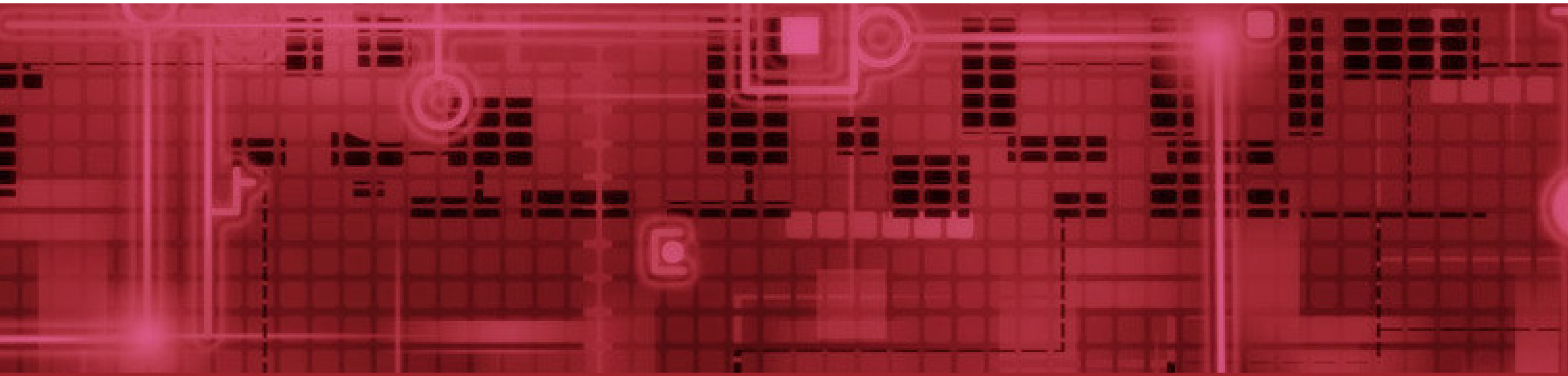


Technology Review

Liquid Cooling, 2010 to 2011

Qpedia continues to present new technologies developed for electronics cooling applications. The selected patents below were awarded in recent years to developers finding new methods to address cooling challenges. This Technology Review series will increase your awareness of the historic developments and the latest breakthroughs in both product design and applications.

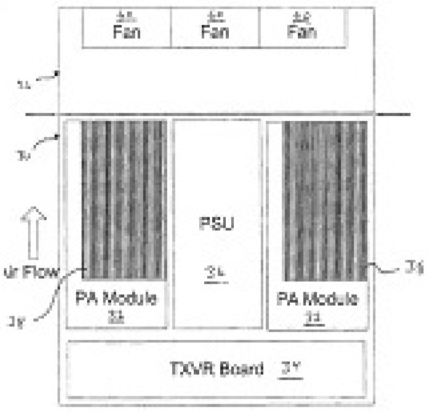
These newly patented technologies show the breadth of development in thermal management product sectors. Please note that there are many patents within these areas. We are presenting a small number to offer a representation of the entire field. You are encouraged to do your own patent investigation. Further, if you have been awarded a patent and would like to have it included in these reviews, please send us your patent number or patent application.

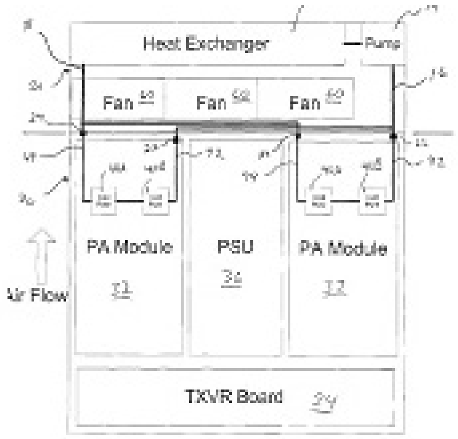
In this issue our spotlight remains on liquid cooling. There is much discussion about its deployment in the electronics industry, and these patents show some of the salient features that are the focus of different inventors.

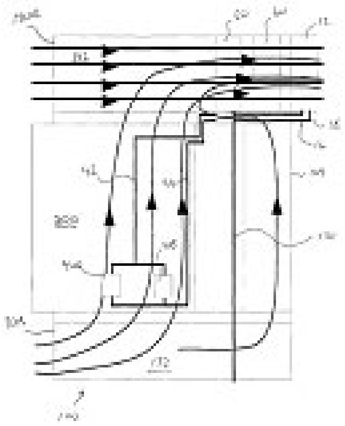
PATENT NUMBER	TITLE	INVENTORS	DATE OF AWARD
7,701,714 B2	LIQUID-AIR HYBRID COOLING IN ELECTRONICS EQUIPMENT	Shabany	Apr. 20, 2010
2010/0313590 Al	LIQUID-COOLED COOLING APPARATUS, ELECTRONICS RACK AND METHODS OF FABRICATION THEREOF	Campbell, et al.	Dec. 16, 2010
7,913,507 B2	ELECTRONIC EQUIPMENT COOLING SYSTEM	Kondo, et al.	Mar. 29, 2011
8,035,972 B2	METHOD AND APPARATUS FOR LIQUID COOLING COMPUTER EQUIPMENT	Ostwald, et al.	Oct. 11, 2011

LIQUID-AIR HYBRID COOLING IN ELECTRONICS EQUIPMENT

7,701,714 B2, Shabany







A hybrid cooling system is provided for use within an electronics chassis. As provided, the chassis includes a base portion that has a fan and heat exchanger mounted thereon. An electronics module is selectively engage-able with the base portion in a manner to have air displaced across the electronics module when engaged. The electronics module also includes a conduit for carrying cooling fluid that may be utilized to cool one or more portions of the electronic module. The conduit includes an inlet connector and an outlet connector for connection with a source of cooling fluid associated with the base portion of the chassis. In this regard, the base portion includes conduits that are in fluid communication with the heat exchanger. These conduits include mating connectors for connection to the inlet and outlet connectors of the electronics module.

The inlet and outlet connectors of the electronics module couple with the mating connectors of the base portion when the electronics module is engaged with the base portion. Further, a fluid flow path may be established through the conduit of the electronics module for cooling purposes. In this regard, the airflow may be passed over a surface of the electronics module in conjunction with fluid flow passing through the conduit on the electronics module. The base portion will typically further include a pump that is located thereon and which is in fluid communication with the heat exchanger and conduits in order to move fluid through the conduits and the heat exchanger and, hence, the electronics module.

In addition to coupling with the mating connectors of the base portion when the electronics module is engaged, the inlet and outlet connectors of the electronics module are also operative to disengage the mating connectors when the electronics is disengaged from the base portion. Further, the mating connectors and/or the inlet and outlet connectors of the electronics module may be operative to form a fluid-tight seal upon disengagement. In this regard, such connectors may be drip-free connectors that prevent fluid spillage within the electronics chassis.

The system may be utilized in one or more different chassis configurations. For instance, the base portion, including the fan and heat exchanger, as well as the electronics modules, may be housed within a common structure. In one arrangement, such a common structure may include vertical side-walls wherein the electronics modules are vertically aligned with the sidewalls. In such an arrangement, the chassis may be compatible with ATCA standards. In other arrangements, the chassis may include a plurality of individual modules that are horizontally disposed between opposing sidewalls. An example is a cabinet or rack including 1U, 2U, etc., electronics modules such as servers.

In one arrangement, a fan within the chassis is adapted to both provide airflow across the electronics module(s) disposed therein, as well as provide airflow circulation over the heat exchanger. In one arrangement, the fan is operative to draw air across the electronics module(s) while blowing air across the heat exchanger. In another arrangement, different sets of fans may be utilized to generate airflow within the chassis. In such arrangements, airflow may be blown across the electronics module(s) and/or drawn across the module(s) in conjunction with blowing and/or drawing air across the heat exchanger.

In order to provide a self-contained unit, the cooling system may also include a reservoir of cooling fluid and/or one or more manifolds for supplying cooling fluid to the individual slots within the chassis.

The chassis may utilize connectors that allow for a drip-free connection when an electronics module is engaged therein. Further, such connectors may allow for automatic or near automatic engagement and disengagement with the chassis. In any arrangement, a plurality of electronics modules may share a common cooling system that provides fluid cooling thereof and/or that provides airflow cooling over the electronics modules. According to another aspect, an electronics module is provided for engagement with a slot of an electronics chassis.

The module includes an electronics board supporting one or more electrical components (e.g., power sources, circuit boards, processors, etc.). The electronics board also includes at least a first cooling plate that is thermally contacting a first portion of the electronics board. This cooling plate includes an internal conduit. Interconnected to this internal conduit are inlet and outlet conduits for carrying cooling fluid to and from the cooling plate. The ends of these inlet and outlet conduits include connectors for fluidly connecting the conduits with an external fluid cooling system within an electronics chassis.

The module further includes a trigger mechanism that is adapted to move the connectors between open and closed positions. In this regard, the connectors may be engaged with mating connectors when in an open position and may be locked therewith in a closed position.

LIQUID-COOLED COOLING APPARATUS, ELECTRONICS RACK AND METHODS OF FABRICATION THEREOF

2010/0313590 Al, Campbell, et al.

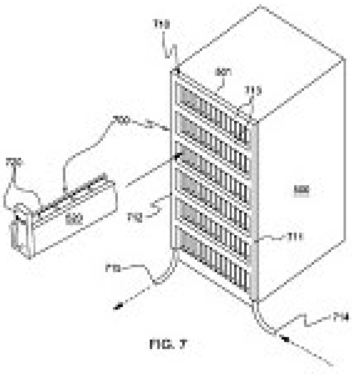


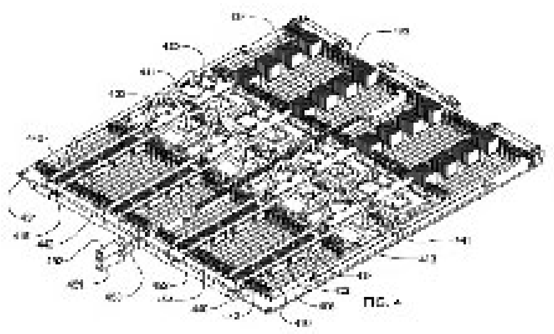
FIG. 7

The shortcomings of the prior art are overcome and additional advantages are provided through the provision of a cooling apparatus for facilitating cooling of an electronic subsystem. The cooling apparatus includes a liquid-cooled cooling structure and a heat transfer element.

The liquid-cooled cooling structure is configured to mount to a front of a housing within which the electronic subsystem is configured to dock. The electronic subsystem is slide-able relative to the housing for docking or undocking thereof relative to the housing through the front of the housing. The liquid-cooled cooling structure includes a cold plate and comprises coolant-carrying channel extending there through. The cold plate is configured to couple to one or more heat-generating components of the electronic subsystem, and is configured to physically contact the liquid-cooled cooling structure when the liquid-cooled cooling structure is mounted to the front , cold plate is coupled to the one or more components of the electronic subsystem and the electronic subsystem is docked within the housing, wherein the cold plate provides a thermal transport path from the one or more components of the electronic subsystem to the liquid-cooled cooling structure, and the electronic subsystem is dockable within or undockable from the housing without affecting flow of coolant through the liquid-cooled cooling structure.

In another aspect, a liquid-cooled electronics rack is provided which includes:

- an electronics rack comprising a plurality of subsystem docking ports,
- a plurality of electronic subsystems slide-able relative to the plurality of subsystem docking ports through a front of the electronics rack for docking or undocking thereof relative to the electronics rack,
- and, a cooling apparatus for facilitating cooling of the plurality of electronic subsystems when docked within the electronics rack.



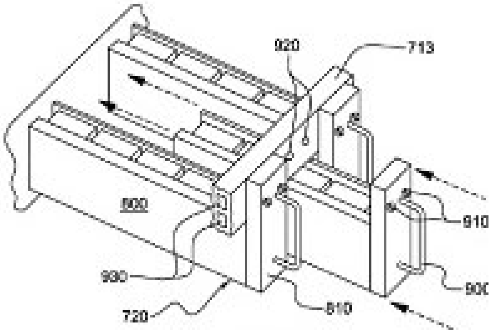


FIG. 9

The cooling apparatus includes a liquid-cooled cooling structure mounted to a front of the electronics rack, and a plurality of cold plates. The liquid-cooled cooling structure includes a cold plate and coolant-carrying channel extending there-through. Each cold plate is coupled to one or more components of a respective electronic sub-system of the plurality of electronic subsystems, and configured to physically contact the liquid-cooled cooling structure when the respective electronic subsystem is docked within the electronics rack, wherein each cold plate provides a thermal transport path from the one or more components of the respective electronic sub-system to the liquid-cooled cooling structure, and wherein the plurality of electronic subsystems are dockable within or undockable from the electronics rack without affecting flow of coolant through the liquid-cooled cooling structure.

In a further aspect, a method of fabricating a liquid-cooled electronics rack is provided. The method includes: employing an electronics rack comprising a plurality of sub-system docking ports, and a plurality of electronic sub-systems slide-able relative to the plurality of subsystem docking ports for docking or undocking thereof relative to the electronics rack; and providing a cooling apparatus for facilitating cooling of the plurality of electronic subsystems when docked within the electronics rack.

The providing of the cooling apparatus includes: mounting a liquid-cooled cooling structure to the electronics rack adjacent to the plurality of subsystem docking ports, the liquid-cooled cooling structure comprising a thermally conductive material and comprising at least one coolant-carrying channel extending there through; and providing a plurality of cold plate and securing each of them to one or more heat-generating components of a respective electronic subsystem of the plurality of electronic subsystems, each cold plate being configured to physically contact the liquid-cooled cooling structure when the respective electronic subsystem is docked within the electronics rack, wherein each cold plate provides a thermal transport path from the one or more heat-generating components of the respective electronic subsystem to the liquid-cooled cooling structure, and wherein the electronic subsystems are dockable within or undockable from the electronics rack without affecting flow of coolant through the liquid-cooled cooling structure.

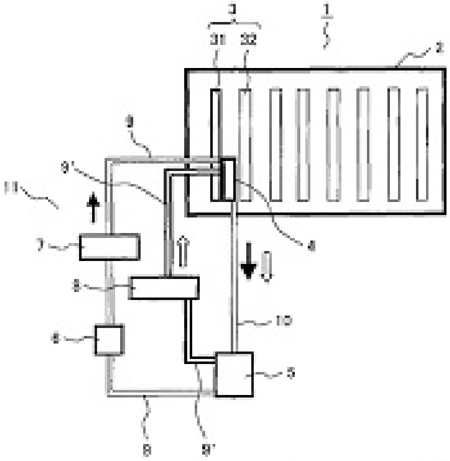
ELECTRONIC EQUIPMENT COOLING SYSTEM

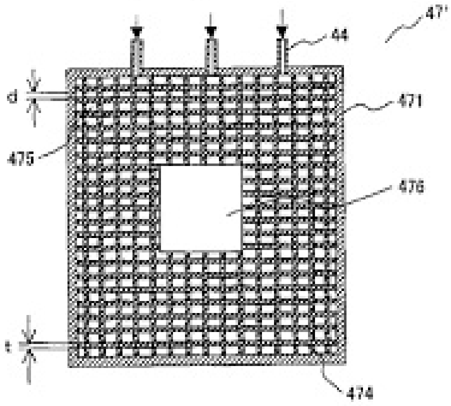
7,913,507 B2, Kondo, et al.

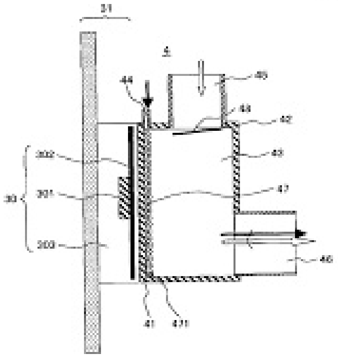
This invention provides an electronic equipment cooling system which can efficiently and stably cool heat generating components in electronic equipment even when the temperature of such components changes (due to a change in the load of the equipment).

According to one aspect of the invention, there is provided a cooling system for cooling a heat generating component in electronic equipment, which comprises: a heat receiver thermally connected to the heat generating component, the heat receiver including:

- a heat receiver base contacting the heat generating component and having a substantially flat surface,
- a box,
- a gas flow space surrounded by the heat receiver base and box,
- a liquid refrigerant inlet through which a liquid refrigerant dribbles down along an internal surface of the heat receiver base on the side of the gas flow space,







- a liquid refrigerant spreader for spreading the liquid refrigerant there across to form a film, the spreader having a mesh portion with an opening for passing a vapor of the refrigerant and releasing the vapor into the gas flow space,
- a gas inlet through which a gas used for vaporizing the refrigerant is fed from a blower,
- and a gas outlet for venting, from the gas flow space, the gas containing the vapor released from the spreader,
- and, a closed refrigerant circulation path, including:
    - the heat receiver
    - a refrigerant condenser
    - a refrigerant pump
    - and a refrigerant tank
    - and a closed gas circulation path, including: the heat receiver; the refrigerant condenser; and the blower.

In the above aspect of the present invention, the following modifications and changes can be made.

- The liquid refrigerant spreader is disposed along a substantially entire area of the internal surface of the heat receiver base.
- The size of the opening of the mesh portion of the liquid refrigerant spreader is from 0.2 to 1.8 mm.
- The mesh portion of the liquid refrigerant spreader is a plain weave of metal wires with a diameter of 0.2 to 0.5 mm.
- The liquid refrigerant spreader further includes a cut-out portion facing a semiconductor chip mounted on the heat generating component and having substantially the same projected shape as that of the semiconductor chip.
- The distance between the internal surface of the heat receiver base and a surface of the mesh portion of the spreader remote from the heat receiver base is from 1 to 1.5 mm.
- The temperature of the gas fed into the heat receiver is controlled, by means of a temperature control mechanism, to be higher than that of the liquid refrigerant dribbling down along the internal surface of the heat receiver base.

METHOD AND APPARATUS FOR LIQUID COOLING COMPUTER EQUIPMENT

8,035,972 B2, Ostwald, et al.

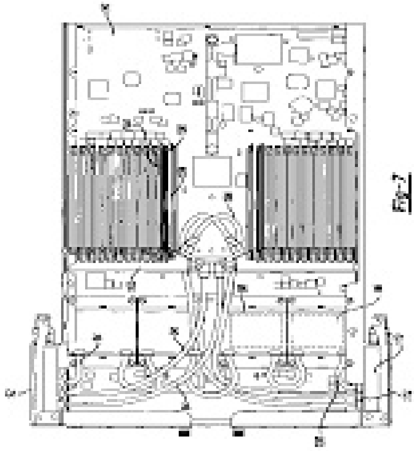
A non-pressurized system, or low pressure system, is disclosed for cooling computer components. A supply of coolant is provided at atmospheric or low pressure to an inlet side of the computer equipment that is circulated through tubing and channels formed in thermally conductive jackets that are assembled to computer equipment modules. (As used herein, the term low pressure should be understood to be less than 5 psi.) The coolant flows through the computer equipment modules and is drained from the modules to an open system that is maintained at atmospheric pressure.

In one embodiment, both the liquid inlet and liquid outlet sides of the system are open to atmospheric pressure. A liquid coolant is provided to the top of the cabinet or rack and is distributed in a controlled fashion down a vertical distribution manifold to a plurality of vertically spaced in-feed branches.

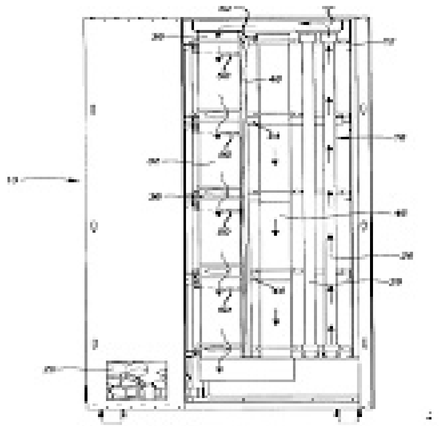
A constant supply of water is provided at a low pressure, or at atmospheric pressure, at each level of the distribution system. The in-feed branches may function as holding tanks for the liquid. The liquid flows through channels that are provided at locations adjacent to the electronic components to be cooled.

Liquid flowing through the channels absorbs heat directly from the electronic components and is ported to a drain branch or drain that removes the liquid from the electronic components. The liquid may be returned to the reservoir from which the coolant liquid was initially pumped in a closed loop system. The coolant liquid in the reservoir may be circulated to a coolant loop of a chiller or building coolant system.

Several advantages may be directly achieved as a result of providing a low pressure (gravity based) cooling system. Pressure causing liquid flow is limited and does not vary with the addition or removal of components that must be cooled in the system. The addition or removal of an electronics module will not affect head pressure or the flow of liquid to other modules because the in-feed branches function as holding tanks that are open to atmospheric pressure, or at low pressure. As water in the in-feed branches flows through the system, additional water flows by gravity to replenish the supply. The disclosed low pressure system does not require high pressure pumps that may vary depending upon pump speed or size. The low pressure also is not subject to electrical control variations.



Another advantage of using a low pressure liquid cooling circuit is that liquid connections are less prone to leakage and are consequently more reliable. Low pressure liquid connections are also less expensive than high pressure fluid connections. Another aspect of this disclosure relates to providing a cooling system for computer components on a computer equipment rack, or the like. Liquid is provided to the computer components at atmospheric, or at low pressure. Each computer card defines a plurality of channels that receive the liquid from the branch tank and directs the liquid around the electronic components to transfer heat from the electronic components to the liquid. A drain branch or other conduit that is maintained at atmospheric pressure receives the liquid from the channels.



According to other aspects of the cooling system, a reservoir may be provided that contains a liquid that is pumped to a discharge port, or weir, located above the computer equipment rack. A coolant feed manifold may receive liquid from the weir and directs the liquid by gravity flow to fill at least one branch tank that is disposed above at least one computer equipment card. The branch tank may be open to atmospheric pressure or otherwise maintained at low pressure. Similarly, the drain branch may also be simply maintained at atmospheric pressure. In this way, a balanced flow of coolant is provided to the computer equipment that is not affected by changes in the number of

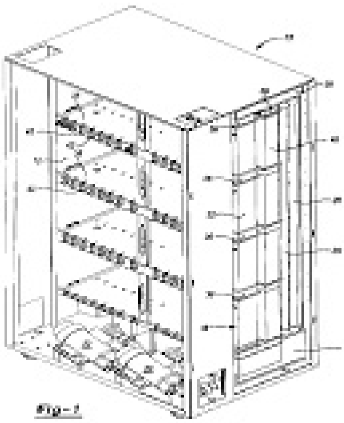


Fig-1

components to be cooled or other variations in the system.

According to another aspect of this disclosure, a method is provided for cooling computer equipment. The method includes providing a liquid to a circuit board that includes at least one channel, but preferably several channels, directing the liquid around the electronic components and transferring heat from the electronic components to the liquid. The liquid is ported from the channel to a manifold that is maintained at a 25 atmospheric pressure.

According to other aspects of the method, method may include pumping the liquid from a reservoir of cooling liquid to a weir, or discharge port. The liquid over-flow the weir into a vertical feed conduit and feeds the liquid from the vertical feed conduit to a diverter. The liquid is diverted from the vertical feed conduit to a tank that is open to atmospheric pressure.

The method may also include the step of restricting the flow of liquid to reduce noise by providing a porous member in the vertical feed conduit through which the liquid flows. Further, during the porting step, the flow of liquid from the channels may be adjusted to control the rate at which the liquid drains from the channel depending upon the cooling requirements of the components to be cooled. The method may also include the step of venting air from above the tank to maintain atmospheric pressure. The liquid may also be circulated from an external cooling system, such as a chiller or cooling tower, to maintain the temperature of the liquid in the reservoir at a relatively cool temperature.

According to another aspect of the disclosure, an article of 45 computer equipment is provided that includes a rack and a plurality of spaced rows of computer components that are assembled to the rack. The cooling system includes a reservoir for a cooling liquid and a pump that pumps the liquid from the reservoir to a discharge port disposed above the rack.

A feed column receives the liquid from the discharge port and directs the downward flow of the liquid. A first branch tank may be provided that is maintained at atmospheric pressure and is disposed above a first row of computer components. The first row of computer components may define a plurality of channels that receive the liquid from the first branch tank and direct the liquid around the electronic components. Heat is transferred from the electronic components through the channels and to the liquid.

The second branch tank is maintained at atmospheric pressure and is disposed above a second row of computer components. The second row of computer components defines a second plurality of channels that receive liquid from the second branch tank and direct the liquid around the second row of electronic components to transfer heat from the electronic components to the liquid. A drain column is provided that receives liquid from the channels to be returned to the reservoir.