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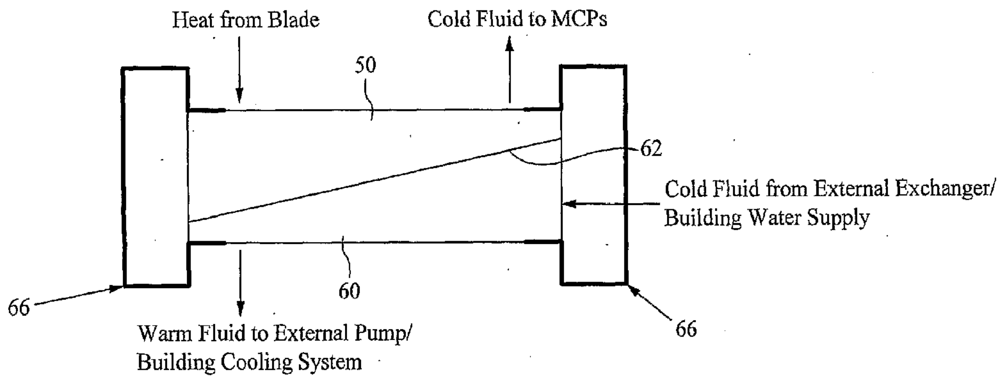

(57) **Abstract:** Liquid-based cooling solutions used to transfer heat produced by one or more heat generating devices from one or more electronics servers to the ambient. Each electronics server includes one or more heat generating devices. Integrated onto each electronics server is a liquid based cooling system. Each liquid based cooling system includes a server pump and one or more microchannel cold plates (MCP) coupled together via fluid lines. The liquid based cooling system for each electronics server includes a rejector plate configured with micro-channels. The MCPs, the server pump and the rejector plate form a first closed loop. The rejector plate is coupled to a chassis cold plate via a thermal interface material. In a multiple electronics server configuration, the rejector plates for each of the electronics servers are coupled to the chassis cold plate configured with fluid channels which are coupled via fluid lines to a liquid-to-air heat exchanging system to form a second closed loop.

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LIQUID COOLING LOOPS FOR SERVER APPLICATIONS

Related Applications

This application claims priority of U.S. provisional application, serial number 60/774,764, filed February 16, 2006, and entitled "Thermal Interconnect", by these same inventors. This application incorporates U.S. provisional application, serial number 60/774,764 in its entirety by reference.

Field of the Invention

The invention relates to a method of and apparatus for cooling a heat producing device in general, and specifically, to a method of and apparatus for cooling server applications using liquid-based cooling systems.

Background of the Invention

Cooling of high performance integrated circuits with high heat dissipation is presenting significant challenge in the electronics cooling arena. Conventional cooling with heat pipes and fan mounted heat sinks are not adequate for cooling chips with every increasing wattage requirements, including those exceeding 100W.

Electronics servers, such as blade servers and rack servers, are being used in increasing numbers due to the higher processor performance per unit volume one can achieve. However, the high density of integrated circuits also leads to high thermal density, which is beyond the capability of conventional air-cooling methods.

A particular problem with cooling integrated circuits on electronics servers is that multiple electronics servers are typically mounted in close quarters within a server chassis. In such configurations, electronics servers are separated by a limited amount of space, thereby reducing the dimensions within which to provide an adequate cooling solution. Typically, stacking of electronics servers does not provide the mounting of large fans and heat sinks for each electronics server. Often electronics server stacks within a single server chassis are cooled by one large fan, a heat sink or both. Using this configuration, the integrated circuits on each electronics server are cooled using the heat sink and the large fan that blows air over the heat sink, or simply by blowing air directly over the electronics servers. However, considering the limited free space surrounding the stacked electronics servers within the server chassis, the amount of air available for cooling the integrated circuits is limited.

Closed loop liquid cooling presents alternative methodologies for conventional cooling solutions. Closed loop cooling solutions more efficiently reject heat to the ambient than air cooling solutions.

What is needed is a more efficient cooling methodology for cooling integrated circuits on an electronics server. What is also needed is a more efficient cooling methodology for cooling integrated circuits on multiple electronics servers mounted within a server chassis.

Summary of the Invention

Cooling systems of the present invention are directed to cooling solutions used to transfer heat produced by one or more heat generating devices, such as microprocessors or other integrated circuits, from one or more electronics servers to the ambient. In some embodiments, a liquid-based cooling system is used. A server chassis is configured to house multiple electronics servers. Examples of electronics servers includes, but are not limited to, blade servers and rack servers. Each electronics server is coupled to a backplane or mid-plane within the server chassis. For purposes of this disclosure, the terms "backplane" and "mid-plane" are used interchangeably. Each electronics server includes one or more heat generating devices. Integrated onto each electronics server is a liquid based cooling system. Each liquid based cooling system includes a server pump and one or more microchannel cold plates (MCP). Fluid lines preferably couple the MCPs and the server pump. In other embodiments, heat pipes or conduction means are used instead of the liquid-based cooling system.

In a first embodiment, the liquid based cooling system for each electronics server includes a rejector plate. Each rejector plate is configured with fluid channels, preferably micro-channels. Alternatively, each rejector plate is configured with macro-channels. The fluid channels are coupled to the fluid lines thereby forming a first closed loop including the

MCPs, the server pump and the rejector plate. The rejector plate is coupled to a chassis cold plate via a thermal interface material, thereby forming a thermal interface. The thermal interface is configured along a plane that is non-perpendicular to an insertion vector of the electronics server into a server rack chassis. In some embodiments, the thermal interface plane is parallel to the insertion vector. The rejector plates for each of the electronics servers are coupled to the chassis cold plate in this manner. The chassis cold plate includes one or more heat exchanging elements.

The chassis cold plate includes fluid channels which are coupled via fluid lines to a liquid-to-air heat exchanging system. The liquid-to-air heat exchanging system includes a heat rejector, one or more fans, and an external pump. The chassis cold plate, the heat rejector, the external pump, and fluid lines connected thereto form a second closed loop.

Fluid is pumped through the first closed loop such that heat generated by each heat generating device on the electronics server is transferred to the fluid flowing through each respective MCP coupled to the heat generating devices. The heated fluid flows into the fluid channels within the rejector plate. Within the second closed loop system, fluid is pumped through the fluid channels in the chassis cold plate by the external pump. Heat within the fluid flowing through each rejector plate is transferred through a thermal interface to the chassis cold plate and to the fluid flowing through the chassis cold plate. Heated fluid within the chassis cold plate is pumped to the heat rejector within the liquid-to-air heat exchanging system, where heat is transferred from the fluid to the air. Fluid flowing in the first closed loop system is independent of fluid flowing in the second closed loop system.

In a second embodiment, the liquid-to-air heat exchanging system of the first embodiment is replaced by an external water supply. In operation, fresh water from the external water supply flows to the chassis cold plate. Heat from the chassis cold plate is transferred to the water. The heated water flows from the chassis cold plate to the external water supply, where the heated water is disposed.

In a third embodiment, the chassis cold plate is modified with quick connects and the rejector plate is removed from each electronics server such that the fluid lines within the liquid based cooling system of each electronics server are coupled directly to the micro-channels within the chassis cold plate via the quick connects. The fluid lines within each liquid based cooling system are modified with appropriate fittings to couple with the quick connects on the chassis cold plate.

Other features and advantages of the present invention will become apparent after reviewing the detailed description of the embodiments set forth below.

Brief Description of the Drawings

Figure 1 illustrates a perspective view of an exemplary cooling system according to the first embodiment of the present invention.

Figure 2 illustrates a side view of the nth electronics server coupled to the liquid-to-air heat exchanging system.

Figure 3 illustrates a side view of an exemplary cooling system according to a second embodiment of the present invention.

Figure 4 illustrates an exemplary heat transfer configuration between a mating surface of the rejector plate and a mating surface of the chassis cold plate.

Figure 5 illustrates a side view of an exemplary cooling system according to the third embodiment of the present invention.

The present invention is described relative to the several views of the drawings. Where appropriate and only where identical elements are disclosed and shown in more than one drawing, the same reference numeral will be used to represent such identical elements.

Detailed Description of the Present Invention

Embodiments of the present invention are directed to a cooling system that transfers heat generated by one or more heat generating devices on a electronics server to a liquid-to-air heat exchanging system. The cooling system described herein can be applied to any electronics sub-system that is mounted to a backplane, including but not limited to, a blade server and a rack server. A server chassis is configured to house multiple electronics servers. Each electronics server is coupled to a backplane or mid-plane within the server chassis. Each electronics server includes one or more heat generating devices as is well known in the art. Integrated onto each electronics server is a cooling system. In some embodiments, the cooling system is a liquid-based cooling system. Each liquid-based cooling system includes a server pump and one or more microchannel cold plates (MCP). Preferably, each liquid-based cooling system is configured with one MCP for each heat generating device on the electronics server. The MCPs and the server pump are preferably mounted to the electronics server. Fluid lines couple the MCPs and the server pump. Alternatively, any means for transporting fluid within a sealed environment can be used. The server pump is any conventional pump, including, but not limited to, an electro-osmotic pump and a mechanical pump. In other embodiments, heat pipes or conduction means are used instead of the liquid-based cooling system.

In a first embodiment, the liquid based cooling system for each electronics server includes a rejector plate. The fluid lines coupling the MCPs and the server pump are also coupled to the rejector plate with fluid channels configured therein. The MCPs, the server pump, the rejector plate, and the fluid lines connected thereto form a first closed loop. Each server chassis includes at least one chassis cold plate. The rejector plate is coupled to the chassis cold plate via a thermal interface material. The rejector plates for each of the electronics servers are coupled to the chassis cold plate in this manner such that all rejector plates, and therefore the cooling system for each electronics server, are coupled to the chassis cold plate. Each electronics server is installed into a backplane along an insertion vector. The thermal interface between the rejector plate of the electronics server and the chassis cold plate is formed along a non-perpendicular plane relative to the insertion vector. In some embodiments, the thermal interface plane is parallel to the insertion vector. In order to couple the rejector plate to the chassis cold plate, a mounting mechanism is used.

The chassis cold plate includes fluid channels which are coupled via fluid lines to a liquid-to-air heat exchanging system. The liquid-to-air heat exchanging system includes a heat rejector, one or more fans, and an external pump. Fluid lines couple the chassis cold plate to the heat rejector, the heat rejector to the external pump, and the external pump to the chassis cold plate. The chassis cold plate, the heat rejector, the external pump, and the fluid lines connected thereto form a second closed loop. At least one blowing fan is preferably included to generate airflow over the surface of the heat rejector. The heat rejector is preferably a counter flow radiator. In some embodiments, the entire chassis cold plate and the liquid-to-air heat exchanging system is included within a single enclosure, such as the server housing. In other embodiments, a portion of the chassis cold plate extends external to the server housing and the liquid-to-air heat exchanging system is remotely located to the server housing.

In operation, within the liquid based cooling system for each electronics server, fluid is pumped through the fluid lines and the MCPs by the server pump such that heat generated by each heat generating device on the electronics server is transferred to the fluid flowing through each respective MCP coupled to the heat generating devices. Heat is transferred from the heat generating devices to the fluid flowing through the MCPs, and the heated fluid flows into the fluid channels within the rejector plate. Within the second closed loop system, fluid is pumped through the fluid channels in the chassis cold plate by the external pump. Thermal characteristics of the rejector plate, the chassis cold plate, and the thermal interface material between the rejector plate and the chassis cold plate are configured such that heat within the fluid flowing through each rejector plate is transferred to the fluid flowing through the chassis cold plate. Heated fluid within the chassis cold plate is pumped to the heat rejector within the liquid-to-air heat exchanging system, where heat is transferred from the fluid to the air. The cooled fluid exits the liquid-to-air heat exchanging system and is pumped back to the chassis cold plate.

Figure 1 illustrates a perspective view of an exemplary cooling system 10 according to the first embodiment of the present invention. The cooling system 10 includes a chassis housing 12 for housing a back plane 20, a chassis cold plate 60, and a liquid-to-air heat exchanging system 70. The cooling system 10 is configured to cool up to N electronics servers. A first electronics server 30, a second electronics server 32, and an nth electronics server 34 are each mounted and electronically coupled to the back plane 20. For purposes of discussion, each electronics server 30, 32, 34 includes two processors. It is understood that each electronics server can be configured independently and that each electronics server can include more or less than two processors. Coupled to each electronics server 30, 32, 34 is a liquid based cooling system that includes at least one server pump 40, an MCP 42, an MCP 44, and a rejector plate 50. Preferably, the liquid based cooling system includes one MCP for each processor on the corresponding electronics server. In this exemplary case in which each electronics server 30, 32, 34 includes two processors, each liquid based cooling system includes two corresponding MCPs, preferably one per processor.

Preferably, the server pump 40 is a mechanical pump. Alternatively, the server pump 40 is an electro- osmotic pump. However, it is apparent to one skilled in the art that any type of pump is alternatively contemplated. Preferably, each MCP 42, 44 is a fluid-based, micro-channel heat exchanger of the type described in U.S. Patent No. 7,000,684, which is hereby incorporated by reference. However, it is apparent to one skilled in the art that any type of fluid-based heat exchanger is alternatively contemplated. Preferably, the rejector plate 50 is configured with micro-channels that maximize a surface area exposed to a fluid passing therethrough.

A bottom surface of the rejector plate 50 is thermally coupled to a top surface of the chassis cold plate 60. In this manner, the rejector plate 50 for each electronics server 30, 32, 34 is thermally coupled to the chassis cold plate 60. The chassis plate 60 is preferably configured with micro-channels that maximize a surface area exposed to a fluid passing there through.

Each of the electronics servers 30, 32, 34 is coupled to the backplane 20 along an insertion vector. The insertion vector is perpendicular to the backplane 20. A thermal interface between the rejector plate 50 and the chassis cold plate 60 is formed along a non-perpendicular plane relative to the insertion vector. In some embodiments, the thermal interface plane is parallel to the insertion vector.

The liquid-to-air heat exchanging system 70 includes an external pump 72, a heat rejector 74, and a fan 76. The external pump 72 and the heat rejector 74 are coupled to the chassis cold plate 60. Preferably, the external pump 72 is a mechanical pump. Alternatively, the external pump 72 is an electro-osmotic pump. However, it is apparent to one skilled in the art that any type of pump is alternatively contemplated. The heat rejector 74 is preferably a radiator with micro-channels and fins positioned closely together. More preferably, the heat rejector 74 is a counter flow radiator of the type described in U.S. Patent No. 6,988,535, which is hereby incorporated by reference. However, it is apparent to one skilled in the art that any type of heat rejector is alternatively contemplated. The fan 76 comprises one or more blowing fans for generating air flow across and/or through the heat rejector 74.

Figure 2 illustrates a side view of the nth electronics server 34 coupled to the liquid-to-air heat exchanging system 70. As shown in Figure 2, the server pump 40 is coupled to the MCP 42 by one or more fluid lines 46. The MCP 42 is coupled to the MCP 44 by one or more fluid lines 46. The MCP 44 is coupled to the rejector plate 50 by one or more fluid lines 46. The rejector plate 50 is coupled to the server pump 40 by one or more fluid lines 46. The fluid lines 46 are metallic or non-metallic.

Although the MCP 42 and the MCP 44 are shown in Figure 2 as being coupled in series, alternative configurations are also contemplated. For example, each MCP within a given liquid based cooling system can be configured in parallel such that fluid reaching any of the MCPs has not previously passed through, and been heated by, another MCP. In this manner, fluid reaching any MCP configured in parallel is cooler than if the fluid first passes through a serially connected MCP. In such an alternative configuration, the server pump 40 is coupled to the MCP 42 by one or more fluid lines 46, and separate fluid lines couple the server pump 40 to the MCP 44. In this alternative embodiment, one or more fluid lines couple the MCP 42 to the rejector plate 50 and one or more fluid lines couple the MCP 44 to the rejector plate 50. Alternatively, the one or more fluid lines leaving the MCP 42 and the one or more fluid lines leaving the MCP 44 are joined prior to coupling with the rejector plate 50. In yet other alternative configurations, multiple MCPs are configured in any combination of series and parallel configurations.

The MCP 42, the MCP 44, the rejector plate 50, the server pump 40, and the fluid lines 46 form a first closed loop through which fluid flows. A function of the liquid-based cooling system of Figure 2, which includes the first closed loop, is to capture heat generated by the two processors (not shown) on the electronics server 34. The MCP 42 is thermally coupled to a first processor on the electronics server 34. Similarly, the MCP 44 is thermally coupled to a second processor on the electronics server 34. As fluid flows through the MCP 42, heat from the first processor is transferred to the fluid. As fluid flows through the MCP 44, heat from the second processor is transferred to the fluid.

The type of fluid used in the liquid-based cooling system is preferably water-based. Alternatively, the fluid within the liquid-based cooling system is based on combinations of organic solutions, including but not limited to propylene glycol, ethanol and isopropanol (IPA). Still alternatively, the fluid within the liquid-based cooling system is a pumped refrigerant. The fluid used in the liquid-based cooling system also preferably exhibits a low freezing temperature and has anti-corrosive characteristics. Depending on the operating characteristics of the liquid-based cooling system and the electronics server processors, in one embodiment, the fluid exhibits single phase flow while circulating within the liquid-based cooling system. In another embodiment, the fluid is heated to a temperature to exhibit two phase flow, wherein the fluid undergoes a phase transition from liquid to a vapor or liquid/vapor mix.

The heated fluid flows from the MCPs 42, 44 into the micro-channels within the rejector plate 50. Heat is transferred from the heated fluid within the micro-channels to the material of the rejector plate 50. A thermal interface material 62 provides efficient heat transfer between the rejector plate 50 and the chassis cold plate 60 so that heat from the rejector plate 50 is transferred to the material of the chassis cold plate 60. The thermal interface material 62 is preferably a compliant material such as thermal grease, solder, or any type of thermally conducting gap filling material.

As shown in Figure 2, the chassis cold plate 60 is coupled to the external pump 72 by one or more fluid lines 64. The chassis cold plate 60 is coupled to the heat rejector 74 by one or more fluid lines 64. The heat rejector 74 is coupled to the external pump 72 by one or more fluid lines 64. The fluid lines 64 are metallic or non-metallic. The chassis cold plate 60, the heat rejector 74, the external pump 72, and the fluid lines 64 form a second closed loop through which fluid flows. The fluid in second closed loop preferably comprise the same type of fluid discussed above in relation to the first closed loop. The fluid in the second closed loop is independent of the fluid in the first closed loop.

A function of the second closed loop and the liquid-to-air heat exchanging system 70 is to transfer heat from the chassis cold plate 60 to the ambient. As fluid flows through the micro-channels within the chassis cold plate 60, heat from material of the chassis cold plate 60 is transferred to the fluid. The heated fluid flows to the heat rejector 74.

As the heated fluid flow through the heat rejector 74, heat is transferred from the fluid to the material of the heat rejector 74. The fan 76 blows air over the surface of the heat rejector 74 such that heat is transferred from the heat rejector 74 to the ambient. Preferably, the chassis 12 (Figure 1) includes intake vents and exhaust vents through which air enters and leaves the cooling system 10 (Figure 1). Cooled fluid leaving the heat rejector 74 flows back to the chassis cold plate 60.

Figure 3 illustrates a side view of an exemplary cooling system according to a second embodiment of the present invention. The cooling system 110 can be identical to the cooling system 10 of Figure 1 with the exception that the liquid-to-air heat exchanging system 70 (Figure 1) of cooling system 10 is replaced by an external water supply 170. The external water supply 170 represents a continuous running water supply, such as the public water supply provided to most commercial and residential facilities. Alternatively, the external water supply 170 represents an external source of any type of fluid to which heat is transferred. In operation of the cooling system 110, fresh water from the external water supply 170 flows to the chassis cold plate 60. Heat from the chassis cold plate 60 is transferred to the water in the same manner as that described in relation to cooling system 10 (Figure 1). The heated water flows from the chassis cold plate 60 to the external water supply 170, where the heated water is disposed. Pressure from the water entering the fluid lines 64 from the external water supply 170 is sufficient to circulate the water through the chassis cold plate 60 and back to the external water supply for disposal. Alternatively, an external pump is coupled to the fluid lines 64 between the external water supply 170 and the chassis cold plate 60 to pump the water to the chassis cold plate 60.

In both the cooling system 10 (Figure 1) and the cooling system 110 (Figure 3), heat conduction between the first closed loop (the electronics server loop) and the second closed loop (the external cooling loop) plays a role in the overall thermal performance of the cooling system. Figure 4 illustrates an exemplary embodiment of a heat transfer configuration between a mating surface of the rejector plate 50 and a mating surface of the chassis cold plate 60 coupled together via the thermal interface material 62. In the configuration shown in Figure 4, the two mating surfaces of the rejector plate 50 and the chassis cold plate 60 are configured as wedges. A thick portion of the rejector plate wedge 50 is aligned with a thin portion of the chassis cold plate wedge 60. A thin portion of the rejector plate wedge 50 is aligned with a thick portion of the chassis cold plate wedge 60. By sliding the electronics server into the back plane the wedge shapes cause pressure between the rejector plate wedge 50 and the chassis cold plate 60. This pressure serves to form an enhanced thermal interface. In the first closed loop, heated fluid flows from the MCPs 42 and 44 (Figures 2 and 3) to the thick portion of the rejector plate wedge 50. Cooled fluid flows out of the thin portion of the rejector plate wedge 50 to the server pump 40 (Figures 2 and 3). In the second closed loop, fluid flows from the liquid-to-air heat exchanging system 170 (Figure 2), or the external water supply 170 (Figure 3), to the thick portion of the chassis cold plate wedge 60. Heated fluid flows out of the thin portion of the chassis cold plate 60 to the liquid-to-air heat exchanging system 70 (Figure 2), or the external water supply 170 (Figure 3). Each of the rejector plate wedge 50 and the chassis cold plate wedge 60 include channeled features to enable efficient heat transfer from the flowing fluid of the first closed loop, to the wedge interface, the flowing fluid of the second closed loop. In alternative embodiments, the rejector plate 50 and the chassis cold plate 60 are configured using dimensions and shapes different than wedges.

A mounting mechanism 66 secures the rejector plate wedge 50 to the chassis cold plate 60. The mounting mechanism 66 can include clips, screw, or any other conventional retention mechanism.

In a third embodiment, the chassis cold plate is modified with quick connects and the rejector plate is removed from each electronics server such that the fluid lines within the liquid based cooling system of each electronics server are coupled directly to the micro-channels within the chassis cold plate via the quick connects. The fluid lines within each liquid based cooling system are modified with appropriate fittings to couple with the quick connects on the chassis cold plate. In an alternative configuration of the third embodiment, the quick connects are configured onto the fluid lines of the liquid based cooling system, and the chassis cold plate is configured with appropriate fittings to couple with the quick connects on each electronics server.

Figure 5 illustrates a side view of an exemplary cooling system 210 according to the third embodiment of the present invention. Although cooling system 210 is shown in Figure 5 as including only a single electronics server 134, it is understood that the cooling system 210 also includes a chassis housing (not shown) and a back plane (not shown) configured to hold up to N electronics servers in a manner similar to that described in relation to cooling system 10 in Figure 1. For purposes of discussion, each electronics server within the cooling system 210 is described as including two processors. It is again understood that each electronics server in the cooling system 210 can be configured independently and that each electronics server can include more or less than two heat generating devices, such as processors.

A liquid based cooling system is coupled to the electronics server 134. The liquid based cooling system includes an MCP 142 and an MCP 144 coupled together via one or more fluid lines 146. The liquid based cooling system includes one MCP coupled to each processor on the electronics server 134. Each MCP 142, 144 is functionally equivalent to the MCPs 42, 44 (Figures 1-3)

The cooling system 210 includes the liquid-to-air heat exchanging system 70 coupled to a chassis cold plate 160 via one or more fluid lines 164. The chassis cold plate 160 is configured with micro-channels that enhance a surface area exposed to a fluid passing there through. The chassis cold plate 160 is also configured with quick connects 170 and 172. The fluid lines 146 are configured with appropriate fittings to couple with the quick connects 170 and 172. In the cooling system 210, the fluid lines 146 are coupled directly to the micro-channels of the chassis cold plate 160 via the quick connects 170, 172. In this manner, the liquid based cooling system coupled to electronics server 134, the chassis cold plate 160, the heat rejector 74, the external pump 72, and the fluid lines 164 form a single closed loop. Within this closed loop, the fluid is pumped by the external pump 72. The type of fluid used in the cooling system of the third embodiment is the same type of fluid used in the cooling system 10 of the first embodiment.

Although Figure 5 shows a single quick connect 170 through which fluid flows from the chassis cold plate 160 to the fluid lines 146, the quick connect 170 is representative of one or more physical quick connects through which fluid flows from the micro-channels in the chassis cold plate 160 to the one or more fluid lines 146. Similarly, although Figure 5 shows a single quick connect 172 through which fluid flows from the fluid lines 146 to the chassis cold plate 160, the quick connect 172 is representative of one or more physical quick connects through which fluid flows from the one or more fluid lines 146 to the micro-channels in the chassis cold plate 160.

Although the MCP 142 and the MCP 144 are shown in Figure 5 as being coupled in series, alternative configurations are also contemplated. For example, each MCP within a given liquid based cooling system is configured in parallel. In such an alternative configuration, the quick connects 170 are coupled to the MCP 142 by one or more fluid lines 146, and separate fluid lines couple the quick connects 170 to the MCP 144. In this alternative embodiment, one or more fluid lines couple the MCP 142 to the quick connects 172 and one or more fluid lines couple the MCP 144 to the quick connects 172. Alternatively, there is not a one to one relationship between the number of quick connects 170 to the number of MCPs in the liquid based cooling system, and there is not a one to one relationship between the number of MCPs and the number of quick connects 172. In yet other alternative configurations, multiple MCPs are configured in any combination of series and parallel configurations.

A function of the liquid-based cooling system of Figure 5, which includes the MCPs 142, 144 and the fluid lines 146, is to capture heat generated by the two processors (not shown) on the electronics server 134. The MCP 142 is thermally coupled to a first processor on the electronics server 134. Similarly, the MCP 144 is thermally coupled to a second processor on the electronics server 134. As fluid flows through the MCP 142, heat from the first processor is transferred to the fluid. As fluid flows through the MCP 144, heat from the second processor is transferred to the fluid.

The heated fluid flows from the fluid lines 146 into the micro-channels within the chassis cold plate 160 via the quick connect 172. As shown in Figure 5, the chassis cold plate 160 is coupled to the external pump 72 by one or more fluid lines 164. In addition, the chassis cold plate 160 is coupled to the heat rejector 74 by one or more fluid lines 164. The heated fluid in the micro-channels of the chassis cold plate 160 flows to the heat rejector 74 via fluid lines 164. The fluid lines 164 are metallic or non-metallic.

As previously described, a function of the liquid-to-air heat exchanging system 70 is to transfer heat from a fluid to the ambient. As the heated fluid flow through the heat rejector 74, heat is transferred from the fluid to the material of the heat rejector 74. The fan 76 blows air over the outer surface of the heat rejector such that heat is transferred from the heat rejector 74 to the ambient. Cooled fluid leaving the heat rejector 74 flows back to the chassis cold plate 160 via fluid lines 164. The cooled fluid flows through the chassis cold plate 160 to the fluid lines 146 via the quick connect 170. The cooled fluid flows to the MCPs 142 and 144.

It is apparent to one skilled in the art that the present cooling system is not limited to the components shown in Figure 1-5 and alternatively includes other components and devices. For example, although not shown in Figure 1, the cooling system 10 can also include a fluid reservoir coupled to either the closed loop of the liquid based cooling system, the closed loop of the chassis cold plate 60, the heat rejector 74, the external pump 72, and the fluid lines 64, or both closed loops. The fluid reservoir accounts for fluid loss over time due to permeation.

When connecting an electronics server to a rack system through the use of quick disconnects, additionally factors are to be considered. One consideration is that such a liquid connection is made in the data room. Anytime a connection is made or broken, there is a chance for a leak. The connection also usually occurs as a separate step from the electrical connections which occur when the electronics server is inserted and locked into the rack. As a separate connection, this is not fail safe. For example, the processor can be turned on without having connected the cooling loop causing an overheating event or damage to the CPU. Another consideration is that if the cooling loop is correctly connected, the cooling loop on the electronics server will share the same fluid as the full rack system. Sharing the rack system fluid can lead to reliability issues, specifically clogging. The length scales of features in an efficient heat exchanger used to transfer heat from a processor are measured in microns. Chilled water lines can have scale and other particulate which may not be an issue at rack level cooling but can quickly clog a heat exchanger at the board level. Another consideration is that the level of control of materials used for larger scale cooling applications is also different then that for a electronics server cooling loop and corrosion may become an issue. For the independent cooling loop systems described above in relation to Figures 2 and 3, these considerations are eliminated.

Additionally, although each of the embodiments described above in regards to Figures 1-5 are directed to liquid-based cooling systems, alternative cooling systems, such as heat pipes and conduction means, can be used.

The present invention has been described in terms of specific embodiments incorporating details to facilitate the understanding of the principles of construction and operation of the invention. Such reference herein to specific embodiments and details thereof is not intended to limit the scope of the claims appended hereto. It will be apparent to those skilled in the art that modifications may be made in the embodiment chosen for illustration without departing from the spirit and scope of the invention.

CLAIMS

What is claimed is:

1. A cooling system for cooling a plurality of electronics servers, the cooling system comprising:
   a. a plurality of electronics servers, each electronics server including one or more heat generating devices;
   b. a plurality of fluid based cooling systems, one fluid based cooling system thermally coupled to a corresponding electronics server, wherein each fluid based cooling system includes a first fluid to receive heat transferred from the one or more heat generating devices of the corresponding electronics server;
   c. a second heat exchanging system including a second fluid and a heat rejector; and
   d. a thermal interface coupled to the plurality of fluid based cooling systems and the second heat exchanging system to transfer heat from the first fluid to the second fluid,

   wherein each of the plurality of electronics servers is configured to be inserted along an insertion vector into an electronics chassis, and wherein the thermal interface is disposed along a thermal interface plane that is non-perpendicular to the insertion vector.

2. The cooling system of claim 1 wherein each fluid based cooling system forms a first closed fluid loop.

3. The cooling system of claim 1 wherein the first fluid is physically isolated from the second fluid.

4. The cooling system of claim 1 wherein the thermal interface includes a chassis cold plate, wherein the chassis cold plate is configured with fluid channels.

5. The cooling system of claim 1 wherein the heat rejector and the thermal interface form a second closed fluid loop.

6. The cooling system of claim 5 wherein the second heat exchanging system further

comprises a first pump, wherein the first pump is included in the second closed fluid loop.

7. The cooling system of claim 1 wherein each fluid based cooling system includes a rejector plate, wherein each rejector plate is configured with micro-channels.

8. The cooling system of claim 7 wherein the thermal interface layer further comprises a thermal interface material to couple each rejector plate to the chassis cold plate.

9. The cooling system of claim 1 wherein the heat rejector comprises a radiator.

10. The cooling system of claim 1 wherein each fluid based cooling system further comprises one or more microchannel cold plates through which the first fluid flows.

11. The cooling system of claim 10 wherein one microchannel cold plate is coupled to each heat generating device.

12. The cooling system of claim 1 wherein each fluid based cooling system further comprises a second pump.

13. The cooling system of claim 1 wherein each electronics server comprises a blade server.

14. The cooling system of claim 1 wherein each electronics server comprises a rack server, and the electronics chassis comprises an electronics rack.

15. A cooling system for cooling an electronics server, the cooling system comprising:
   a. a electronics server including one or more heat generating devices;
   b. a fluid based cooling system thermally coupled to the electronics server, wherein the fluid based cooling system includes a first fluid to receive heat transferred from the one or more heat generating devices;
   c. a second heat exchanging system including a second fluid and a heat rejector; and
   d. a thermal interface coupled to the fluid based cooling system and to the second heat exchanging system to transfer heat from the first fluid to the

second fluid,

wherein the electronics server is configured to be inserted along an insertion vector into an electronics chassis, and wherein the thermal interface is disposed along a thermal interface plane that is non-perpendicular to the insertion vector.

16. The cooling system of claim 15 wherein the fluid based cooling system forms a first closed fluid loop.

17. The cooling system of claim 15 wherein the first fluid is physically isolated from the second fluid.

18. The cooling system of claim 15 wherein the thermal interface includes a chassis cold plate, wherein the chassis cold plate is configured with fluid channels.

19. The cooling system of claim 15 wherein the heat rejector and the thermal interface form a second closed fluid loop.

20. The cooling system of claim 19 wherein the second heat exchanging system further comprises a first pump, wherein the first pump is included in the second closed fluid loop.

21. The cooling system of claim 15 wherein the fluid based cooling system includes a rejector plate configured with micro-channels.

22. The cooling system of claim 21 wherein the thermal interface layer further comprises a thermal interface material to couple the rejector plate to the chassis cold plate.

23. The cooling system of claim 15 wherein the heat rejector comprises a radiator.

24. The cooling system of claim 15 wherein the fluid based cooling system further comprises one or more microchannel cold plates through which the first fluid flows.

25. The cooling system of claim 24 wherein one microchannel cold plate is coupled to each heat generating device on the electronics server.

26. The cooling system of claim 15 wherein the fluid based cooling system further comprises a second pump.

27. The cooling system of claim 15 further comprising a plurality of electronics servers, each electronics server including one or more heat generating devices, and a plurality of fluid based cooling systems, one fluid based cooling system thermally coupled to a corresponding electronics server, wherein each of the plurality of fluid based cooling systems is thermally coupled to the thermal interface.

28. The cooling system of claim 15 wherein each electronics server comprises a blade server.

29. The cooling system of claim 15 wherein each electronics server comprises a rack server, and the electronics chassis comprises an electronics rack.

30. A cooling system for cooling an electronics server, the cooling system comprising:
    a. a electronics server including one or more heat generating devices;
    b. a fluid based cooling system thermally coupled to the electronics server, wherein the fluid based cooling system includes a first fluid to receive heat transferred from the one or more heat generating devices;
    c. an external fluid supply to provide a fresh supply of a second fluid; and
    d. a thermal interface coupled to the fluid based cooling system and to the external fluid supply to receive the fresh supply of the second fluid and to transfer heat from the first fluid to the second fluid,

    wherein the electronics server is configured to be inserted along an insertion vector into an electronics chassis, and wherein the thermal interface is disposed along a thermal interface plane that is non-perpendicular to the insertion vector.

31. The cooling system of claim 30 wherein the fluid based cooling system forms a first closed fluid loop.

32. The cooling system of claim 30 wherein the first fluid is physically isolated from the second fluid.

33. The cooling system of claim 30 wherein the thermal interface includes a chassis cold

plate, wherein the chassis cold plate is configured with fluid channels.

34. The cooling system of claim 30 further comprises a first pump coupled between the external fluid supply and the thermal interface.

35. The cooling system of claim 30 wherein the fluid based cooling system includes a rejector plate configured with micro-channels.

36. The cooling system of claim 35 wherein the thermal interface layer further comprises a thermal interface material to couple the rejector plate to the chassis cold plate.

37. The cooling system of claim 30 wherein the fluid based cooling system further comprises one or more microchannel cold plates through which the first fluid flows.

38. The cooling system of claim 37 wherein one microchannel cold plate is coupled to each heat generating device on the electronics server.

39. The cooling system of claim 30 wherein the fluid based cooling system further comprises a second pump.

40. The cooling system of claim 30 further comprising a plurality of electronics servers, each electronics server including one or more heat generating devices, and a plurality of fluid based cooling systems, one fluid based cooling system thermally coupled to a corresponding electronics server, wherein each of the plurality of fluid based cooling systems is thermally coupled to the thermal interface.

41. The cooling system of claim 30 wherein the external fluid supply comprises an external water supply that provides a fresh supply of water.

42. The cooling system of claim 30 wherein each electronics server comprises a blade server.

43. The cooling system of claim 30 wherein each electronics server comprises a rack server, and the electronics chassis comprises an electronics rack.

44. A cooling system for cooling an electronics server, the cooling system comprising:

a. a electronics server including one or more heat generating devices;

b. a fluid based cooling system thermally coupled to the electronics server, wherein the fluid based cooling system includes a fluid to receive heat transferred from the one or more heat generating devices;

c. a second heat exchanging system including a heat rejector; and

d. a thermal interface coupled to the fluid based cooling system and to the second heat exchanging system to direct the fluid to the heat rejector to transfer heat from the fluid to the air,

wherein the electronics server is configured to be inserted along an insertion vector into an electronics chassis, and wherein the thermal interface is disposed along a thermal interface plane that is non-perpendicular to the insertion vector.

45. The cooling system of claim 44 wherein the fluid based cooling system, the thermal interface, and the heat rejector form a closed fluid loop.

46. The cooling system of claim 44 wherein the thermal interface includes a chassis cold plate, wherein the chassis cold plate is configured with fluid channels.

47. The cooling system of claim 44 wherein the second heat exchanging system further comprises a pump, wherein the pump is included in the closed fluid loop.

48. The cooling system of claim 44 wherein the heat rejector comprises a radiator.

49. The cooling system of claim 44 wherein the fluid based cooling system further comprises one or more microchannel cold plates through which the fluid flows.

50. The cooling system of claim 49 wherein one microchannel cold plate is coupled to each heat generating device on the electronics server.

51. The cooling system of claim 44 further comprising a plurality of electronics servers, each electronics server including one or more heat generating devices, and a plurality of fluid based cooling systems, one fluid based cooling system thermally coupled to a corresponding electronics server, wherein each of the plurality of fluid based cooling systems is coupled to the thermal interface to enable fluid flow from each of the

plurality of fluid based cooling systems to the thermal interface.

52. The cooling system of claim 51 wherein each of the plurality of fluid based cooling systems is coupled to the thermal interface via a plurality of quick connects.

53. The cooling system of claim 44 wherein each electronics server comprises a blade server.

54. The cooling system of claim 44 wherein each electronics server comprises a rack server, and the electronics chassis comprises an electronics rack.

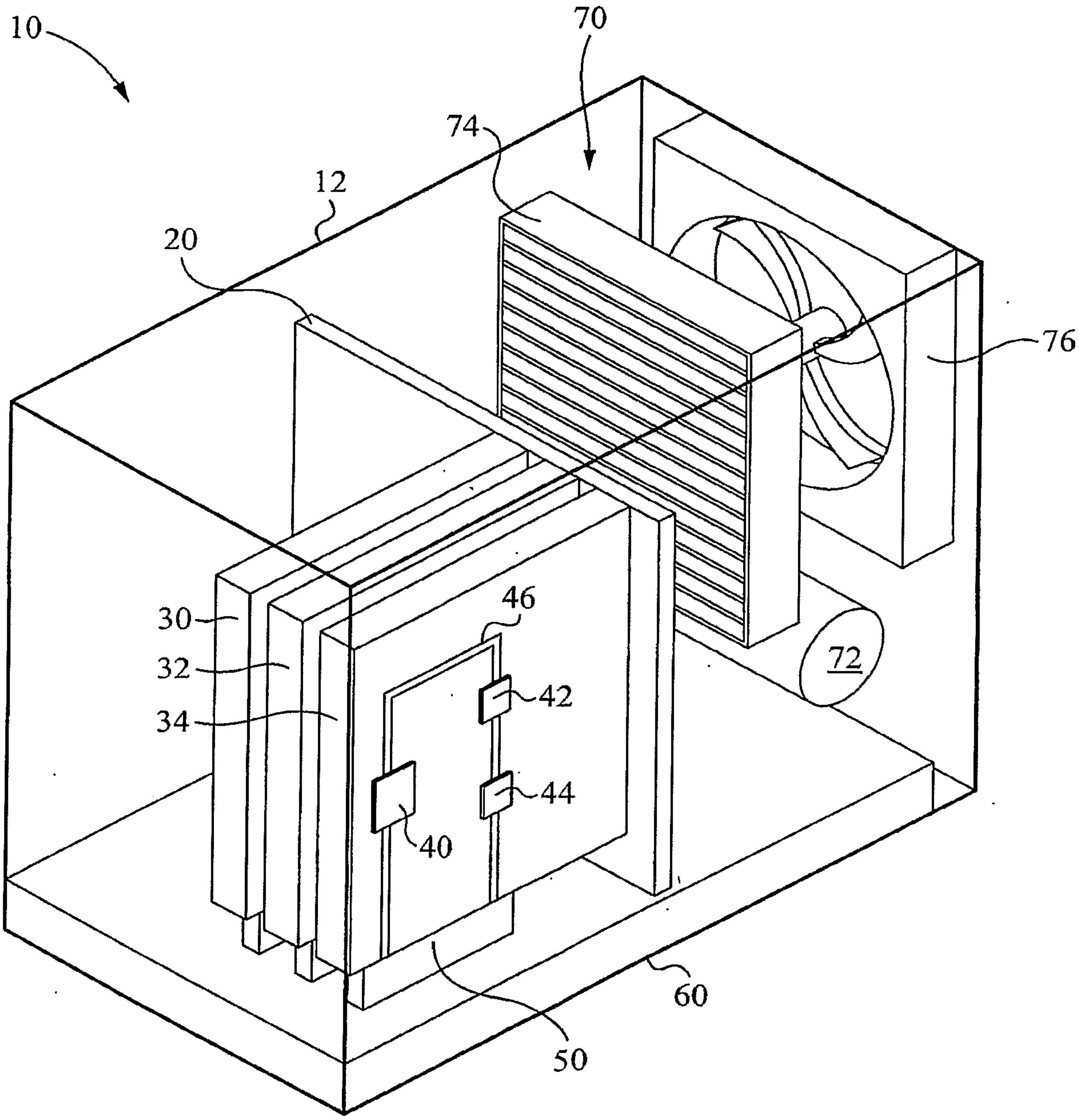

Fig. 1

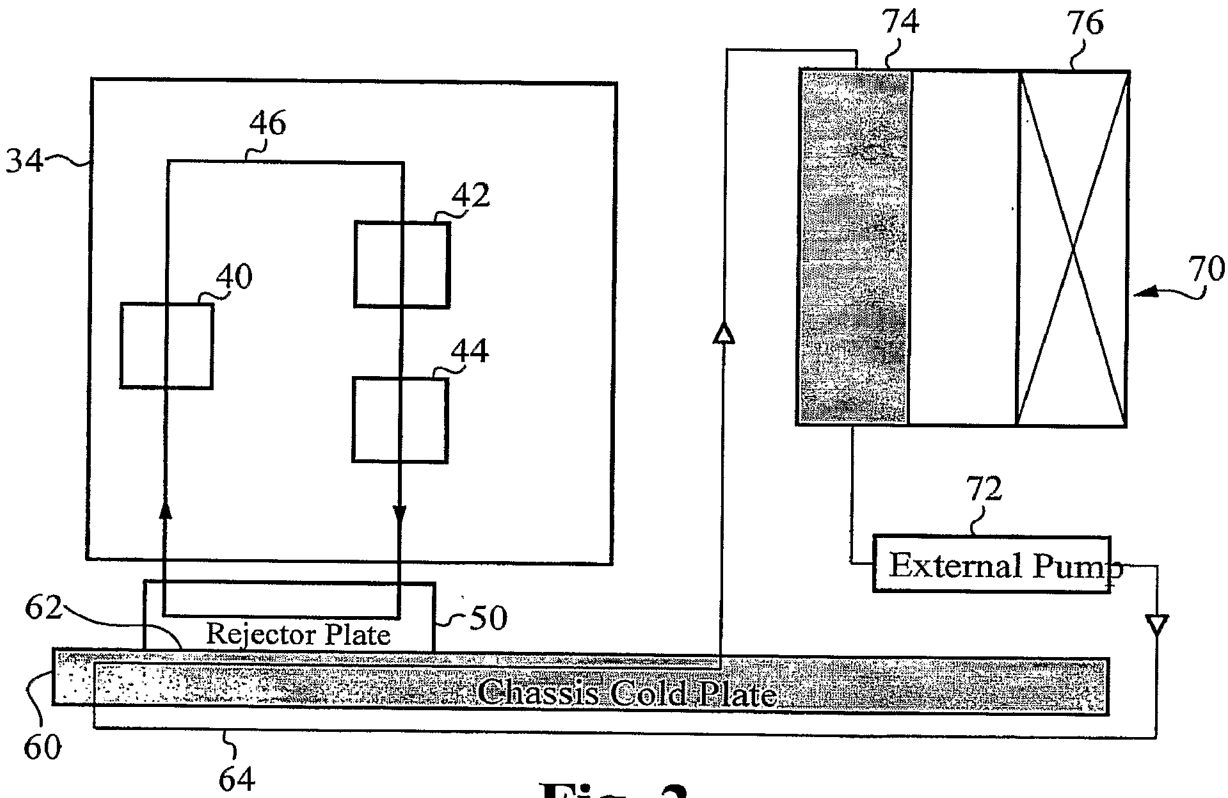
74
76
46
34
42
40
70
44
72
External Pump
62
Rejector Plate
50
Chassis Cold Plate
60
64

Fig. 2

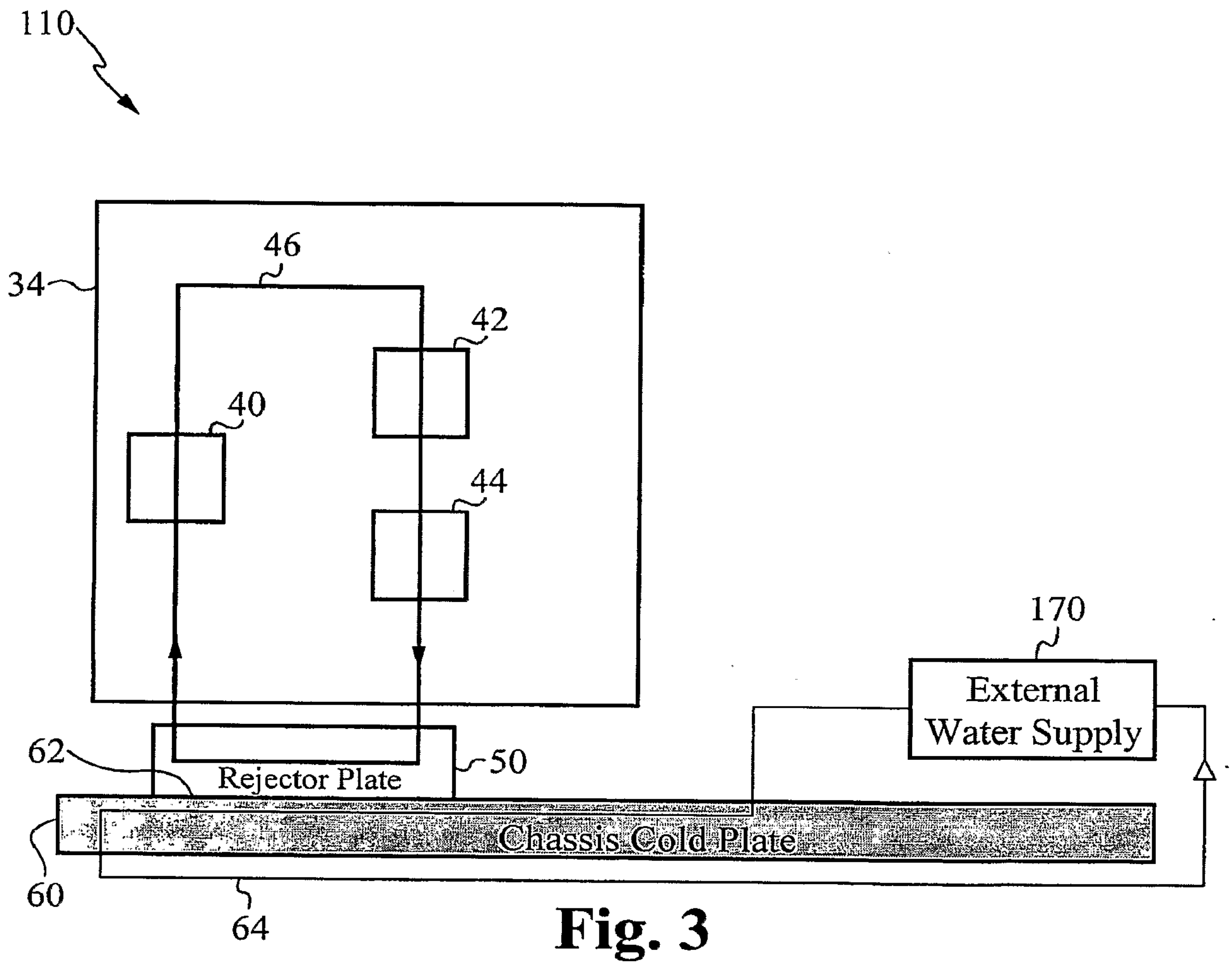
110
34
46
42
40
44
170
External
Water Supply
62
Rejector Plate
50
Chassis Cold Plate
60
64

Fig. 3

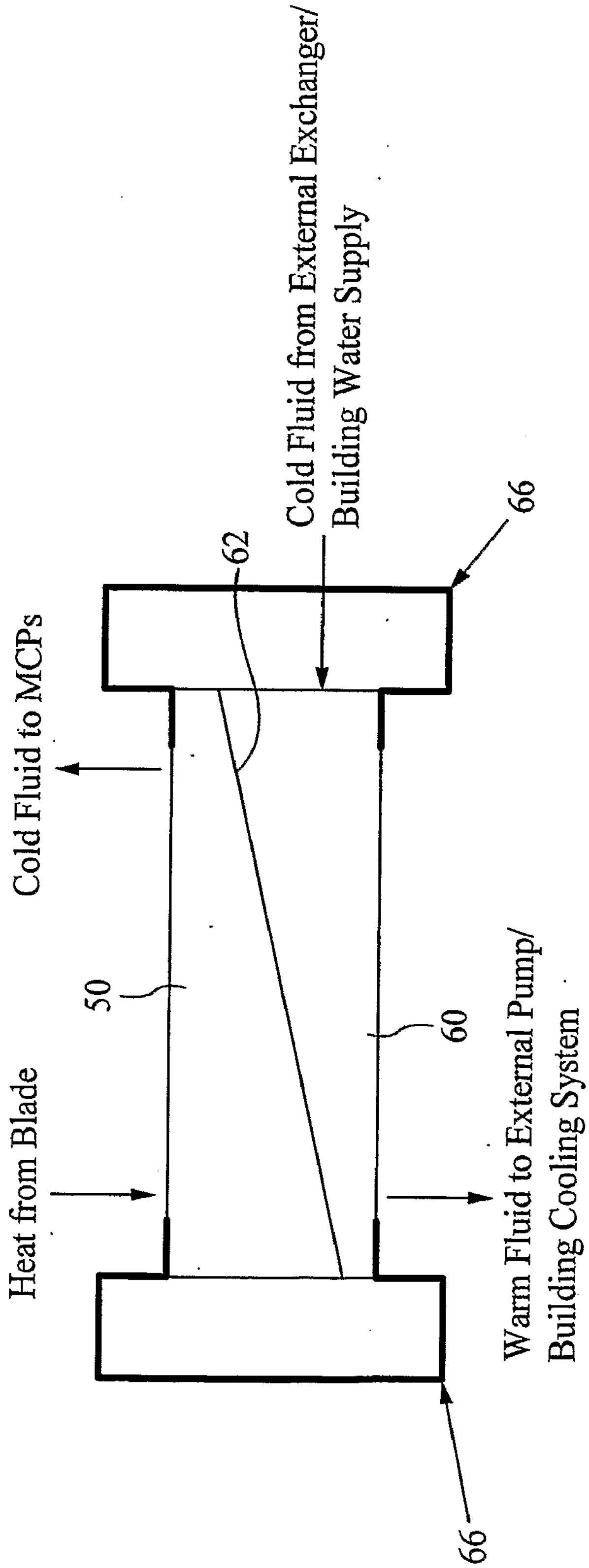
Cold Fluid from External Exchanger/
Building Water Supply
66
62
Cold Fluid to MCPs
50
60
Heat from Blade
Warm Fluid to External Pump/
Building Cooling System
66

Fig. 4

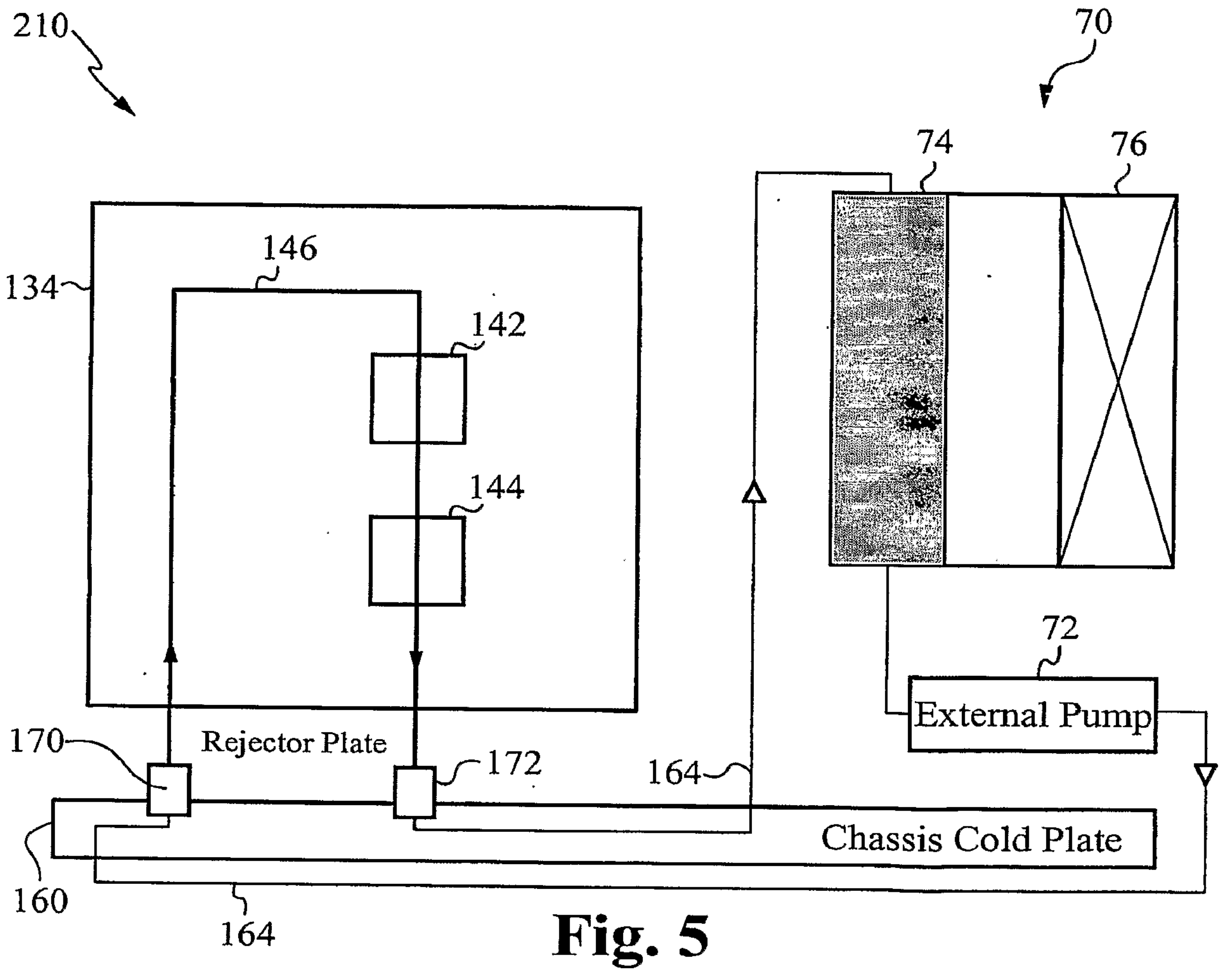
210
70
74
76
134
146
142
144
72
External Pump
170
Rejector Plate
172
164
Chassis Cold Plate
160
164

Fig. 5