

Pump Assembly and Liquid Cooling Chassis Housing

Technical Field of the Disclosure

5 The disclosure concerns a pump docking assembly for receiving one or more replaceable pumps. A liquid cooling chassis housing (or module) for holding at least one (electronic) heat generating components together with the pump docking assembly (with one or more coolant pumps) is also provided.

Background to the Disclosure

10 Within computers, servers, or other devices used for data processing (referred to as IT, or Information Technology), are a number of electronic devices called Integrated Circuits (IC). The electronic devices within the integrated circuits may include central processing units (CPUs), Application Specific Integrated Circuits (ASICs), Graphical Processing Units (GPUs), Random Access Memory (RAM), etc. Each of these devices
15 produce heat when in use. In order to maintain the devices at an optimum temperature for correct operation, this heat should be transferred away from the devices. As the processing power of IT increases and so the number of electronic devices within a computer, server or other IT grows, the challenge of removing sufficient heat created by the electronic devices increases.

20 The electronic devices, normally mounted on a printed circuit board (PCB), are usually housed or enclosed within a case, housing or chassis, to form an electronic module. In a server for instance, this enclosure is sometimes referred to as the server chassis, although the term "chassis" is used herein to relate to any type of overall housing used for electronic components. A server chassis typically adheres to a number of industry
25 standards that specify the height of each chassis, referred to as 1RU (one rack unit) or 1OU (one open unit), these are also abbreviated to 1U or 1OU. The smaller of the 2 main standards is the 1RU/1U, which is 44.45mm or 1.75 inches in height. Although such server typically fit into a rack, it may not be necessary for such a server chassis to slot or plug into a backplane, for example.

30 A method for removal of heat from each case or chassis is used to maintain the electronic devices within the chassis at an appropriate temperature. It is common to cool an electronic module by passing air over or through each case or chassis. The flow of air may be sufficient to remove some heat from inside the enclosure, to the surrounding environment. This method of cooling has, until recently, been used almost exclusively for
35 mass-manufactured IT and server equipment. However, it has been found that, as

technology size decreases for the same computing performance, the heat produced by electronic devices is increasing even as the footprint decreases. As such, the peak performance of IT systems has been throttled or constrained by the limitations of cooling an electronic module with air cooled systems.

5 Accordingly, more complex systems and methods for cooling electronic modules have been proposed. In some cases, liquid cooling has been used, in which a liquid coolant is flowed over, or flowed in proximity to a heat sink coupled to, the electronic devices. The heat can then be transferred away from the electronic devices, to an area or element at which the heat can be removed from the liquid coolant. Liquid cooling can in
10 some cases provide more efficient transfer of heat away from the electronic devices or components, and so a greater cooling power than air cooled systems. However, state of the art liquid cooling systems often use customised systems, which can be complex and expensive to install. Furthermore, improvements to the cooling performance will always be desired.

15 A preferred mode of liquid cooling generally immerses the electrical components in a coolant liquid so as to provide a large surface area for heat exchange between the heat generating electrical components and the coolant. Such systems may use a single phase coolant, in which case the coolant remains in liquid phase or a phase-change coolant, where the liquid coolant evaporates and must be condensed for continuous, effective
20 cooling.

 International Patent publication WO-2018/096362 (commonly assigned with the present disclosure, the details of which are incorporated herein by reference) describes a cooling system in which a primary dielectric coolant liquid is provided within a chassis and used to cool electronic components housed within. The primary dielectric coolant liquid is
25 pumped to a heat exchanger, where heat is transferred to a secondary liquid coolant. The heat exchanger is provided within the chassis and the secondary liquid coolant, which is typically water or water-based (advantageous as having a high specific heat capacity), is pumped to the chassis and the heat exchanger within, before then being pumped out of the chassis and may be shared between multiple chassis. Pipes that end with nozzles are
30 provided for conveying the primary dielectric coolant from the heat exchanger to the electronic components being cooled.

 International Patent publication WO-2019/048864 (commonly assigned with the present disclosure, the details of which are incorporated herein by reference) describes heat sinks and heat sink arrangements for an electronic device. Such a heat sink may
35 allow a primary dielectric coolant to be accumulated adjacent a specific electronic

component, thereby cooling the electronic component effectively. The coolant may flow out of the heat sink, by overflowing the heat sink and/or by one or more apertures in the heat sink, and join the remainder of the coolant in the chassis that cools other electronic components within. In this way, multiple levels of coolant may be provided and the total
5 quantity of coolant required may be minimized. Pipes that end with nozzles are provided for conveying the primary dielectric coolant from a heat exchanger to each heat sink.

International patent application publication WO-2022/106582 (commonly assigned with the present disclosure, the details of which are incorporated herein by reference) discusses an approach in which liquid immersion cooling, for instance based on a dielectric
10 coolant, may be combined with cold plates, fed by a second liquid coolant, for example a water-based coolant. Heat may be transferred from the dielectric coolant to the second liquid coolant in a heat exchanger, which is advantageously in the same chassis as the immersion coolant and electronics being cooled. The second liquid coolant is typically provided from external the chassis, for instance from a building or facility water supply.

15 In these systems, pumping of liquid coolants and particularly the primary coolant, is a significant implementation issue. Use of more than one pump (each of which may be, for example, an impeller pump) is known and this may provide advantages in terms of capacity and/or redundancy. Improvements in pumping for this purpose are desirable.

20 Summary of the Disclosure

Against this background, there is provided a pump docking assembly according to claim 1 and a liquid cooling chassis housing in line with claim 10. Further preferable and/or advantageous features are detailed in the dependent claims and/or other described herein.

A removable or replaceable (liquid coolant) pump for a coolant flow loop is
25 particularly capable of being inserted and removed during operation of the coolant flow loop (so-called 'hot-swappable'). The pump may have a body with a coolant inlet and a coolant outlet. The inlet and/or outlet are intended to match with a corresponding port on an interface (such as a pipe, cradle or docking assembly) within the coolant flow loop. A handle or gripping surface on the body allows its insertion and/or removal, especially during
30 operation of the coolant flow loop (for instance, the handle or gripping surface may be thermally decoupled and/or insulated from the body to ease removal). The liquid coolant is typically a dielectric liquid, but the pump may be used for other fluid or liquid coolants.

In another sense (which may be combined with any other aspect or feature of the disclosure), there may be considered a method for operating a coolant flow loop for a
35 (liquid) coolant. During operation of the coolant flow loop for heat transfer (for example,

from electronics, which may include a circuit board) to the liquid coolant, the coolant flow loop is modified, by inserting or removing a (liquid) coolant pump. The coolant flow loop continues operation throughout.

5 The individual pumps are thus designed to be hot-swappable in a service event. If a pump fails, it can be replaced without disabling the coolant loop (or without turning off any of the system). This may replicate the hot-swap function used on fans in air-cooled systems.

10 Another aspect of the disclosure (combinable with any other aspect or feature of the disclosure) may be found in a pump docking assembly (cradle) for receiving one or more (liquid) coolant pumps as part of a coolant flow loop. The pump docking assembly has at least one pump receiving device (or means for supporting each pump) and a coolant port (a first port) for each pump and connectable to the pump. Each coolant port is typically a coolant liquid outlet, such that it directs coolant to the respective pump, but it can be configured as an inlet in some implementations. The pump docking assembly may be
15 arranged to cause coolant to flow between each first port and another (a second) coolant port that provides flow into (or out of) the pump docking assembly. Typically, there is only one second coolant port, common to all the pumps coupled to the pump docking assembly and this may be enabled by a manifold coupled to each of the first coolant ports, but there could be more than second coolant port in some implementations. The pump docking
20 assembly thereby allows insertion and/or removal of pumps from the coolant flow loop. It may particularly allow continued transferral of liquid coolant between the pump docking assembly and a remainder of the coolant flow loop when any of the plurality of (liquid) coolant pumps is removed. This may allow redundancy operation. The pump docking assembly can be combined with one or more pumps to provide a (liquid) coolant pump
25 assembly or system.

Each pump receiving device advantageously comprises a releasable push-fit clip mechanism.

To enable insertion and/or removal of the pump, its handle or gripping surface (which facilitates engagement and disengagement of the pump with the pump receiving
30 device) is advantageously located on a top portion of the body. The inlet and outlet are preferably on a lower portion of the body. As an example, the inlet may be provided on a base of the body and/or the outlet may be provided on a side of the body. In the latter case, the outlet may be configured for cooperating with a port on a pump docking assembly or pipe.

The pump can be of any type, but an impeller pump is typically used. This may have an impeller housing within the body. A (vertically oriented) pipe may be coupled to each of the first coolant ports. Each coolant liquid flow loop port (which may be an outlet or inlet) may include: a one-way or non-return valve device, particularly configured at a height
5 above a corresponding pump impeller housing; and/or a pressure release device or gas escape mechanism, for instance between the one-way or non-return valve device and the first coolant port. The pressure release device or gas escape mechanism may thus allow priming of the respective (liquid) coolant pump when gas is present between the impeller housing and the one-way or non-return valve device. The pressure release device or gas
10 escape mechanism could be a hole or air bleed orifice (for instance, sized for allowing gas to escape the body but preventing significant flow of liquid coolant out of the body) or a priming valve. This may allow natural filling of the impeller housing with coolant to the nominal coolant level in the chassis.

An electrical (power) connector may be coupled to or integrated with an upper
15 portion of the body, for receiving electrical power at the pump, typically a male connector. This may be in the form of a cable and/or an electrical port (such a plug or socket). By providing the power connector at a high level, typically above the coolant level, insertion and/or removal is made more straightforward. Each pump receiving device may include a (typically, female) electrical connector configured to mate with the corresponding electrical
20 connector located on each pump. In some implementations, the electrical connection is automatic when the pump is removed or replaced.

In some embodiments, an anti-vortex device for the liquid coolant inlet may be provided as part of the pump. Alternatively, an anti-vortex device may form part of the pump receiving device of the pump docking assembly, for example as part of its support
25 means (especially when the pump coolant inlet is on the base of the body). In that case, an individual anti-vortex device may be provided for each pump. Each anti-vortex device may be disposed so as to cooperate with the liquid coolant inlet of each pump when the pump is engaged with the pump receiving device.

Each of the first coolant ports in the pump docking assembly preferably comprises
30 an O-ring seal. Additionally or alternatively, a clip may be used to secure the port on the pump docking assembly with a pump (typically outlet) port. The clip may be releasable with one hand, which may allow the pump to be removed with a second hand. Insertion of the pump may cause the clip to hold the pump in place automatically.

The pump docking assembly may (for instance, as part of its support means)
35 include a rail system, for example a trammel rail, advantageously to engage with the each

pump during engagement with the pump receiving device, to guide pump and pump receiving device into correct engagement. The remainder of the pump docking assembly may be mounted on the rails or each pump is mounted on the rails. The rail system allows movement of the pump docking assembly and/or the pump (or pumps), advantageously together.

The pump docking assembly may include some form of control, for example a processor, which preferably provides control signals. The processor may be software operated. This may allow pump identification on each port.

Advantageously, a fluid (typically, liquid) cooled module may be provided.

Additionally or alternatively, there may be provided a liquid cooling chassis housing (which may be part of the liquid cooled module) enclosing a heat generating (electronic) component or device (for instance, electronics, which may be mounted inside). Optionally, a (primary or first, typically liquid) coolant fluid is also provided in the chassis. A pump docking assembly as described herein is further provided (preferably within the chassis). Beneficially, the chassis housing also has a liquid coolant distribution device interconnects a liquid coolant flow loop with the pump docking assembly. This allows the coolant flow loop within the chassis (preferably entirely within the chassis), for example with coolant flowing from the pump or pumps into the chassis (for providing direct impingement cooling or partially or fully immersing the heat generating component or device) and then back to the pump. The pump (or pumps) are beneficially mounted in the pump docking assembly. Such a module or chassis housing may be used for cooling IT, for example a computer server. The module or chassis housing may be mounted in a rack.

The level of primary coolant is advantageously lower than one or more of: the releasable push-fit clip mechanism; the pump handle (or gripping surface); one, some or all of the (female) electrical connector or connectors of the pump docking assembly; the pump (male) electrical connector; and a release clip handle for pump interconnect with the pump docking assembly. Additionally or alternatively, the level of primary coolant is at least as high as the liquid coolant inlet. A pump can be removed and/or inserted (that is, replaced) without the user needing to contact the coolant or without the power connections interfering. Beneficially, the primary coolant level is at least as high as (and preferably higher than) an impeller housing of the pump (or pumps). A level of the primary coolant liquid is lower than one or more of: the at least one releasable push-fit clip mechanism; the handle or gripping surface; the female electrical connector and/or wherein

The module or the liquid cooling chassis housing preferably includes a second (secondary) coolant liquid inlet and a second (secondary) coolant liquid outlet.

Advantageously, the secondary coolant liquid inlet is connected to the liquid coolant distribution device and the secondary coolant liquid outlet is connected to the pump docking assembly coolant liquid flow loop outlet.

Preferably, the coolant flow loop also comprises a heat exchange device, which
5 transfers heat from the liquid coolant to a heat sink (for example secondary coolant, which is typically a liquid and isolated from the primary coolant), typically downstream from the pump (or from one, some or all of the pumps), for example between the secondary coolant liquid inlet and the liquid coolant distribution device and between the secondary coolant liquid outlet and the pump docking assembly. The heat exchanger is beneficially within or
10 forms part of the chassis. A pipe may be provided to transfer the liquid coolant between the pump (or pumps) and the heat exchanger.

A piping arrangement may direct the liquid coolant from the pump (or each of multiple pumps) to one or more components within the chassis. The electronic component (or components) is beneficially located within a sump that receives the primary coolant
15 liquid from the liquid coolant flow loop. The electronic component (or components) is thus typically in thermal contact either directly or indirectly with the primary coolant liquid. A liquid coolant heat sink may be used to accumulate received liquid coolant adjacent to a component (for example as discussed in WO-2019/048864).

20 Brief Description of the Drawings

The disclosure may be put into practice in a number of ways and preferred embodiments will now be described by way of example only and with reference to the accompanying drawings, in which:

Figure 1 shows a plan view of an example liquid cooled module having a pump
25 assembly according to the disclosure as part of a dielectric coolant loop cooling two circuit boards within a chassis;

Figure 2A depicts a front isometric view of the example liquid cooled module of Figure 1;

Figure 2B shows a rear isometric view of the example liquid cooled module of
30 Figure 1;

Figure 3 illustrates an isometric view of the parts internal the chassis of the example liquid cooled module of Figure 1;

Figure 4 depicts an isometric view of Figure 3 with one circuit board and one pump removed;

Figure 5A shows an isometric view of the pump assembly from the example liquid cooled module of Figure 1;

Figure 5B shows an isometric view of Figure 5A with one pump in the process of removal;

5 Figure 5C depicts an isometric view of Figure 5A with one pump removed;

Figure 6A shows an isometric view of a pump and cradle support and interconnect portions of the pump assembly of Figure 5A;

Figure 6B illustrates a first side view of a pump and cradle support and interconnect portions of the pump assembly of Figure 5A;

10 Figure 6C illustrates a second, partial section side view of a pump and cradle support and interconnect portions according to a variant of the pump assembly of Figure 5A;

Figure 7 shows an isometric view of a single pump in line with a variant embodiment according to the disclosure;

15 Figure 8A depicts a pump assembly according to an alternative embodiment, in a first configuration;

Figure 8B depicts the pump assembly of Figure 8A in a second configuration; and

Figure 8C depicts the pump assembly of Figure 8A in a third configuration.

20 All drawings are schematic in nature. The same reference numerals are used to indicate the same features throughout the drawings.

Detailed Description of Preferred Embodiments

25 As discussed above, a key advantageous feature of the present disclosure is the ability for an individual pump (or pumps) to be hot-swappable, for example in a service event. Each pump is designed for ease of insertion and/or removal, for example with a handle placed for this purpose. Hence if a pump fails, it can be easily replaced without turning off a liquid coolant loop (or without turning any of the system off). This may replicate the hot-swap function used on fans in air cooled servers.

30 To illustrate this implementation, an example will be discussed using a dielectric coolant loop (for which the present disclosure is particularly advantageous). Referring first to Figure 1, there is shown a plan view of an example liquid cooled module having a pump assembly according to the disclosure as part of a dielectric coolant loop cooling two circuit boards within a chassis.

35 There is provided: a chassis 1; IT motherboards 3; liquid coolant heatsinks 4; RAM sticks 5; liquid coolant pumps 6; pump manifold 7; heat exchanger 8; outlet pipe 9; coolant

distribution manifold 10; feed pipes 11; coolant nozzles 12; secondary coolant outlet 13; and secondary coolant inlet 14. Each of the IT motherboards also includes a plurality of integrated circuits (for example, including a CPU or GPU), each of which is not visible in Figure 1, due to the liquid coolant heatsinks 4. In this example each IT motherboard
5 (circuit board) 3 has two CPUs with respective liquid coolant heatsinks 4 attached and a bank of the RAM 5 sticks on each side of the CPUs, but other configurations are possible.

A dielectric coolant (not visible in Figure 1) is used for removing heat from the integrated circuits and the RAM sticks 5. This dielectric coolant pools in a base of the chassis 1 for a coolant sump 2. From there, it is drawn by the pumps 6 and transported,
10 via the pump manifold 7, for cooling at the heat exchanger 8 (more details of which will be discussed below). The cooled coolant passes from the heat exchanger 8 through the outlet pipe 9 to the coolant distribution manifold 10. From there, the coolant is distributed between the feed pipes 11 (four are shown in Figure 1), each feed pipe 11 delivering coolant to a respective liquid coolant heatsink 4. The liquid coolant heatsinks 4 are as
15 described fully in WO-2019/048864, so their details are omitted here for the sake of brevity. The delivered liquid coolant accumulates within each of the liquid coolant heatsinks 4, thereby providing a sink for heat from the respective integrated circuit positioned under each liquid coolant heatsink 4. The accumulated liquid coolant flows out from each liquid coolant heatsink 4 (for example, flowing over an outer wall of the liquid coolant heatsink 4
20 or flowing through a designed flow path) and may then cool other components within the chassis 1, for example the RAM sticks 5. This hot liquid coolant then accumulates in the base of the chassis 1, at the coolant sump 2, thereby completing the coolant flow loop. It is noted that the level of liquid coolant accumulating the chassis 1 (that is, in the coolant sump 2) is lower than the level of coolant accumulating in the each of the liquid coolant
25 heatsinks 4, such that there are multiple levels of coolant for providing tailored cooling to different components within the chassis 1.

Four pumps 6 are shown in this design, but fewer or more pumps may be used in practice. The use of multiple pumps may increase pumping capacity and/or efficiency, and/or redundancy may be improved. As discussed above, the pumps 6 may be inserted
30 or removed during operation of the dielectric liquid coolant flow loop. This may be particularly possible due to the use of a cradle (pump docking assembly) feeding the pump manifold 7 (although the pump manifold 7 can be seen as part of the cradle in some embodiments and may even be omitted), as will be discussed below and/or the use of multiple pumps 6. However, hot-swapping of pumps may even be possible with a single
35 pump and without a cradle, depending on the configuration of the coolant flow loop.

The heat exchanger 8 is typically a plate heat exchanger, although other options are possible. The dielectric coolant entering the heat exchanger 8 is a primary coolant in this example and the heat exchanger 8 also receives a secondary coolant (which is typically water or water-based) via the coolant inlet 14. The received secondary coolant is
5 generally cold and receives heat from the primary coolant within the heat exchanger 8 before passing out via the secondary coolant outlet 13. There may also be formed a secondary coolant flow loop, including a pumping arrangement and one or more pumps or pumping systems in accordance with the present disclosure may also be suitable for that flow loop, but this is not discussed herein. The secondary coolant inlet 14 is typically at the
10 opposite end of the heat exchanger 8 to the primary (dielectric) coolant inlet of the heat exchanger 8, as this may ensure contraflow between the coolants. Both the secondary coolant inlet 14 and the secondary coolant outlet 13 advantageously have drip free connectors.

Referring next to Figure 2A, there is depicted a front isometric view of the example
15 liquid cooled module of Figure 1. As the same features are shown, the reference numerals used are identical. In this example, it can be seen that the pump manifold 7 is positioned above the pumps 6. The dielectric coolant outlet pipe 9 then travels between the pump manifold 7 and the pumps 6. Both the pump manifold 7 and the dielectric coolant outlet pipe 9 are positioned to leave enough room that allows insertion or removal (and
20 replacement) of a pump.

With reference to Figure 2B, there is shown a rear isometric view of the example liquid cooled module of Figure 1. The secondary coolant (water) side of the chassis 1 is more visible and the drip free connectors providing the secondary coolant outlet 13 and secondary coolant inlet 14 on the heat exchanger 8 transiting through the wall of the
25 chassis 1.

Now referring to Figure 3, there is illustrated an isometric view of the parts internal the chassis of the example liquid cooled module of Figure 1. This is similar to the view of Figure 2A, without the chassis. In this example, a fully populated system can be seen with four pumps 6 and two IT motherboards 3. In this example, three of the four pumps 6 are
30 required for cooling the IT and one pump 6 is used for redundancy.

Referring next to Figure 4, there is depicted an isometric view of Figure 3 with one circuit board (IT motherboard 3) and one pump removed. This shows the ports 16 on the dielectric manifold 10 that are not needed. The unused ports 16 are blocked to stop any coolant from flowing out of them.

In this example, three pumps 6 are used. Consequently, a portion of the cradle 30 is visible, specifically anti-vortex device 15 in the empty portion of the cradle 30. This will be further discussed below. Fewer pumps 6 may be required when only one IT motherboard 3 needs to be cooled. If an additional IT motherboard 3 were added, an
5 additional pump 6 could also be provided.

Reference is now made to Figure 5A, in which there is shown an isometric view of the pump assembly from the example liquid cooled module of Figure 1. This example pump assembly 40 comprises two cradles 30, two pumps 6 being coupled to each cradle 30. Each pump 6 comprises: a body 26; a handle 21 attached to the upper part of the body
10 26; and a power connector 20 also located at an upper part of the body 26. From the cradle 30, there is visible a rail system 27, which will be discussed in more detail below.

Referring now to Figure 5B, there is shown an isometric view of Figure 5A with one pump in the process of removal. This view allows greater visibility of the cradle 30, which can be seen to comprise: anti-vortex device 15; pump port 19; priming valve 18; non-return
15 valve (NRV) 17; and rail system 27. The anti-vortex device 15 is mounted on the rail system 27 and together form a support portion of the cradle 30 upon which the pump is mounted. Also labelled is pump inlet 28 on the base of the pump 6.

The pump inlet 28 fits on the anti-vortex device 15, which is shown in a position distal the remainder of the cradle 30 and specifically the pump port 19. This position is a
20 removal position for the anti-vortex device 15, as the pump has been removed from the pump assembly 40. When the pump 6 is inserted to the pump assembly or system 40, it (and specifically the pump inlet 28) is positioned on the anti-vortex device 15 and moved along the cradle 30 (the cradle 30 may slide along the rails with the pump 6 when it is removed or replaced), such that an outlet of the pump 6 couples with the pump port 19.
25 This will be discussed in more detail below.

The pump can be positioned and removed by means of the handle 21, which allows easy access and precise positioning within the pump assembly 40. The handle is advantageously positioned above the dielectric coolant level (in the coolant sump 2), to avoid the need for user contact with the dielectric coolant. The handle 21 may be thermally
30 insulated or decoupled from the body 26 of the pump 6, such that it can readily be used even if the pump 6 has recently been operative.

The power connector 20 is coupled to suitable internal electrical connections (in particular, on the cradle 30). The power connector 20 may not only provide the pump with power, but advantageously control signals are additionally (or alternatively) provided via it.
35 To insert or remove the pump 6 the power connector needs connecting or disconnecting

respectively. The power connector 20 (and inline cable) is also above the dielectric coolant level (in the coolant sump 2).

The NRV 17 is positioned along a vertically oriented pipe (or piping) from the pump port 19 towards a connection to the pump manifold 7, which will be seen more clearly in subsequent drawings. The NRV 17 may stop reverse flow through the pump port 19 if it is empty. When a pump 6 is first installed, air may be trapped between an impeller housing within the pump 6 and the NRV 17. This may make it difficult for the pump 6 to prime, because the pumps are designed to pump liquid, not air.

When turning on the pump 6 for the first time, the pump 6 will attempt to force any air trapped in the impeller housing or the pump port 19 through the coolant loop. To achieve this, the pump 6 is required to create enough pressure to open the NRV 17. However, this is not always possible, as the pump 6 cannot effectively pump the trapped air out to overcome the back pressure before the NRV 17. The priming valve 18 (a gas escape mechanism) therefore allows air to be purged out of the impeller housing within the pump 6 and the pump port 19 before the NRV 17, naturally filling the impeller housing with coolant to the nominal coolant level in the chassis 1. This may ensure that the pump 6 can prime itself.

An individual NRV 17 is provided for each pump port 19 of the cradle 30, so 1, 2, 3 or 4 pumps can be used. The number of pumps used may depend on the cooling and/or coolant requirements.

Referring next to Figure 5C, there is depicted an isometric view of Figure 5A with one pump removed. The portions of the cradle 30 around the pump port 19 are more visible and a retaining clip 29 of the cradle 30 can be seen. When the pump 6 is coupled to the cradle 30, the outlet of the pump 6 pushes into the opening of the pump port 19, also having an O-ring (or equivalent) seal. The retaining clip 29 holds the pump 6 in position. The retaining clip 29 can straightforwardly be released (for instance, with one hand), allowing the pump 6 to be removed (with the other hand, for example). When a replacement pump 6 is inserted to couple to the pump port 19, the retaining clip 29 automatically holds the new pump 6 in place. The retaining clip 29 has a handle that is above the dielectric coolant level (in the coolant sump 2). Thus, a pump can be removed and replaced without the user needing to contact the dielectric coolant.

The cradle advantageously includes a processor (not shown), which may be able to control the pumps 6. Such control (which may be implemented in hardware or firmware, but is preferably implemented as software) may permit the hot swap function, by disabling and/or enabling pumps 6 accordingly. Since all pumps operate according to the same

pump coolant loop design, cost and/or complexity may be reduced. Beneficially, the processor may be able to identify which pump is connected to each pump port 19 through software recognition.

Control may be used to effect optimal redundant pump operation. Different
5 pumping redundancy requirements may be applied in practice. For example, if only one pump is required to meet cooling needs, 2 pumps may be provided to provide N+N redundancy. An alternative approach is to use N+1 redundancy, for example where 3 pumps may be required so 4 pumps are provided.

Redundancy control for the pumps may be implemented in two different ways. In
10 one approach, all pumps (N+1) in the chassis could run together at a lower power (or RPM). Then if a pump then fails, the remaining pumps (N) can run at a higher power (or RPM) until the failed pump is replaced. This may be a preferred option, as the redundant pump is already running. A second approach is for the redundant pump (+1) to be switched off when the system is running normally and only when a pump fails, is the
15 redundant pump turned on.

In a general sense, there may be considered (liquid) coolant pump, comprising a body, having a (liquid) coolant inlet and a (liquid) coolant outlet, at least one of the (liquid) coolant inlet and the (liquid) coolant outlet being configured for cooperation with a corresponding coolant port as part of a coolant flow loop. Advantageously, a handle or
20 gripping surface is also provided, for example on the body of the pump, which may be arranged to allow the (liquid) coolant pump to be positioned in and removed from the coolant flow loop and/or to facilitate engagement and disengagement of the pump with a pump receiving device. For example, the handle or gripping surface may be located on a top portion of the body. Then, the liquid coolant inlet and the liquid coolant outlet are
25 beneficially located on a lower portion of the body, which may also contain a pump mechanism, for instance an impeller housing. The handle may be thermally insulated or decoupled from the body, in particular the pump mechanism (which may heat up).

In an associated aspect (which may be distinct from or combined with any other aspect disclosed herein), there may be considered a cradle for receiving one or more
30 (liquid) coolant pumps as part of a coolant flow loop. The cradle comprises, for each of the one or more (liquid) coolant pumps: a respective support portion, configured to support a body of the respective (liquid) coolant pump; and a respective first coolant port, configured for transferral of (liquid) coolant fluid between the respective (liquid) coolant pump and the cradle when the respective (liquid) coolant pump is positioned in the support portion.
35 Advantageously, the cradle further comprises at least one second coolant port, configured

for transferral of coolant fluid between the cradle and a remainder of the coolant flow loop. The cradle thereby allows each of the one or more (liquid) coolant pumps to be inserted into and removed from the coolant flow loop (during operation of the coolant flow loop). The combination of the cradle with one or more (liquid) coolant pumps as disclosed herein is also considered.

Another aspect (which may be distinct from or combined with any other aspect disclosed herein) may provide a pump docking assembly, configured to interconnect at least one pump with a coolant liquid flow loop, said pump docking assembly comprising: at least one pump receiving device arranged to releasably engage with the at least one pump; and a coolant liquid flow loop port connectable to the at least one pump. The at least one pump advantageously includes a liquid coolant inlet.

Another aspect of the disclosure (which again may optionally be combined with any other aspect disclosed herein) is found in a liquid cooled module, comprising: a chassis; at least one heat generating component mounted in the chassis; a liquid coolant (for example, a dielectric liquid) within the chassis for cooling the at least one heat generating component; and one or more (liquid) coolant pumps (in particular, as disclosed herein), configured to provide a coolant flow loop within the chassis.

A yet further aspect (which may likewise optionally be combined with any other aspect disclosed herein) provides a liquid cooling chassis housing enclosing at least one electronic component. The liquid cooling chassis housing comprises a liquid coolant distribution device interconnecting a liquid coolant flow loop with a pump docking assembly as disclosed herein. The liquid cooling chassis housing may form part of fluid (liquid) cooled module, for example.

At least one of the (liquid) coolant pumps may be removed during operation of the coolant flow loop, in particular without disrupting functional operation of the coolant flow loop. The one or more (liquid) coolant pumps are beneficially provided in a cradle or pump docking assembly as herein disclosed. Additionally or alternatively, the one or more (liquid) coolant pumps may be mounted within the chassis (together with the cradle or pump docking assembly). Typically, the at least one electronic device and/or heat generating component comprises a circuit board (for instance, a motherboard) having a plurality of electronic components mounted thereon.

A further aspect may be considered in a method for operating a coolant flow loop for a liquid coolant. The method comprises: operating the coolant flow loop to transfer heat from at least one heat generating component to the liquid coolant; and modifying the coolant flow loop during operation of the coolant flow loop, by inserting or removing a

(liquid) coolant pump from the coolant flow loop, such that the coolant flow loop continues operation. The coolant flow loop is typically entirely within a chassis of a liquid cooled module. As discussed herein, the chassis may house the at least one heat generating component, the liquid coolant and the (liquid) coolant pump. Where the coolant flow loop
5 comprises a plurality of (liquid) coolant pumps, operating the coolant flow loop may further comprise directing the coolant liquid between at least one of the plurality of (liquid) coolant pumps and the at least one heat generating component.

Various optional and/or advantageous features may be applied to any aspect of the disclosure, as will be discussed below, although they may apply particularly to one or more
10 certain aspects more than others. Some of these will be detailed now.

For example, the liquid coolant inlet is typically located on a base of a body of the pump. The liquid coolant outlet of the pump may be located on a side of the body and configured for cooperation with a corresponding coolant port of the pump receiving device.

The (liquid) coolant pump may further comprise: an impeller housing within the
15 body. The cradle or pump docking assembly may further comprise a pipe coupled to each of the first coolant ports or pump receiving devices for coupling towards the at least one second coolant port or coolant liquid flow loop port. Each pipe or the coolant liquid flow loop port may include: a one-way or non-return valve device. This is preferably configured at a height above an impeller housing of a respective (liquid) coolant pump (or at least at a
20 height above the respective first coolant port). Additionally or alternatively, each pipe or the coolant liquid flow loop port may include a pressure release device or a gas escape mechanism. For example, this may be between the one-way or non-return valve device and the first coolant port (in the sense of coolant flow) and may be configured to allow priming of the respective (liquid) coolant pump when gas is present between the first coolant port
25 (or more strictly, the impeller housing) and the non-return valve. For instance, the pressure release device or gas escape mechanism may comprise one of: a hole or air bleed orifice (for instance, sized for allowing gas to escape the body but preventing significant flow of liquid coolant out of the body); and a (priming) valve.

The (liquid) coolant pump may further comprise a electrical (power) connector for
30 receiving electrical power at the pump. This is typically a male electrical connector. The pump docking assembly may comprise an electrical connector (typically female), configured to mate with a corresponding electrical connector located on the at least one pump. Advantageously, the power connector is coupled to or integrated with an upper portion of the body (in particular, above the level of the dielectric coolant).

The pump docking assembly or cradle may be configured for a plurality of (liquid) coolant pumps. Then, the pump docking assembly or cradle may be further configured to allow continued transferral of (liquid) coolant between the pump docking assembly or cradle and a remainder of the coolant flow loop when any of the plurality of (liquid) coolant pumps is removed. This may allow pump redundancy, for example. In embodiments, a (single) common second coolant port is provided. Then, the pump docking assembly or cradle may accordingly be configured for transferral of (liquid) coolant between the respective first coolant port of each of the plurality of (liquid) coolant pumps and the common second coolant port. For example, a liquid coolant distribution device or manifold may be provided. This may form part of the cradle and then coupled to each of the first coolant ports and configured for transferral of liquid coolant between the respective first coolant port of each of the plurality of (liquid) coolant pumps and the common second coolant port. Alternatively, it may be a separate part within the module or liquid cooling chassis housing, interconnecting a liquid coolant flow loop with the pump docking assembly.

Preferably, each of the first coolant ports comprises an O-ring seal and/or a clip for securing the respective first coolant port with a corresponding port of a respective one of the one or more (liquid) coolant pumps. Each pump may have the same or a corresponding feature to permit a seal between the pump outlet (or inlet) and the respective one of the first coolant ports.

For each of the one or more (liquid) coolant pumps, the pump docking assembly or cradle may comprise a respective anti-vortex device (for example, as part of the respective support portion or each of the at least one pump receiving device). The anti-vortex device may be positioned to be adjacent a (liquid) coolant inlet of the respective (liquid) coolant pump and/or disposed so as to cooperate with the liquid coolant inlet of the at least one pump when the pump is engaged with the pump receiving device. For instance, the (liquid) coolant inlet may be on a base of the (liquid) coolant pump, such that the anti-vortex device may be positioned to receive the base of the pump.

The pump docking assembly (or one or more support portions of the cradle) may comprise a rail system, for instance a trammel rail. This may be disposed proximal to the pump receiving device. The rail system or rail may be configured to engage with the at least one pump during engagement with the pump receiving device to guide the pump into correct engagement with the pump receiving device. Additionally or alternatively, a remainder of the pump docking assembly or cradle may be mounted on the rail system or rail and each of the one or more (liquid) coolant pumps can be mounted thereon. Thus, the

rail system or rail may be configured to allow movement of the remainder of the pump docking assembly or cradle and/or each of the one or more (liquid) coolant pumps (in particular the cradle and pump or pumps may be moved together).

The pump docking assembly or cradle advantageously further comprises a
5 processor, configured provide control signals to each of the one or more (liquid) coolant pumps for controlling pump operation.

A level of liquid coolant is beneficially lower than one or more of: the respective handle or gripping surface of each of the one or more (liquid) coolant pumps; the at least one releasable push-fit clip mechanism; an (female) electrical connector on the pump
10 docking assembly or cradle; a electrical (power) connector of each of the one or more (liquid) coolant pumps; and a respective release clip handle associated with the respective first coolant port for each of the one or more (liquid) coolant pumps and/or wherein the level of liquid coolant is at least as high as the liquid coolant inlet of the pump docking assembly or an impeller housing of each of the one or more (liquid) coolant pumps.

The liquid coolant flow loop typically includes a first or primary coolant fluid
15 (generally, a liquid), which is preferably a dielectric coolant. The module and/or liquid cooling chassis housing advantageously further includes a second or secondary coolant liquid inlet and a second or secondary coolant liquid outlet. Then, the liquid inlet may be connected to the liquid coolant distribution device (or manifold), and the liquid outlet may
20 be connected to the pump docking assembly coolant liquid flow loop port.

The (liquid cooled) module and/or liquid cooling chassis housing preferably further comprises a heat exchanger or heat exchange device, which is advantageously configured as part of the coolant flow loop, and may receive the (first or primary) coolant and transfer heat from the liquid coolant to a heat sink. For example, the heat exchange device may be
25 located between the secondary coolant liquid inlet and the liquid coolant distribution device and between the secondary coolant liquid outlet and the pump docking assembly. The heat exchanger or heat exchange device is typically within or forms part of the chassis. The heat sink of the heat exchanger is generally the secondary (liquid) coolant that is isolated from the primary coolant flowing through the pump (or pumps). In some embodiments, the
30 module or liquid cooling chassis housing further comprises a pipe for transferring the liquid coolant between the one or more (liquid) coolant pumps and the heat exchanger. The at least one electronic component (being cooled) may be located within a sump that receives the primary coolant liquid from the liquid coolant flow loop. Then, the at least one
35 electronic component is beneficially in thermal contact either directly or indirectly with the primary coolant liquid (in the heat exchange device).

Optionally, the liquid cooled module further comprises a piping arrangement for directing the liquid coolant from the pump to the at least one heat generating component. Additionally or alternatively, the liquid cooled module further comprises one or more liquid coolant heat sinks, each of the one or more liquid coolant heat sinks being configured to receive the liquid coolant and to accumulate the received liquid coolant adjacent to a
5 respective one of the at least one heat generating component.

More specific implementation details will now be presented. However, further discussion according to the general sense now discussed will be provided subsequently.

Reference is next made to Figure 6A, in which there is shown an isometric view of a
10 pump and cradle support and interconnect portions of the pump assembly of Figure 5A. Visible in this drawings are: anti-vortex device 15 (as part of a support portion of the cradle 30); pump port 19; cradle vertically oriented piping 31; NRV 17; priming valve 18; and from pump 6: pump outlet 32; handle 21; and power connector 20. Here, the handle 21 can be seen as situated above the coolant level, which may ensure that the user removing or
15 replacing the pump 6 does not have to touch the coolant. The power (and control) connector 20 is connected to a wire in this example. The connector is manually either unplugged on removing the pump 6 or plugged in when inserting the pump 6. The positioning of the pump outlet 32 for coupling with the pump port 19 can also be seen. The NRV 17 and priming valve 18 are along the piping 31.

20 Referring now to Figure 6B, there is illustrated a first side view of the pump 6 and cradle support and interconnect portions of the pump assembly of Figure 5A. The priming valve 18 and power connector 20 can be seen above line 22, representing the dielectric coolant depth. It is desirable for the coolant depth 22 to be deep enough to submerge the pump impeller housing within the body 26 of the pump 6. If the coolant depth is shallower
25 than this, the pump may be prone to sucking in air.

Referring next to Figure 6C, there is illustrates a partial section side view of a pump and cradle support and interconnect portions of the pump assembly according to a variant of Figure 5A. A single pump 6 is inserted into the pump port 19 of a cradle 30'. The partial section is in the region of the pump port 19, revealing the O-ring seal 24 (as discussed
30 previously) for the outlet of the pump 6.

The only difference in this example with the embodiment of the cradle discussed above, is that an alternative way of venting trapped air out of the pump port 19 is shown. A small air bleed hole 23 is used between the impeller housing and the NRV 17, instead of a priming valve. However, this way of venting trapped air may also allow coolant to flow out

of the hole 23 after all the air has escaped, reducing flow rate. Therefore, this method of venting air is not preferable.

Referring then to Figure 7, there is shown an isometric view of a single pump in line with a variant embodiment according to the disclosure. As in the previously disclosed
5 embodiments, the pump 6' comprises: a handle 21; a body 26; and a pump outlet 32. However, the power connector 25 (which may additionally or alternatively provide control signals) is integrated with the body 26 and does not include a cable.

This may be beneficial over a cabled solution (along the lines discussed above), since it may connect power and control of the pump at the same time as the pump outlet 32
10 engages with the pump port 19 of the cradle 30. Ultimately, this may remove an extra process of unplugging or plugging in the connector, in addition to removing the extra cables in the system. In fact, the electrical connection may even be made automatic when the pump is removed or replaced.

Reference is now made to Figures 8A, 8B and 8C, in which there are depicted a
15 pump assembly according to an alternative embodiment. A first configuration is shown in Figure 8A. The cradle 30'' does not use a retaining clip, but has a push-fit mechanism 35, which together with the rail system 27, may allow coupling of the pump outlet 32 with the pump port 19 of the cradle 30'' along axial line 33. In this first configuration, a handle of the push-fit mechanism 35 is not used. The pump 6 is spatially separated from the cradle 30''
20 with the pump outlet 32 being decoupled from the pump port 19.

A second configuration is shown in Figure 8B. Here, the handle of the push-fit mechanism 35 is open, but the pump 6 is brought into contact with the cradle 30'' and the pump outlet 32 is coupled to the pump port 19. A third configuration is shown in Figure 8C, in which the pump 6 remains in contact with the cradle 30'' and the handle of the push-fit
25 mechanism 35 is closed, to couple the pump outlet 32 to the pump port 19 more completely. Release of the pump 6 from the cradle 30'' may be effected by opening the handle of the push-fit mechanism 35 and spatially separating the pump 6 from the cradle 30'' (along axial line 33), to decouple the pump outlet 32 from the pump port 19 of the cradle 30''.

30 Although specific embodiments have now been described, the skilled person will appreciate that various modifications and alternations are possible. Different types of chassis (and/or different types of servers or IT in the chassis) may have different cooling requirements. The maximum number of 4 pumps shown herein may be varied (to 6, for example). The cradle is typically designed for multiple pumps, with the associated
35 advantages as discussed above, but the principle may even be applied to a single pump.

Removal of a single pump may not always disrupt the coolant flow loop, at least temporarily. Coolant may continue to flow, even without a pump, due to convection.

The arrangement of chassis, components, heat sinks, pumps, support structures and other configurations may be varied, combined or otherwise configured in a range of different ways, of which those disclosed herein are simply examples. Different types of liquid pumps (for instance, in terms of structures and/or pumping mechanisms) may be used with different shapes and/or configurations (for example with different types, shapes and/or numbers of ports). The support portion of the cradle may differ from that shown, for example with different rail systems (or no rail system) and/or without an anti-vortex device and/or retaining ring. The design of the coolant ports on the cradle may also differ. Also, the cradle may have multiple output ports. Alternatively, the flow of coolant may be different from that described herein. For example, the flow between the pumps and heat exchanger may differ. More than one heat exchanger might be used. In some embodiments, the coolant flow may be the opposite of that described herein, for example, with coolant flowing from the heat exchanger (or heat exchangers) to the pumping system. In this case, the cradle may also as a manifold for supplying multiple pumps.

The number, structure and/or configuration of each heat generating (electronic) component or device cooled by the dielectric coolant and optionally one or more heat sinks may vary significantly. Where heat sinks are used, the configuration, exact shape and/or size of the heat sink may also be modified. For example, each heat sink may be formed as a multi-part assemblies or as an integrally constructed device.

Although the disclosure is described with reference to a chassis (server module) of a specific shape and size, this can be varied (for example, a chassis with a vertical orientation may be used) and indeed, aspects of the disclosure may be applied for cooling other types of device. For example (and as discussed in at least WO-2020/178579, commonly assigned with the present disclosure), cooling technology according to the disclosure can be used to cool a wide variety of different heat-generating (generally electrical and/or electronic) components, including but not limited to IT devices.

The primary and/or secondary coolant are liquids and are advantageous maintained in liquid form (single phase coolant). However, this need not necessarily be the case for a coolant not passing through a (liquid) coolant pump in accordance with the disclosure. A two-phase coolant (which may be allowed to change to and from gas phase) and/or refrigerant coolant may be used, for example for the secondary coolant.

Although the anti-vortex device described herein has been provided in the cradle, it may form part of the pump, for instance molded as part of the pump body. This may

reduce the number of parts in the assembly, cost and complexity of the cradle sliding with the pump.

Returning to the general sense of the disclosure above, the (liquid) coolant pump may further comprise an anti-vortex device for the (liquid) coolant inlet (for example,
5 integrated with the liquid coolant inlet and/or a portion of the body adjacent the liquid coolant inlet).

The or each at least one pump receiving device may comprise a releasable push-fit clip mechanism.

All of the features disclosed herein may be combined in any combination, except
10 combinations where at least some of such features and/or steps are mutually exclusive. In particular, the preferred features of the invention are applicable to all aspects of the invention and may be used in any combination. Likewise, features described in non-essential combinations may be used separately (not in combination).

15

CLAIMS

1. A pump docking assembly, configured to interconnect at least one pump with a coolant liquid flow loop, said pump docking assembly comprising:
5 at least one pump receiving device arranged to releasably engage with the at least one pump; and
a coolant liquid flow loop port connectable to the at least one pump;
wherein the at least one pump includes a liquid coolant inlet.
- 10 2. The pump docking assembly of claim 1, wherein the at least one pump receiving device comprises a releasable push-fit clip mechanism.
3. The pump docking assembly of claim 1 or claim 2, wherein the coolant liquid flow loop port includes a one-way valve device.
15
4. The pump docking assembly of any preceding claim, wherein the coolant liquid flow port includes a pressure release device.
5. The pump docking assembly of claim 4, wherein the pressure release device is a
20 priming valve or an air bleed orifice.
6. The pump docking assembly of any preceding claim, wherein the at least one pump receiving device includes an anti-vortex device disposed so as to cooperate with the liquid coolant inlet of said at least one pump when said pump is engaged with said pump
25 receiving device.
7. The pump docking assembly of any preceding claim, further comprising one or more removable pumps, each of the one or more removable pumps being configured to include a handle or gripping surface to facilitate engagement and disengagement of the
30 respective removable pump with the pump receiving device.
8. The pump docking assembly of any preceding claim, wherein the pump docking assembly includes a rail disposed proximal to the pump receiving device, the rail configured to engage with the at least one pump during engagement with the pump

receiving device to guide said pump into correct engagement with the pump receiving device.

9. The pump docking assembly of any preceding claim, wherein the pump receiving
5 device includes a female electrical connector configured to mate with a corresponding male electrical connector located on said at least one pump.

10. A liquid cooling chassis housing enclosing at least one electronic component, the liquid cooling chassis housing comprising:
10 a liquid coolant distribution device interconnecting a liquid coolant flow loop with a pump docking assembly as claimed in any one of claims 1 to 9.

11. The liquid cooling chassis housing of claim 10, wherein the liquid coolant flow loop includes a first coolant liquid.
15

12. The liquid cooling chassis housing of claim 10 or claim 11, wherein the liquid cooling chassis housing includes a second coolant liquid inlet and a second coolant liquid outlet, said liquid inlet is connected to the liquid coolant distribution device, and said liquid outlet is connected to the pump docking assembly coolant liquid flow loop outlet.
20

13. The liquid cooling chassis housing of claim 12, wherein the liquid coolant distribution device is a liquid coolant manifold.

14. The liquid cooling chassis housing of any one of claims 10 to 12, wherein a heat exchange device is located between the second coolant liquid inlet and the liquid coolant distribution device and between the second coolant liquid outlet and the pump docking assembly.
25

15. The liquid cooling chassis housing of any one of claims 10 to 14, wherein the at least one electronic component is located within a sump that receives the first coolant liquid from the liquid coolant flow loop, said at least one electronic component being in thermal contact either directly or indirectly with the first coolant liquid.
30

16. The liquid cooling chassis housing of claim 15, wherein a level of the first coolant liquid is lower than one or more of: the at least one releasable push-fit clip mechanism; the
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handle or gripping surface; the female electrical connector and/or wherein the level of first coolant liquid is at least as high as the liquid coolant inlet.