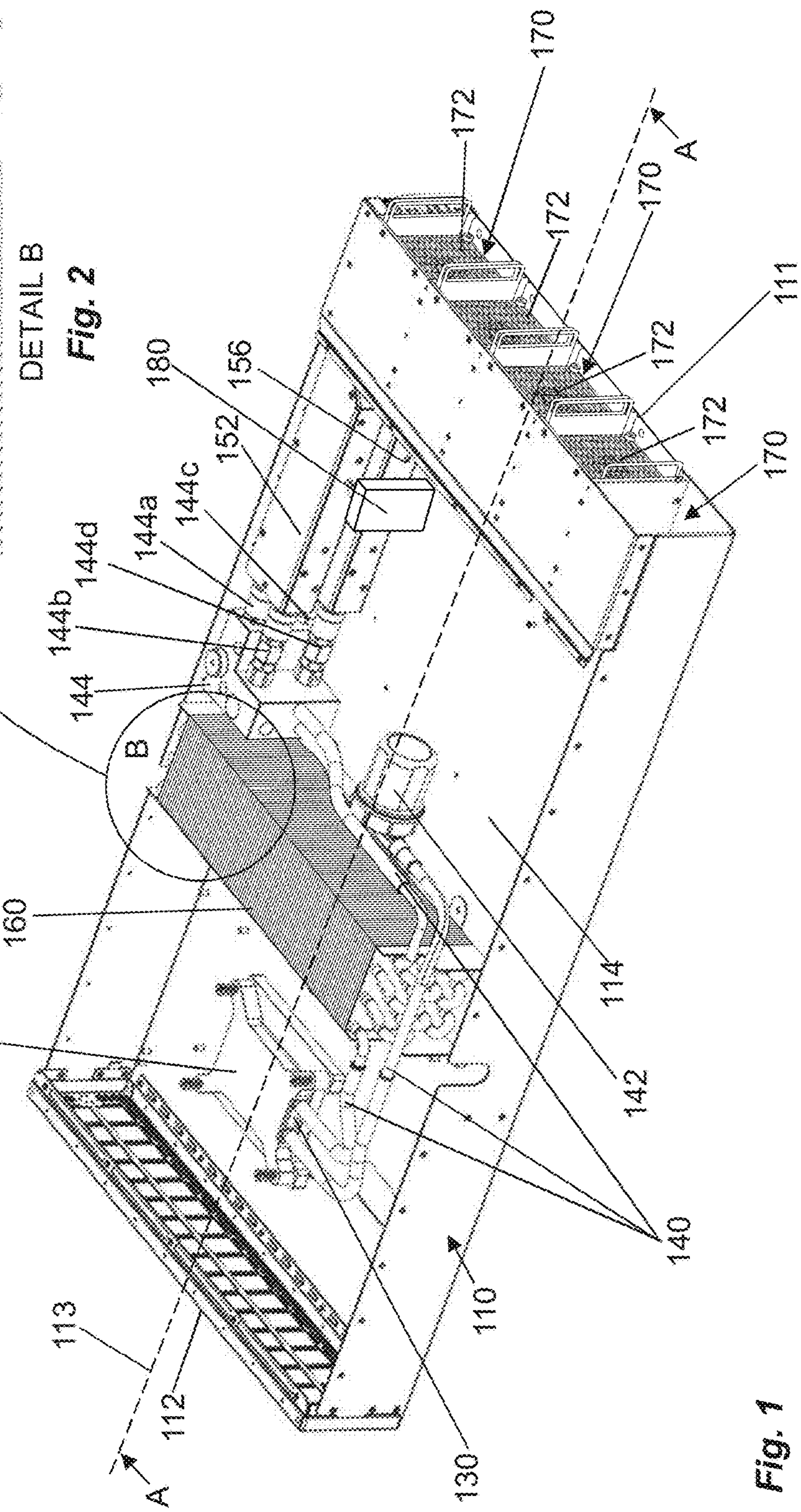


Fig. 1

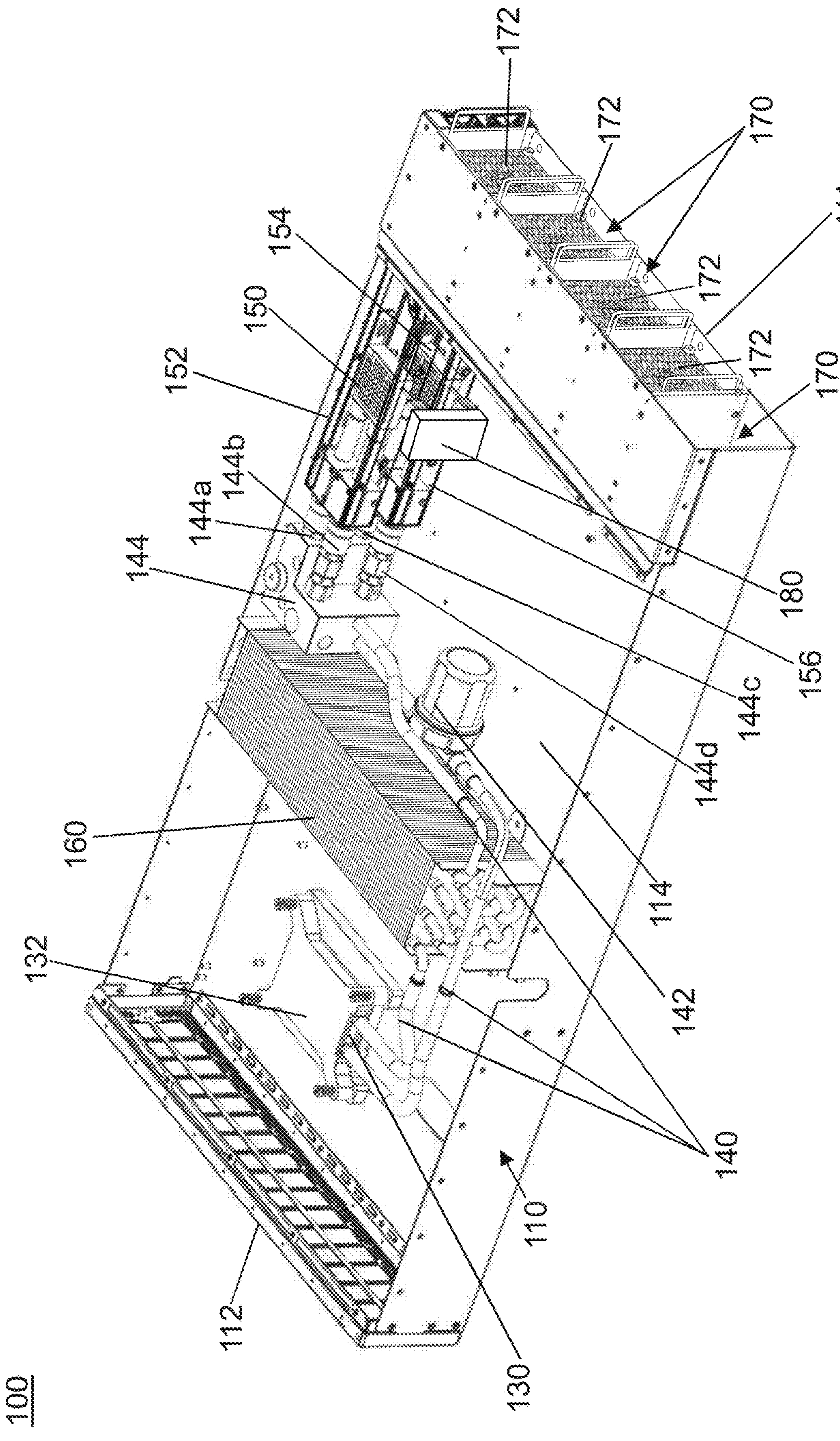
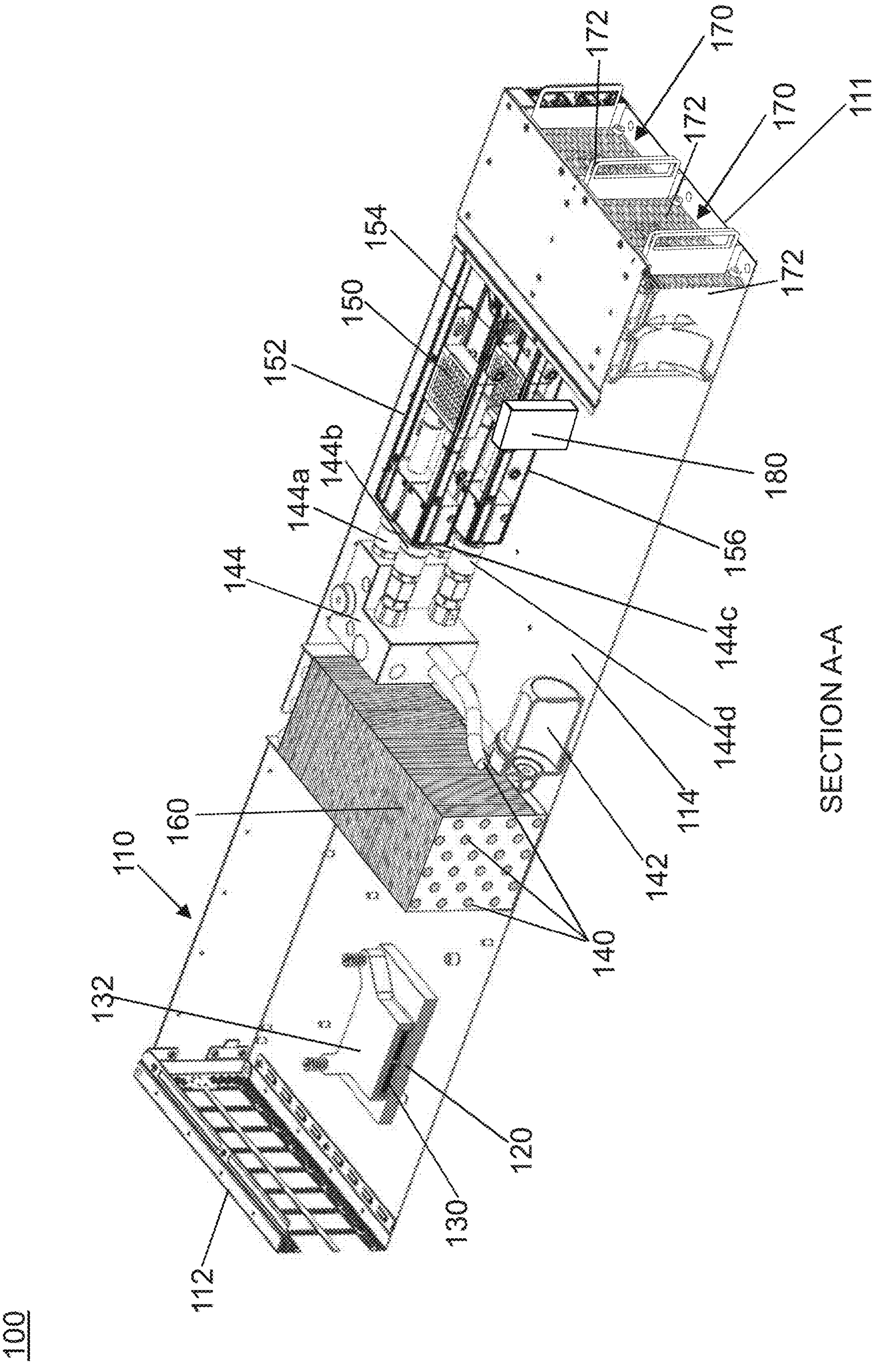
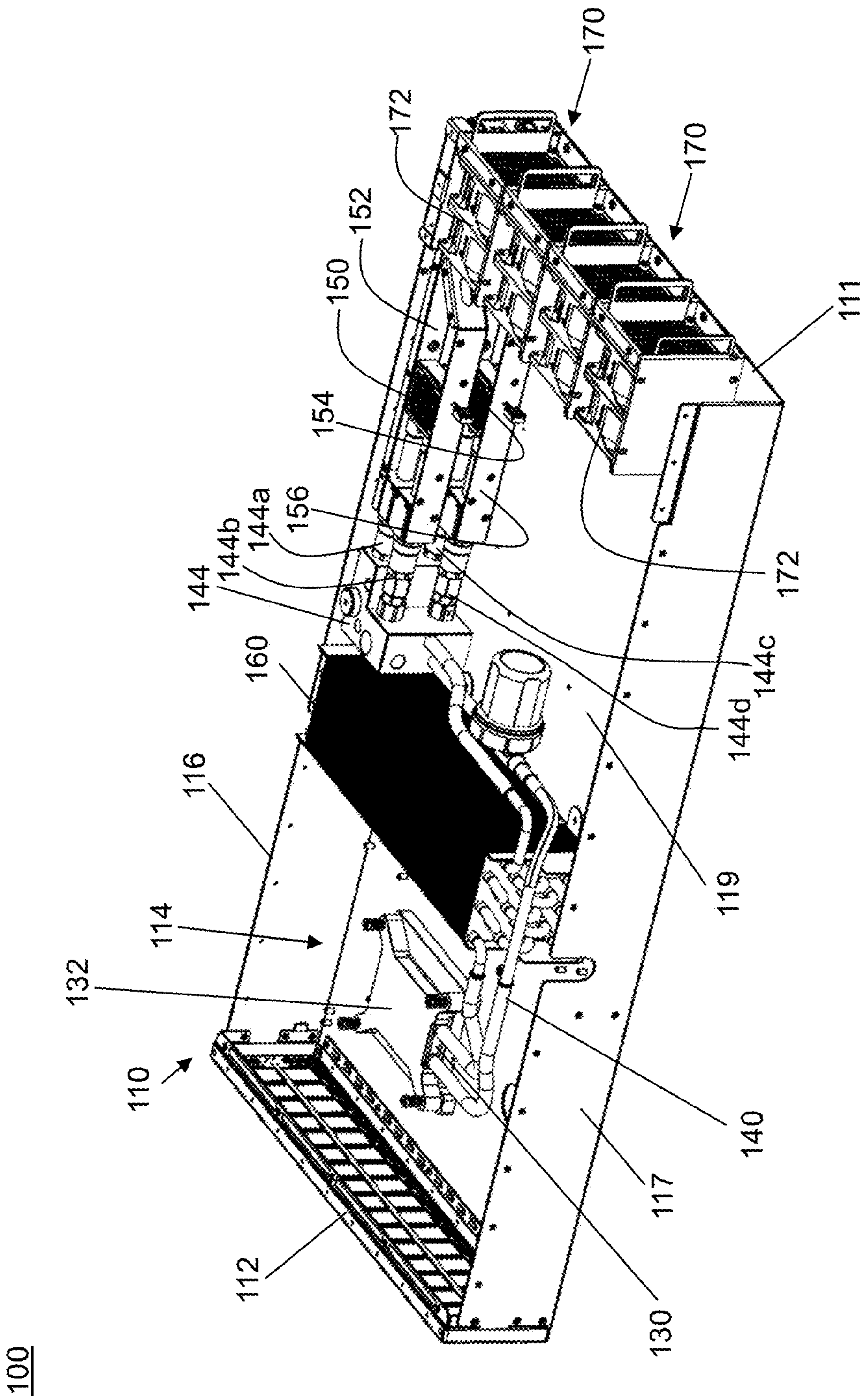

100
112
130
110
140
132
160
142
114
144d
144
144a
144b
144c
156
180
152
150
154
170
172
111

Fig. 3



SECTION A-A

Fig. 4


170
172
170
152
150
111
154
156
144a
144b
144
172
144c
160
144d
116
119
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140
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112
130
100

Fig. 5A

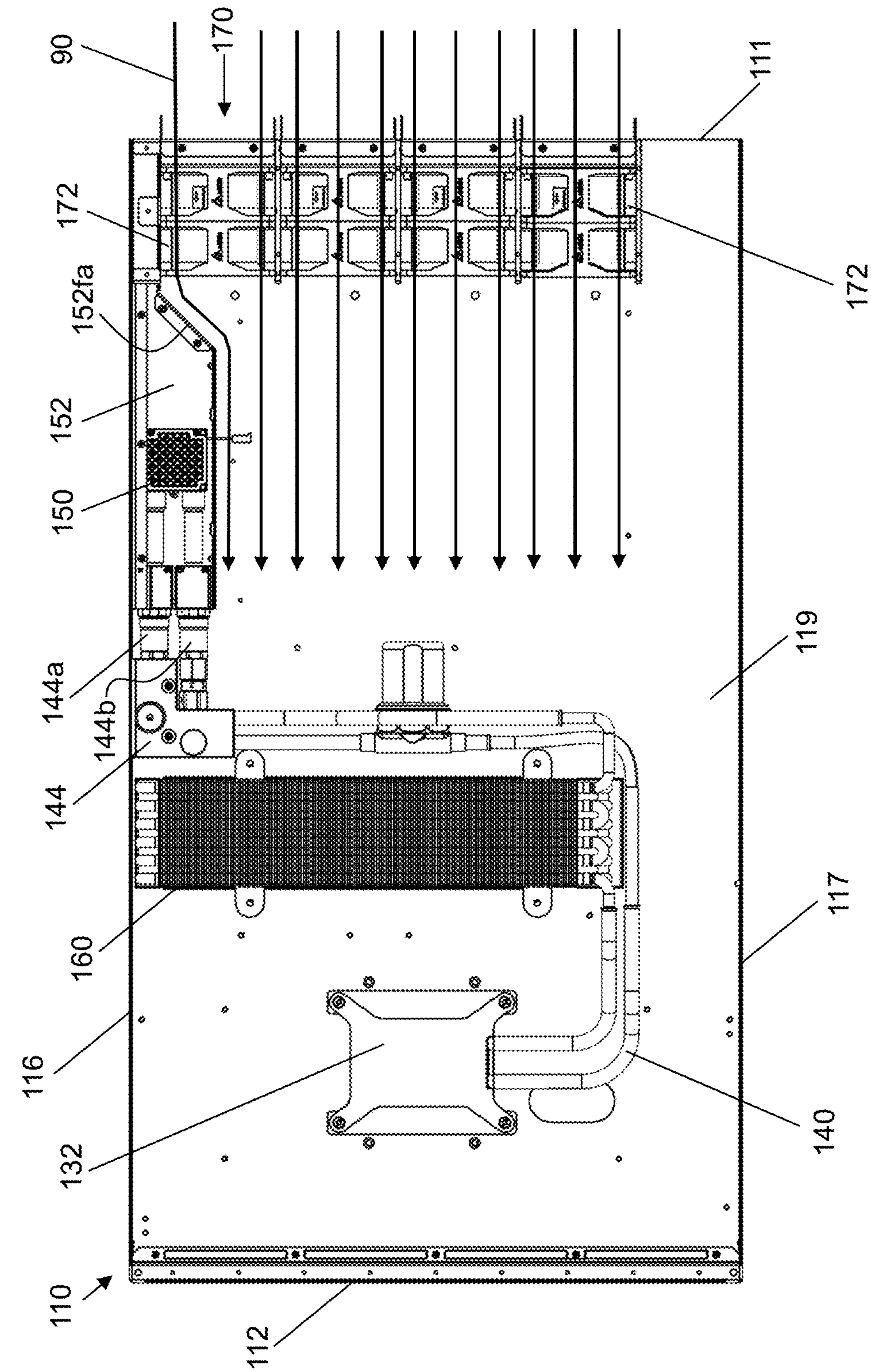
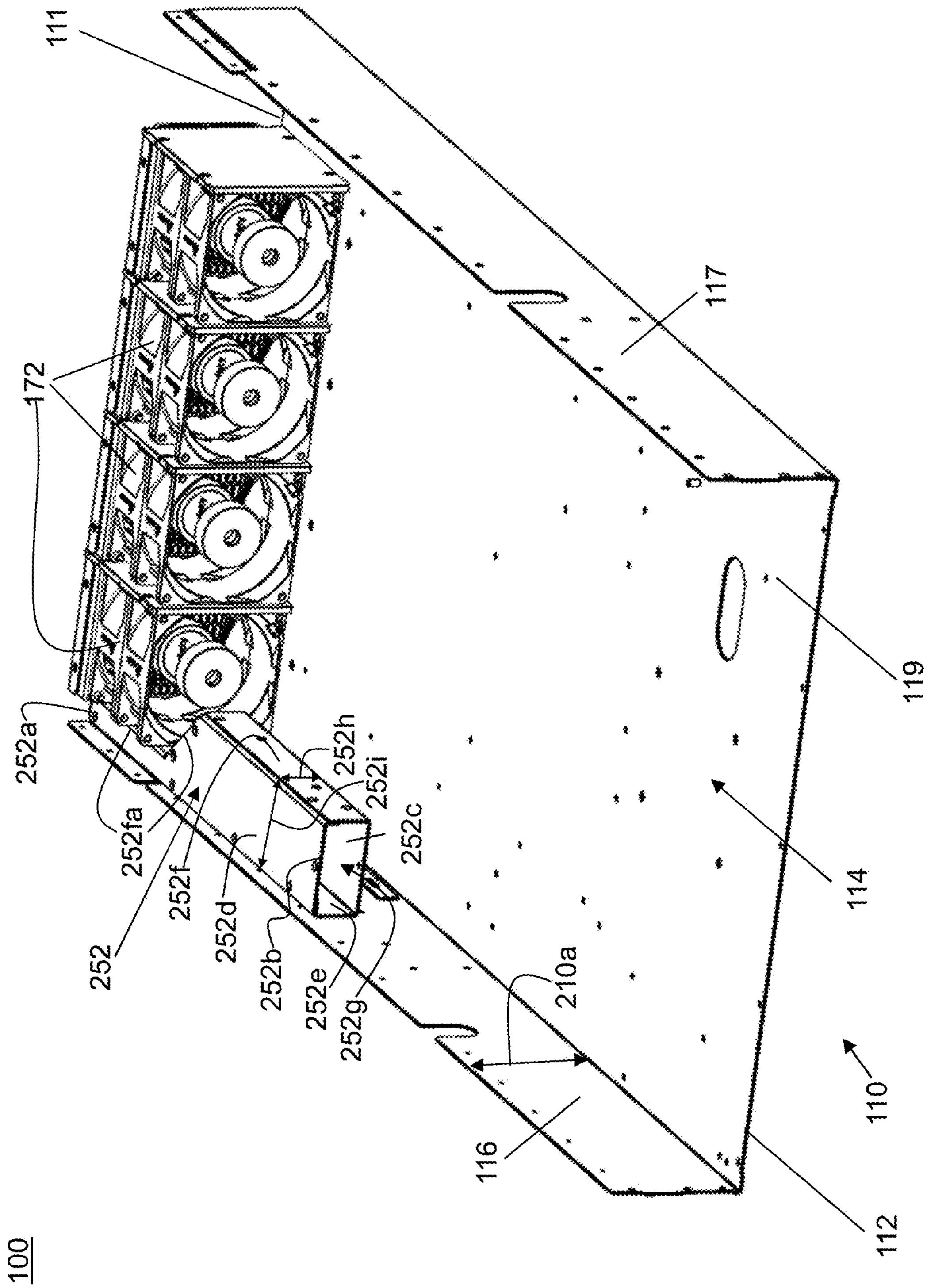

90
170
111
172
172
152fa
152
150
144a
144b
144
119
160
117
116
132
140
110
112

Fig. 5B


100
111
172
117
119
114
110
112
116
210a
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252a
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252c
252d
252e
252f
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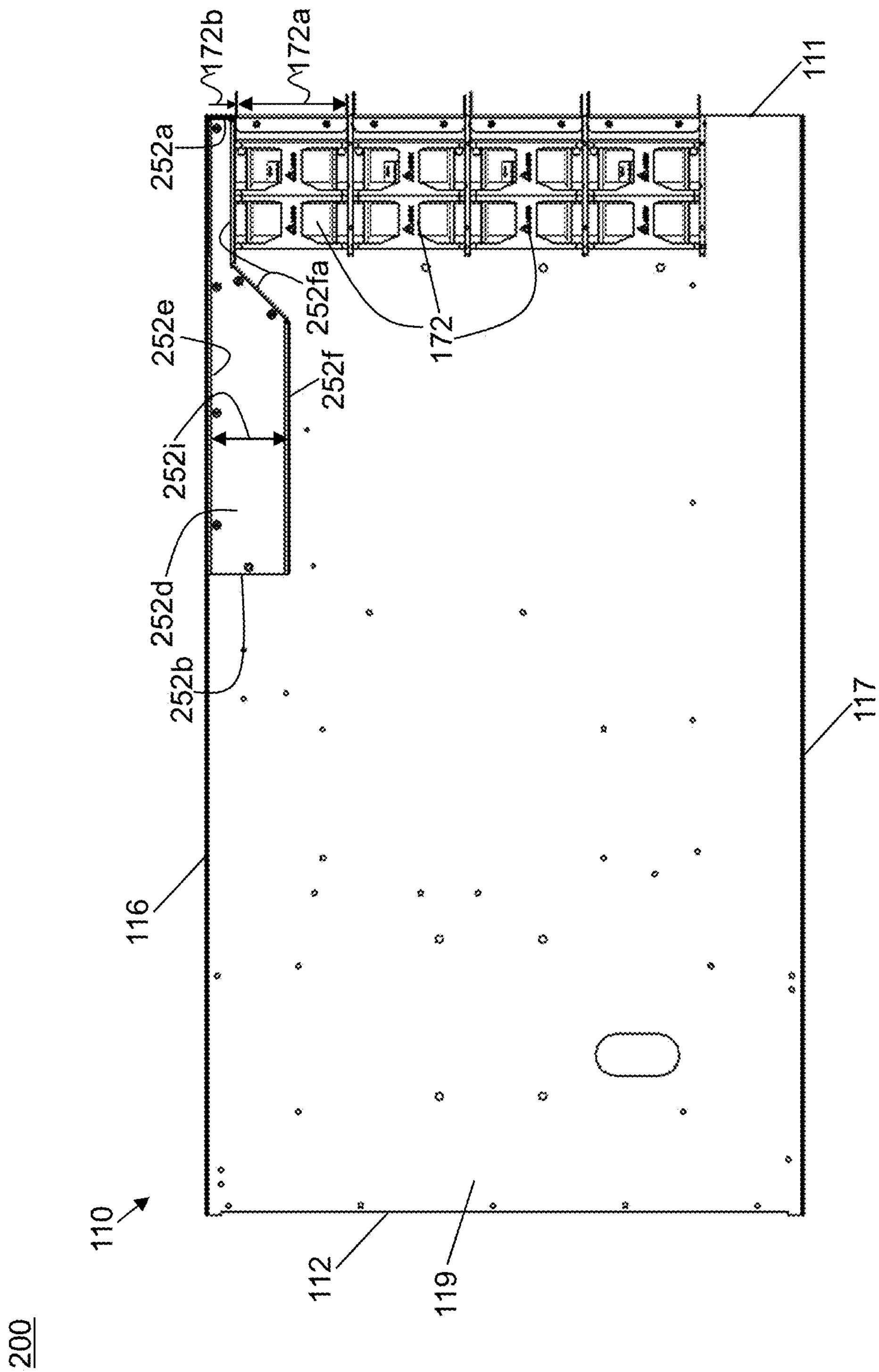
252h
252i

Fig. 6A


172b
172a
111
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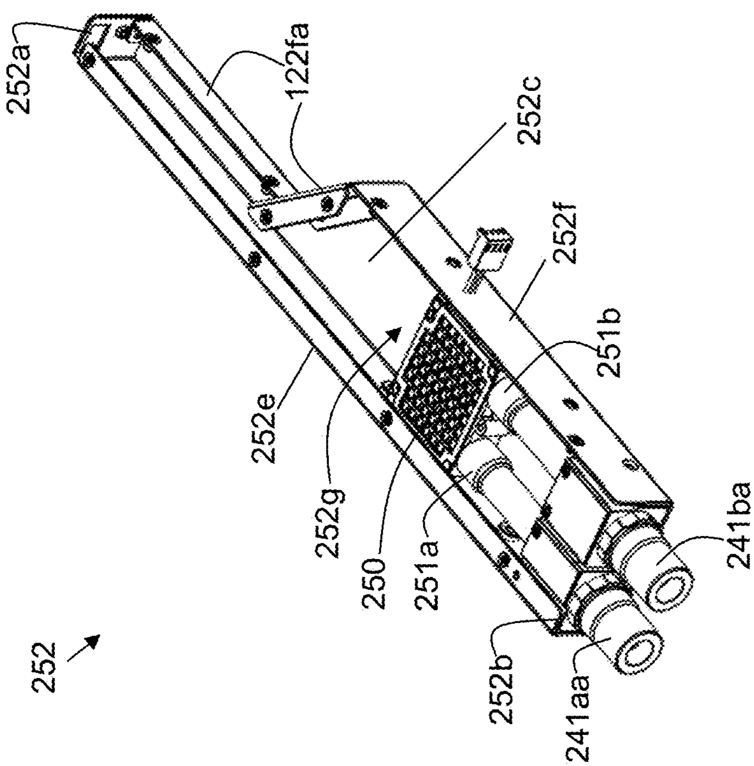
252fa
172
252e
252f
252i
252d
252b
116
117
110
112
119
200

Fig. 6B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251b
252e
252g
250
251a
241ba
252b
241aa

Fig. 7A

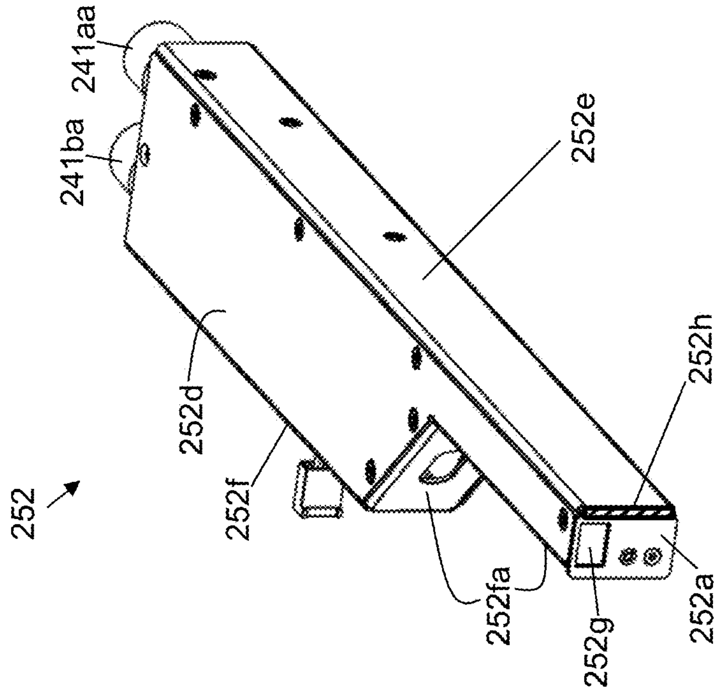
241aa
241ba
252e
252d
252f
252
252h
252fa
252g
252a

Fig. 7B

DEVICE WITH INTEGRATED LIQUID COOLING SYSTEM

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application is a continuation-in-part of U.S. patent application Ser. No. 17/534,645 filed Nov. 24, 2021, which is hereby incorporated by reference in its entirety.

BACKGROUND

[0002] Typically, network devices in network systems, such as for example network switch devices, include heat producing electronic components that may require cooling. Cooling of heat producing electronic components may be done using air and/or liquid. Air cooling of heat producing electronic components is typically less effective than liquid cooling thereof. For example, air cooling systems typically have smaller maximal power and smaller power density as compared to liquid cooling systems. Liquid cooling of heat producing electronic components typically requires dedicated infrastructure at the network system facility to distribute cooling liquid between network system devices and to cool the cooling liquid. The infrastructure may, for example, include pumps, valves, controllers, cooling towers and other components known in the art. Some network system facilities have no such dedicated infrastructure to support liquid cooling of heat producing electronic components of the network devices.

GENERAL DESCRIPTION

[0003] Some embodiments may provide a device or other component including: a frame having an interior; an electronic component; a heat conducting body in thermal contact with the electronic component; a conduit containing a liquid coolant, the conduit being coupled to the heat conducting body to deliver the liquid coolant to and from the heat conducting body; and a pump positioned within the interior of the frame, the pump being removably insertable into the interior of the frame and being removably couplable to the conduit to circulate the liquid coolant through the conduit.

[0004] In some embodiments, the device may include a heat sink positioned within the interior of the frame, wherein at least a portion of the conduit passes through the heat sink.

[0005] In some embodiments, the heat sink may include a plurality of fins that are parallel to an axis extending between a first end and a second end of the frame.

[0006] In some embodiments, the device may include one or more fan receptacles at a first end of the frame, each of the fan receptacles being configured to removably receive a fan.

[0007] In some embodiments, the pump is removably insertable into the interior of the frame through one of the fan receptacles.

[0008] In some embodiments, the device may include one or more fans each being removably received within one of the fan receptacles.

[0009] In some embodiments, the device may include a coupler having a first dripless blind-mate connector and a second dripless blind-mate connector to removably couple the pump to the conduit.

[0010] In some embodiments, the device may include a second pump positioned within the interior of the frame, the second pump being coupled to the conduit to circulate the liquid coolant through the conduit.

[0011] In some embodiments, the device may include a coupler to couple in parallel the pump and the second pump to the conduit.

[0012] In some embodiments, the coupler may include: a first dripless blind-mate connector and a second dripless blind-mate connector to removably couple the pump to the conduit, and a third dripless blind-mate connector and a fourth dripless blind-mate connector to removably couple the second pump to the conduit.

[0013] In some embodiments, the device may include a controller to control the pump and the second pump to maintain a desired flow rate of the liquid coolant through the conduit.

[0014] In some embodiments, the controller is a central processing unit (CPU) of the device.

[0015] In some embodiments, the device is a network switch device.

[0016] Some embodiments may provide a device including: a housing having: a first end, a second end, and an interior; a heat producing component or device; a cooling body in thermal contact with the heat producing component; a conduit containing a coolant, the conduit being coupled to the cooling body to deliver the coolant to and from the cooling body; a heat exchanger positioned within the interior of the housing and having at least a portion of the conduit passing therethrough; one or more fan openings at the first end of the housing; one or more fans each being removably received within one of the fan openings; and a first pump and a second pump positioned within the interior of the housing, the first pump and the second pump being removably insertable into the interior of the housing through one of the fan openings and being removably couplable in parallel to the conduit to circulate the coolant through the conduit.

[0017] In some embodiments, the device may include a coupler including: a first dripless blind-mate connector and a second dripless blind-mate connector to removably couple the first pump to the conduit, and a third dripless blind-mate connector and a fourth dripless blind-mate connector to removably couple the second pump to the conduit.

[0018] In some embodiments, the heat exchanger may include a heat sink.

[0019] In some embodiments, the heat sink may include a plurality of fins that are parallel to an axis extending between the first end and the second end of the housing.

[0020] In some embodiments, the device may include a controller to control the first pump and the second pump to maintain a desired flow rate of the coolant through the conduit.

[0021] In some embodiments, the controller controlling the one or more fans to maintain a desired flow rate of air into the interior of the housing.

[0022] In some embodiments, the controller is a central processing unit (CPU) of the device.

[0023] In some embodiments, the device is a network switch device.

[0024] Some embodiments may provide a device including: a frame; a heat producing device; a cooling body in contact with the heat producing device; a coolant conduit delivering coolant to the cooling body; and a pump positioned within the frame, to circulate the liquid coolant in the conduit.

[0025] In some embodiments, the device is a network switch device.

[0026] Some embodiments may provide a device, which may include: a frame including: a first end, a second end, a bottom surface, a first side wall and a second side wall extending between the first end and the second end, and an interior; a first pump drawer and a second pump drawer positioned within the interior of the frame, the first pump drawer positioned above the second pump drawer, relative to the bottom surface of the frame and along the first side wall of the frame; and a first pump positioned within the first pump drawer and a second pump positioned within the second pump drawer, the first pump and the second pump being removably coupled to a conduit using a plurality of dripless blind-mate connectors; wherein each of the first pump drawer with the first pump and the second pump drawer with the second pump is replaceable without terminating the operation of the device.

[0027] In some embodiments, the device may include a plurality of fans positioned at the first end of the frame between the first side wall and the second side wall, the fans to introduce an airflow into the interior of the frame, wherein the first pump drawer and the second pump drawer are positioned in front of a fan of the plurality of fans.

[0028] In some embodiments, each of the first pump drawer and the second pump drawer tapers towards the first side wall of the frame in a direction towards the first end of the frame including the fans.

[0029] In some embodiments, a fan of the plurality of fans that is positioned adjacent to the first side wall is removably received within a fan receptacle, the fan being replaceable without terminating the operation of the device, and wherein each of the first pump drawer with the first pump and the second pump drawer with the second pump is replaceable through the fan receptacle.

[0030] In some embodiments, a width of the first pump drawer and the second pump drawer is smaller than a width of a fan of the plurality of fans that is positioned adjacent to the first side wall of the frame.

[0031] In some embodiments, the first pump drawer and the second pump drawer partly interfere with the airflow into the interior of the frame provided by a fan of the plurality of fans that is positioned adjacent to the first side wall of the frame.

[0032] In some embodiments, the first pump and the second pump operate simultaneously.

[0033] In some embodiments, the first pump operates, and the second pump a is activated if a rotational speed of the first pump reduces below a predefined threshold.

[0034] In some embodiments, the device may include a controller to control the first pump and the second pump to maintain a desired flow rate of the liquid coolant through the conduit.

[0035] In some embodiments, the controller is a central processing unit of the device.

[0036] In some embodiments, the device may include a heat sink positioned within the interior of the frame, wherein a portion of the conduit passes through the heat sink, the heat sink to cause heat to dissipate from the liquid coolant through the portion of the conduit passing through the heat sink to cool the liquid coolant.

[0037] In some embodiments, the device may include: an electronic component positioned in the interior of the frame, and a cooling body in thermal contact with the electronic component, the cooling body being coupled to the conduit to deliver a liquid coolant to and from the cooling body.

[0038] Some embodiments may provide a device, which may include: a frame including an interior; a cooling body positioned in the interior of the frame; a conduit containing a liquid coolant, the conduit being coupled to the cooling body; and a pump removably coupled to the conduit using a plurality of dripless connectors, the pump being positioned within the interior of the frame along a side wall of the frame, the pump being replaceable without terminating the operation of the device.

[0039] In some embodiments, the device may include a plurality of fans positioned at one end of the frame.

[0040] In some embodiments, a fan of the plurality of fans that is positioned adjacent to the side wall of the frame is removably received within a fan receptacle, the fan being replaceable without terminating the operation of the device.

[0041] In some embodiments, the pump is replaceable through the fan receptacle.

[0042] In some embodiments, a width of the pump is smaller than a width of a fan of the plurality of fans that is positioned adjacent to the side wall of the frame.

[0043] In some embodiments, the pump partly interferes with an airflow into the interior of the frame provided by a fan of the plurality of fans that is positioned adjacent to the side wall of the frame.

[0044] In some embodiments, the pump is supported within a pump drawer, the pump drawer extending along the side wall of the frame.

[0045] In some embodiments, the pump drawer tapers towards the side wall of the frame in a direction towards an end of the frame including a plurality of fans.

BRIEF DESCRIPTION OF THE DRAWINGS

[0046] Various embodiments in accordance with the present disclosure will be described with reference to the drawings, in which:

[0047] FIG. **1** is a three-dimensional (3D) diagram of a network switch device, in accordance with certain embodiments;

[0048] FIG. **2** is a 3D diagram of an enlarged portion of a heat exchanger or heat sink of a network switch device, in accordance with certain embodiments;

[0049] FIG. **3** is a 3D diagram of the network switch device showing transparent view of pump sub-frames, in accordance with certain embodiments;

[0050] FIG. **4** is a 3D diagram of a section view, along line A-A of FIG. **1**, of a network switch device, in accordance with certain embodiments;

[0051] FIGS. **5**A and **5**B are a 3D diagram and a top view, respectively, of a network switch device, in accordance with certain embodiments;

[0052] FIGS. **6**A and **6**B are a 3D diagram and a top view, respectively, of a frame, a pump sub-frame and fans of a network switch device, in accordance with certain embodiments; and

[0053] FIGS. **7**A and **7**B are 3D diagrams of a pump sub-frame supporting a pump, in accordance with certain embodiments.

[0054] It will be appreciated that, for simplicity and clarity of illustration, elements shown in the figures have not necessarily been drawn to scale. For example, the dimensions of some of the elements may be exaggerated relative to other elements for clarity. Further, where considered appropriate, reference numerals may be repeated among the figures to indicate corresponding or analogous elements.

DETAILED DESCRIPTION

[0055] In the following description, various aspects of the present disclosure are described. For purposes of explanation, specific configurations and details are set forth in order to provide a thorough understanding of the present disclosure. However, it will also be apparent to one skilled in the art that the present disclosure can be practiced without the specific details presented herein. Furthermore, well known features can have been omitted or simplified in order not to obscure the present disclosure. With specific reference to the drawings, it is stressed that the particulars shown are by way of example and for purposes of illustrative discussion of the present disclosure only and are presented in the cause of providing what is believed to be the most useful and readily understood description of the principles and conceptual aspects of the disclosure. In this regard, no attempt is made to show structural details of the disclosure in more detail than is necessary for a fundamental understanding of the disclosure, the description taken with the drawings making apparent to those skilled in the art how the several forms of the disclosure can be embodied in practice.

[0056] Before at least one embodiment of the disclosure is explained in detail, it is to be understood that the disclosure is not limited in its application to the details of construction and the arrangement of the components set forth in the following description or illustrated in the drawings. The disclosure is applicable to other embodiments that can be practiced or carried out in various ways as well as to combinations of the disclosed embodiments. Also, it is to be understood that the phraseology and terminology employed herein is for the purpose of description and should not be regarded as limiting.

[0057] Reference is now made to FIG. **1**, which is a three-dimensional (3D) diagram of a network switch device **100**, in accordance with certain embodiments.

[0058] Reference is also made to FIG. **2**, which is a 3D diagram of an enlarged portion of a heat exchanger or heat sink **160** of network switch device **100**, in accordance with certain embodiments.

[0059] Reference is also made to FIG. **3**, which is a 3D diagram of network switch device **100** showing transparent view of pump sub-frames **152**, **156**, in accordance with certain embodiments.

[0060] Reference is also made to FIG. **4**, which is a 3D diagram of a section view, along line A-A of FIG. **1**, of network switch device **100**, in accordance with certain embodiments.

[0061] According to some embodiments, network switch device **100** may include a frame or housing **110**, an electronic component or device or heat producing component **120**, a heat conducting or cooling body **130**, a conduit **140** and a pump **150**. While device **100** is described as a network switch device, other devices may include components as described herein.

[0062] Frame or housing **110** may have a first end **111**, a second end **112** and an interior **114**. Electronic component **120** may be positioned within interior **114** of frame or housing **110**. Electronic component **120** may produce heat. For example, electronic component **120** may be a central processing unit (CPU), graphics processing unit (GPU), networking application-specific integrated circuit (ASIC) or any other heat producing electronic component of network switch device **100**.

[0063] Heat conducting or cooling body **130** may be in thermal contact with electronic component **120**. Heat conducting or cooling body **130** may be made of or may include material such as, for example, copper, aluminum or stainless steel. For example, heat conducting or cooling body **130** may contact, directly or indirectly, electronic component **120** to cause heat to dissipate from electronic component **120** to heat conducting or cooling body **130**. In some embodiments, network switch device **100** may include a heat conducting or cooling body sub-frame **132** to couple heat conducting or cooling body **130** to frame or housing **110** and/or to secure the position of heat conducting or cooling body **130** with respect to electronic component **120**.

[0064] Conduit **140**, e.g., a pipe, tube, possibly in one or more connected sections, may contain a coolant, for example, a liquid coolant. The coolant may, for example, be or include water (e.g., pure water) or water solutions (e.g., glycol-water). Conduit **140** may be coupled to or be in contact with heat conducting or cooling body **130**. Conduit **140** may deliver the coolant to and from heat conducting or cooling body **130**. In some embodiments, conduit **140** includes two or more interconnected conduit portions. In some embodiments, network switch device **100** may include an expansion tank **142** coupled to or in contact with conduit **140**.

[0065] Pump **150** may be positioned within interior **114** of frame or housing **110**. For example, pump **150** may be positioned adjacent (or substantially adjacent) to first end **111** of frame or housing **110**. Pump **150** may be positioned along (e.g. adjacent (or substantially adjacent) to) a side wall of frame or housing **110**. Pump **150** may be coupled to conduit **140** to circulate the coolant through conduit **140** and to deliver the coolant to and from heat conducting or cooling body **130**. Pump **150** may be a centrifugal pump. Pump **150** may be, for example, direct current pump having controllable rotational speed and rotational speed feedback circuity.

[0066] Network switch device **100** may include a heat exchanger or heat sink **160**. Heat exchanger or heat sink **160** may be positioned within interior **114** of frame or housing **110**. In some embodiments, heat exchanger or heat sink **160** may include a plurality of fins **162**. Fins **162** may be parallel (or substantially parallel) to an axis **113** extending between first end **111** and second end **112** of frame or housing **110**. At least a portion of conduit **140** may pass through heat exchanger or heat sink **160**. For example, the portion of conduit **140** passing through heat exchanger or heat sink **160** may be curved such that two or more turns of conduit **140** pass through heat exchanger or heat sink **160**.

[0067] Network switch device **100** may include one or more fan receptacles or openings **170** at first end **111** of frame or housing **110**. Each of fan receptacles or openings **170** may removably receive a fan. Network switch device **100** may include one or more fans **172** each being removably received within one of fan receptacles or openings **170**.

[0068] In some embodiments, pump **150** may be removably inserted into interior **114** of frame or housing **110** through one of fan receptacles or openings **170**. In some embodiments, network switch device **100** may include a coupler **144** to removably couple pump **150** to conduit **140**. Coupler **144** may, for example, include a first dripless blind-mate connector **144*a*** and a second dripless blind-mate connector **144***b* to removably couple pump **150** to conduit **140**. In some embodiments, pump **150** may be positioned within a pump sub-frame or drawer **152**. Pump-sub-frame **152** may be removably coupled (e.g., using bolts or any suitable locking mechanism capable of releasably securing pump sub-frame **152**) to frame or housing **110**. Pump sub-frame **152** may have dimensions that are smaller than dimensions of fan receptacles or openings **170** to removably insert pump sub-frame **152** into interior **114** of frame or housing **110** through one of fan receptacles or openings **170**. Pump sub-frame **152** may ensure proper position of pump **150** with respect to conduit **140** and/or coupler **144**. Pump **150** and/or pump sub-frame **152** may only partly interfere with an airflow into interior **114** of frame or housing **110** provided by fan **172** that is positioned next to the side wall of frame or housing **110**. Pump **150** and/or pump sub-frame **152** may not interfere (or substantially not interfere) with airflow an airflow into interior **114** of frame or housing **110** provided by fans **172** other than fan **172** that is positioned next to the side wall of frame or housing **110**.

[0069] Pump **150** and/or fans **172** may be hot swap units. Hot swapping may refer to replacement or addition of components to a computer system without stopping, shutting down, or rebooting the system. Pump **150** and/or fans **172** may be replaced (e.g., plugged in and/or unplugged) without terminating the operation of network switch device **100**, e.g., without stopping, shutting down, or rebooting network switch device **100**. Pump **150**, pump sub-frame **152** and/or fans **172** may be field replaceable unit (FRUs). Pump **150**, pump sub-frame **152** and/or fans **172** may be replaced (e.g., plugged in and/or unplugged) by a technician or end user without specialized tools or extensive disassembly of network switch device **100**.

[0070] In operation, electronic component **120** of network switch device **100** may produce heat. Pump **150** may circulate the coolant through conduit **140** to deliver the coolant to and from heat conducting or cooling body **130** being in thermal contact with electronic component **120**. Heat being produced by electronic component **120** may dissipate from electronic component **120** through heat conducting or cooling body **130** to the coolant to cool the electronic component **120**. Fans **172** may draw air into interior **114** of frame or housing **110**. The air may flow through heat exchanger or heat sink **160** to cause heat to dissipate from the coolant through the portion of conduit **140** passing through heat exchanger or heat sink **160** to the air to cool the coolant.

[0071] In various embodiments, network switch device **100** may include a controller **180** to control pump **150** and/or fans **172**. In various embodiments, the CPU of network switch device **100** may control pump **150** and/or fans **172**.

[0072] Controller **180** and/or the CPU of network switch device **100** may control rotational speed of pump **150** to generate and maintain a desired flow rate of the coolant through conduit **140**. In some embodiments, pump **150** may include a rotational speed feedback circuity. The rotational speed feedback circuity may output a signal indicative of the actual rotational speed of pump **150**. Controller **180** and/or the CPU of network switch device **100** may receive the signal and send signals to pump **150** to control pump **150** based on the signal from the rotational speed feedback circuity of the respective pump. In some embodiments, network switch device **100** may include a flow rate sensor to measure the flow rate of the coolant through conduit **140** and to generate an output signal related thereto. Controller **180** and/or the CPU of network switch device **100** may control pump **150** further based on the output signal from the flow rate sensor. In various embodiments, controller **180** and/or the CPU of network switch device **100** may issue a notification if the rotational speed of pump **150** or decreases below a predefined threshold.

[0073] Controller **180** and/or the CPU of network switch device **100** may control rotational speed of fans **172** based on a temperature of one or more components of network switch device **100**. For example, electronic component **120** may include a temperature sensor to measure a temperature of electronic component **120** and generate an output signal related thereto. Controller **180** and/or the CPU of network switch device **100** may, for example, detect that the temperature of electronic component **120** increases above a predefined threshold (e.g., based on the output signal from the temperature sensor of electronic component **120**) and control fans **172** to increase their respective rotational speed to increase the flow rate of air through heat exchanger or heat sink **160**. Increased flow rate of air through heat exchanger or heat sink **160** may enhance the cooling of the coolant flowing through conduit **140**, which in turn may enhance the cooling of electronic component **120**. In some embodiments, network switch device **100** may include a coolant temperature sensor to measure the temperature of the coolant in conduit **140** and generate an output signal related thereto. Controller **180** and/or the CPU of network switch device **100** may control the rotational speed of fans **172** further based on the output signal from the coolant temperature sensor to maintain the desired temperature of the coolant.

[0074] In some embodiments, each of fans **172** may include a rotational speed feedback circuity. The rotational speed feedback circuity may output a signal indicative of the actual rotational speed of the respective fan. Controller **180** and/or the CPU of network switch device **100** may receive the signal and output a signal to control fans **172** based on the signals from rotational speed feedback control circuities of fans **172**. For example, if controller **180** and/or the CPU of network switch device **100** detects that the rotational speed of one of fans **172** has smaller value than a preset value thereof, controller **180** and/or the CPU of network switch device **100** may control other fans **172** to increase their respective rotational speeds to maintain the desired flow rate the air through heat exchanger or heat sink **160**. In some embodiments, controller **180** and/or the CPU of network switch device **100** may issue a notification if the rotational speed of one of fans **172** decreases below a predefined threshold.

[0075] In operation, if the rotational speed of pump **150** falls below the predefined threshold, pump **150** may be replaced with new pump without terminating the operation of network switch device **100**. For example, one of fans **172** may be removed from its respective fan receptacle or opening and pump **150** may be decoupled from coupler **144**, pulled external to frame or housing **110** through the respective fan receptacle or opening, and new pump such as pump **150** may be inserted into frame or housing **110** and coupled to coupler **144**. The replacement operations may be performed without terminating the operation of network switch device **100** since pump **150** and fans **172** may be hop swap and/or field replacement units.

[0076] In some embodiments, network switch device **100** may include a second pump **154**. Pump **154** may be provided for redundancy, for example in case of pump failure. Pump **154** may be, for example, direct current pump having controllable rotational speed and rotational speed feedback circuity. Pump **154** may be a centrifugal pump. Pump **154** may be positioned within interior **114** of frame or housing **110**. For example, pump **154** may be positioned adjacent (or substantially adjacent) to first end **111** of frame or housing **110**. Pump **154** may be positioned along (e.g. adjacent (or substantially adjacent) to) the side wall of frame or hosing **110**. Pump **150** may be positioned above pump **150** relative to a bottom surface of frame or housing **110**. Pump **154** may be removably inserted into interior **114** of frame or housing **110** through one of fan receptacles or openings **170**, for example through the same fan receptacle or opening **170** being used to insert and remove pump **150** into/from interior **114** of frame or housing **110**. In some embodiments, coupler **144** may include a third dripless blind-mate connector **144***c* and a fourth dripless blind-mate connector **144***d* to removably couple pump **154** to conduit **140**. For example, coupler **144** may couple in parallel pump **150** and pump **154** to conduit **140**. In some embodiments, pump **154** may be positioned within a second pump sub-frame or drawer **156**. Pump sub-frame **156** may be removably coupled (e.g., using bolts or any suitable locking mechanism capable of releasably securing pump sub-frame **152**) to frame or housing **110**. Pump sub-frame **156** may have dimensions that are smaller than dimensions of fan receptacles or openings **170** to removably insert pump sub-frame **156** into interior **114** of frame or housing **110** through one of fan receptacles or openings **170**. Pump sub-frame **156** may ensure proper position of pump **154** with respect to conduit **140** and/or coupler **144**. Although two pumps **150**, **154** are shown in FIGS. **1-4**, it is to be understood that in various embodiments, network switch device **100** may include a single pump or more than two pumps.

[0077] Pumps **150**, **154** and/or pump sub-frames **152**, **156** may only partly interfere with an airflow into interior **114** of frame or housing **110** provided by fan **172** that is positioned next to the side wall of frame or housing **110**. Pumps **150**, **154** and/or pump sub-frames **152**, **156** may not interfere (or substantially not interfere) with airflow an airflow into interior **114** of frame or housing **110** provided by fans **172** other than fan **172** that is positioned next to the side wall of frame or housing **110**.

[0078] Pump **154** may be a hot swap unit. Pump **154** may be replaced (e.g., plugged in and/or unplugged) without terminating the operation of network switch device **100**, e.g., without stopping, shutting down, or rebooting network switch device **100**. Pump **154** and pump sub-frame **156** may be field replaceable unit (FRU). Pump **154** and pump sub-frame **156** may be replaced (e.g., plugged in and/or unplugged) by a technician or end user without specialized tools or extensive disassembly of network switch device **100**.

[0079] Controller **180** and/or the CPU of network switch device **100** may control rotational speeds of pump **150** and/or pump **154** to generate and maintain the desired flow rate of the coolant through conduit **140**. Controller **180** and/or the CPU of network switch device **100** may control pump **150** and pump **154** based on, for example, output signals from rotational speed feedback circuities of pump **150** and pump **154** and/or based on the output signal from the flow rate sensor (e.g., as described hereinabove).

[0080] In one example, both pump **150** and pump **154** may operate simultaneously during normal operation of network switch device **100**. If controller **180** and/or the CPU of network switch device **100** detects that the rotational speed of one of pump **150** or pump **154** has smaller value than a preset value thereof, controller **180** and/or the CPU of network switch device **100** may control another pump of pump **150** or pump **154** to increase its respective rotational speed to maintain the desired flow rate of the coolant through conduit **140**.

[0081] In another example, only one of pumps **150**, **154** may operate during normal operation of network switch device **100**, while the other pump of pumps **150**, **154** may be turned off. For example, pump **150** may operate and pump **154** may be turned off during normal operation of network switch device **100**. If controller **180** and/or the CPU of network switch device **100** detects that the rotational speed of pump **150** has smaller value than the preset value thereof, controller **180** and/or the CPU of network switch device **100** may turn on pump **154** and control the rotational speed of pump **154** to compensate for the reduced rotational speed of pump **150** to maintain the desired flow rate of the coolant through conduit **140**. In another example, if controller **180** and/or the CPU of network switch device **100** detects that the rotational speed of pump **150** has smaller value than the preset value thereof, controller **180** and/or the CPU of network switch device **100** may turn off pump **150** and turn on pump **154** and control the rotational speed of pump **154** to provide the desired flow rate of the coolant through conduit **140**.

[0082] In various embodiments, controller **180** and/or the CPU of network switch device **100** may issue a notification if the rotational speed of one of pump **150** and/or pump **154** decreases below a predefined threshold. The rotational speed which is below the predefined threshold may be indicative of, for example, a malfunction of the respective pump.

[0083] In operation, if the rotational speed of one of pump **150** or pump **154** reduces below the predefined threshold, the respective pump (e.g., referred herein below as "faulty pump") may be replaced with new pump without terminating the operation of network switch device **100**. For example, one of fans **172** may be removed from its respective fan receptacle or opening and the faulty pump may be decoupled from coupler **144** and pulled external to frame or housing **110** through the respective fan receptacle or opening. Once one of fans **172** is removed, controller **180** and/or the CPU of network switch device **100** may increase rotational speeds of remaining fans **172** to maintain the desired flow rate of air through heat exchanger or heat sink **160**. Once the faulty pump is decoupled from conduit **140**/coupler **144**, dripless blind-mate connectors to which the faulty pump was coupled may prevent the coolant from leaking external to conduit **140**. Once the faulty pump is decoupled from conduit **140**/coupler **144**, controller **180** and/or the CPU of network switch device **100** may increase the rotational speed of the remaining pump to maintain the desired flow rate of the coolant through conduit **140**. New pump may be inserted into interior **114** of frame or housing **110** through the respective fan receptacle or opening and coupled to conduit **140**/coupler **144** by the respective dripless blind-mate connectors. The fan that has been removed may be inserted back to the respective fan receptacle or opening. Controller **180** and/or the CPU of network switch device **100** may control the pumps and the fans in a normal mode of operation, e.g., as described hereinabove.

[0084] Components of network switch device **100** such as cooling body **130**, conduit **140**, pump **150** and/or pump **154** may provide or form a closed-loop liquid cooling subsystem. Hot swap pump **150** and/or hot swap pump **154** may circulate the liquid coolant through the closed-loop cooling subsystem without loss of the liquid coolant during the operation, while heat sink **160** may dissipate the heat from a portion of conduit **140** passing through heat sink **160** to air introduced into interior **114** of frame or housing **110** by fans **172**.

[0085] Reference is made to FIGS. **5**A and **5**B, which are a 3D diagram and a top view, respectively, of network switch device **100**, according to some embodiments.

[0086] Frame **110** of network switch device **100** may include a first side wall **116** and a second side wall **117**. First side wall **116** and second side wall **117** may be opposite to each other. Side walls **116**, **117** may extend between first end **111** and second end **112** of frame **110**. Frame **110** may include a bottom surface **119**. Frame **110** may include a top surface or cover (not shown in FIGS. **5**A and **5**B for simplicity) to cover interior **114** of frame **110**.

[0087] Pump sub-frame or drawer **152** supporting pump **150** may be positioned along first side wall **116** of frame **110**. Pump sub-frame or drawer **156** supporting pump **154** may be positioned along first side wall **116** of frame **110**. Pump sub-frame **152** may be positioned above pump sub-frame **156** relative to bottom surface **119** of frame **110**. Pump sub-frames **152** and **156** may be positioned adjacent to first end **111** of frame **110** which includes fans **172**. Pump sub-frames **152** and **156** may be positioned in front of fan **172** that is adjacent to first side wall **116** of frame **110**. Top covers of pump sub-frames **152** and **156** are not shown in FIGS. **5**A and **5**B for simplicity. Positioning pump sub-frame **152** above pump sub-frame **154** relative to bottom surface **119** and along first side wall **116** of frame **110** may minimize the interference of pump sub-frames **152**, **156** with an airflow **90** into interior **114** of frame **110** provided by fans **172** of network switch device **100**. At most, pump sub-frames **152**, **156** may only partly interfere with the airflow **90** provided by fan **172** positioned next to first side wall **116** of frame **110** (e.g. as shown in FIG. **5**B). Pump sub-frames **152**, **156** may not interfere (or substantially not interfere) with airflow **90** provided by fans **172** other than fan **172** positioned next to first wall **116** of frame **110**. Each of pump sub-frames **152**, **156** may narrow or taper towards first side wall **116** of frame **110** in a direction towards first end **111** of frame **111** (e.g. as shown in FIG. **5**B). Tapered portions of pump sub-frames **152**, **156** (e.g. such as tapered portion **252***fa* described hereinbelow) may guide airflow **90** provided by fan **172** positioned next to first side wall **116** smoothly into interior **114** of frame **110** (e.g. as shown in FIG. **5**B).

[0088] Reference is made to FIGS. **6**A and **6**B, which are a 3D diagram and a top view, respectively, of frame **110**, a pump sub-frame or drawer **252** and fans **172** of a network switch device **100**, according to some embodiments.

[0089] For simplicity and clarity of illustrations, FIGS. **6**A and **6**B show only frame **110**, pump sub-frame **252** (e.g. such as pump sub-frames **152**, **156** described hereinabove) and fans **172** of network switch device **100**. While one pump sub-frame **252** is shown, in some embodiments, network switch device **100** may include more than one pump sub-frame **252**, for example two pump sub-frames such as pump sub-frames **152**, **156** described hereinabove.

[0090] Pump sub-frame or drawer **252** may include a first end **252***a*, a second end **252***b*, a bottom surface **252***c*, a top surface or cover **252***d*, a first side wall **252***e*, a second side wall **252***f* and an interior **252***g*. When positioned within an interior **114** of frame **110**, first side wall **252***e* of pump sub-frame **252** may face or contact first side wall **116** of frame **110**. Second side wall **252***f* of pump sub-frame **252** may include a tapered portion **252***fa* that tapers towards first side wall **252***e* of pump sub-frame **252** in a direction towards first end **252***a* of pump sub-frame **252**.

[0091] Pump sub-frame **252** may be flat (or substantially flat). A ratio of a height **252***h* (measured as a distance between bottom and top surfaces **252***c*, **252***d*) to a width **252***i* (measured as a distance between first and second side walls **252***e*, **252***f*) of pump sub-frame **252** may range from 0.4 to 0.5; other ranges may be used. In one example, pump sub-frame **252** may have height **252***h* of 28 mm and width **252***i* of 57.6 mm, providing height **252***h* to width **252***i* ratio of 0.486; other dimensions may be used.

[0092] A ratio of height **252***h* of pump sub-frame **252** to a height **110***a* (measured as a distance between bottom surface **119** and the top surface or cover) of frame **110** may range from 0.3 to 0.4; other ranges may be used. In one example, pump sub-frame **252** may have height **252***h* of 28 mm and frame **111** may have height **110***a* of 88.1 mm, providing height **252***h* to height **110***a* ratio of 0.317. Accordingly, frame **110** of network switch device **200** may accommodate at least two pump sub-frames **252** (e.g. pump subframes **152**, **156** as described hereinabove) positioned one above the other relative to bottom surface **119** of frame **110** (e.g. as described hereinabove).

[0093] Width **252***i* of pump sub-frame **252** may be smaller than a width **272***i* of fan **272** (or fan opening **270**). A ratio of width **252***i* of pump sub-frame **252** to width **272***i* of fan **272** (or fan opening **270**) may range from 0.65 to 0.75; other ranges may be used. In one example, pump sub-frame **252** may have width **252***i* of 57.6 mm and fan **272** may have width **272***a* of 80 mm, providing width **252***i* to width **272***a* ratio of 0.72; other values may be used. Fans **272** may be offset from first side wall **116** toward second side wall **117** of frame **110** (e.g. as indicated by arrow **272***b* in FIG. **6**B). Offsetting fans **272** from first side wall **215** of frame **110** may reduce the interference of pump sub-frame **252** with the airflow into interior **114** of frame **110** provided by fan **272** positioned next to first side wall **116** of frame **110**. In one example, fans **272** may be offset from first side wall **116** by 21.6 mm, ensuring that only 42.7 mm of pump sub-frame **252** partly interfere with fan **272** positioned next to first side wall **116** of frame **110** (which is only 0.53 of width **272***a* of fan **272** or fan opening **270**). Tapered portion **252***fa* of pump sub-frame **252** may reduce the interference of pump sub-frame **252** with the airflow into interior of frame **110** provided by fan **172** positioned next to first side wall **116** of frame **110**, for example by guiding the airflow smoothly into interior **114** of frame **110** (e.g. as described hereinabove). Other values and ranges may be used.

[0094] Reference is made to FIGS. **7**A and **7**B, which are 3D diagrams of pump sub-frame **252** supporting a pump **250**, according to some embodiments. For simplicity and clarity of illustrations, top surface **252***d* of pump sub-frame **252** is not shown in FIG. **7**A.

[0095] Pump sub-frame or drawer **252** may support pump **250** (e.g. such as pump **150**, **154** described hereinabove). Pump **250** may be positioned within interior **252***g* of pump sub-frame **252**. Pump **250** may be secured within interior **252***g* of pump sub-frame **252** using fasteners (e.g. bolts). Pump **250** may be flat (or substantially flat). For example, a ratio of a height (measured as a distance between bottom and top surfaces) to a width (measured as a distance between side surfaces) of pump **250** may range from 0.25 to 0.35. In one example, pump **250** may have the height of 15.1 mm and the width of 46 mm, providing the height to width ratio of 0.32. Other values and ranges may be used.

[0096] Pump **250** may include an inlet port **251***a* through which the liquid coolant may flow into pump **250**, and an outlet port **251***b* through which the liquid coolant may flow out of pump **250**. Both inlet port **251***a* and outlet port **251***b* of pump **250** may be positioned at the same side or end of pump **250**. Inlet port **251***a* and outlet port **251***b* of pump **250** may be coupled to male or female portions **244***aa*, **244***ba* (e.g. female portions in the example of FIGS. **7**A and **7**B) of dripless blind-mate connectors (e.g. such as dripless blind-mate connectors **144***a*, **144***b* or **144***c*, **144***d* described hereinabove. Portions **244***aa*, **244***ba* of the dripless blind-mate connectors may project externally to interior **252***g* from second end **252***b* of pump sub-assembly **252** (e.g. as shown in FIGS. **7**A and **7**B).

[0097] Pump sub-frame **252** may include, e.g. at its first end **252***a*, a visual indicator **252***g* (e.g. as shown in FIG. **7**B). Visual indicator **252***g* may indicate whether or not pump **250** accommodated within pump sub-frame **2252** is faulty. Visual indicator **252***g* may include a light emitting element such as a light emitting diode (LED).

[0098] Pump sub-frame **252** may include, e.g. at its first end **252***a* or on its first side wall **252***e*, a locking mechanism **252***h* (e.g. as schematically shown in FIG. **7**B). Locking mechanism **252***h* may releasably secure pump sub-frame **252** in a position with respect frame **110** of network switch device **200**. Locking mechanism **252***h*, schematically shown in FIG. **7**B, may include a latch or lever handle to secure engagement of pump sub-frame **252** within the frame of the network switch device, a spring-loaded locking pin or tab to automatically secure pump sub-frame **252** in place, an ejector to safely disengage and remove pump sub-frame **252** from the frame of the network switch device and/or any other component suitable for FRU. Advantageously, the disclosed network switch device **100** includes integrated liquid cooling system and does not require any external infrastructure for supporting the liquid cooling thereof. Furthermore, in some embodiments, network switch device **100** may include two pumps **150**, **154** being coupled in parallel using dripless blind-mate connectors to conduit **140** delivering the coolant to and from heat conducting or cooling body **130** being in thermal contact with heat producing component **120** of network stich device **100**. In the case of malfunction of one of pumps **150**, **154**, the faulty pump may be replaced with new pump through one of fan receptacles or openings **170** without terminating the operation of network switch device **100** (e.g., as described hereinabove). Pumps **150**, **154** may be positioned along side wall **116** of frame or housing **110** of network switch device **100**. Pumps **150**, **154** may be positioned one above the other relative to bottom surface **119** of frame or housing **110**. Pumps **150**, **154** may be supported within pump sub-frames **152**, **156**. Positioning pumps **150**, **154** and/or pump sub-frames **152**, **156** one above the other relative to the bottom surface and along side wall **116** of frame or housing **110** may minimize the interference of pumps **150**, **154** and/or pump sub-frames **152**, **156** with the airflow into interior **114** of frame or housing **110** provided by fans **172** of network switch device **100**. At most, pumps **150**, **154** and/or pump sub-frames **152**, **156** may only partly interfere with the airflow provided by fan **172** positioned next to side wall **116** of frame or housing **110** of network switch device **110**. Pumps **150**, **154** and/or pump sub-frames **152**, **156** may not interfere (or substantially not interfere) with the airflow provided by fans **172** other than fan **172** positioned next to side wall **116** of frame or housing **110** of network switch device **100**.

1. A device comprising:
- a frame comprising: a first end, a second end, a bottom surface, a first side wall and a second side wall extending between the first end and the second end, and an interior;
- a first pump drawer and a second pump drawer positioned within the interior of the frame, the first pump drawer positioned above the second pump drawer, relative to the bottom surface of the frame and along the first side wall of the frame; and
- a first pump positioned within the first pump drawer and a second pump positioned within the second pump drawer, the first pump and the second pump being removably coupled to a conduit using a plurality of dripless blind-mate connectors;
- wherein each of the first pump drawer with the first pump and the second pump drawer with the second pump is replaceable without terminating the operation of the device.

2. The device of claim **1**, comprising a plurality of fans positioned at the first end of the frame between the first side wall and the second side wall, the fans to introduce an airflow into the interior of the frame, wherein the first pump drawer and the second pump drawer are positioned in front of a fan of the plurality of fans.

3. The device of claim **2**, wherein each of the first pump drawer and the second pump drawer tapers towards the first side wall of the frame in a direction towards the first end of the frame comprising the fans.

4. The device of claim **2**, wherein a fan of the plurality of fans that is positioned adjacent to the first side wall is removably received within a fan receptacle, the fan being replaceable without terminating the operation of the device, and wherein each of the first pump drawer with the first pump and the second pump drawer with the second pump is replaceable through the fan receptacle.

5. The device of claim **2**, wherein a width of the first pump drawer and the second pump drawer is smaller than a width of a fan of the plurality of fans that is positioned adjacent to the first side wall of the frame.

6. The device of claim **2**, wherein the first pump drawer and the second pump drawer partly interfere with the airflow into the interior of the frame provided by a fan of the plurality of fans that is positioned adjacent to the first side wall of the frame.

7. The device of claim **1**, wherein the first pump and the second pump operate simultaneously.

8. The device of claim **1**, wherein the first pump operates, and the second pump a is activated if a rotational speed of the first pump reduces below a predefined threshold.

9. The device of claim **1**, comprising a controller to control the first pump and the second pump to maintain a desired flow rate of the liquid coolant through the conduit.

10. The device of claim **9**, wherein the controller is a central processing unit of the device.

11. The device of claim **1**, comprising a heat sink positioned within the interior of the frame, wherein a portion of the conduit passes through the heat sink, the heat sink to cause heat to dissipate from the liquid coolant through the portion of the conduit passing through the heat sink to cool the liquid coolant.

12. The device of claim **1**, comprising:

an electronic component positioned in the interior of the frame,

a cooling body in thermal contact with the electronic component, the cooling body being coupled to the conduit to deliver a liquid coolant to and from the cooling body.

13. A device comprising:

a frame comprising an interior;

a cooling body positioned in the interior of the frame;

a conduit containing a liquid coolant, the conduit being coupled to the cooling body; and

a pump removably coupled to the conduit using a plurality of dripless connectors, the pump being positioned within the interior of the frame along a side wall of the frame, the pump being replaceable without terminating the operation of the device.

14. The device of claim **13**, comprising a plurality of fans positioned at one end of the frame.

15. The device of claim **14**, wherein a fan of the plurality of fans that is positioned adjacent to the side wall of the frame is removably received within a fan receptacle, the fan being replaceable without terminating the operation of the device.

16. The device of claim **15**, wherein the pump is replaceable through the fan receptacle.

17. The device of claim **14**, wherein a width of the pump is smaller than a width of a fan of the plurality of fans that is positioned adjacent to the side wall of the frame.

18. The device of claim **14**, wherein the pump partly interferes with an airflow into the interior of the frame provided by a fan of the plurality of fans that is positioned adjacent to the side wall of the frame.

19. The device of claim **18**, wherein the pump is supported within a pump drawer, the pump drawer extending along the side wall of the frame.

20. The device of claim **19**, wherein the pump drawer tapers towards the side wall of the frame in a direction towards an end of the frame comprising a plurality of fans.

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