Liquid Cooling, 1992 to 2003

In a new series, Qpedia reviews the different technologies that have been developed for electronics cooling applications. This series looks at the patents awarded to developers in industry and academia around the world who are actively involved in addressing cooling challenges. After reading the series, you will be more aware of both the historic developments and the latest breakthroughs in both product design and applications.

We are specifically focusing on patented technologies to show the breath of development in thermal management product sectors. Please note that there are many patents within these areas. Limited by article space, we are presenting a small number that offer some representation of the entire field. We do not mean to ignore the exceptional accomplishments of other inventors, and you are encouraged to do your own patent investigation. Further, if you have been awarded a patent and you would like to have it included in these reviews, please send us your patent number or patent application.

In this issue, the focus is on the liquid cooling. There is much discussion about its deployment in the electronics industry, and these patents show some of the salient features that different inventors have focused on. The following four patents are reviewed:

PATENT NUMBER	TITLE	INVENTORS	DATE OF AWARD
5,159,529	COMPOSITE LIQUID COOLED PLATE FOR ELECTRONIC EQUIPMENT	Lovgren, et al.	Oct. 27, 1992
5,871,042	LIQUID COOLING APPARATUS FOR USE WITH ELECTRONIC EQUIPMENT	Gutfeldt, et al.	Feb. 16, 1999
6,393,853 BI	LIQUID COOLING OF REMOVABLE ELECTRON-IC MODULES BASED ON LOW PRESSURE APPLYING BIASING MECHANISMS	Vukovic, et al.	May 28, 2002
6,580,609 B2	METHOD AND APPARATUS FOR COOLING ELECTRONIC COMPONENTS	Pautsch, G.W.,	Jun.17, 2003

COMPOSITE LIQUID COOLED PLATE FOR ELECTRONIC EQUIPMENT

5,159,529, Lovgren, et al.

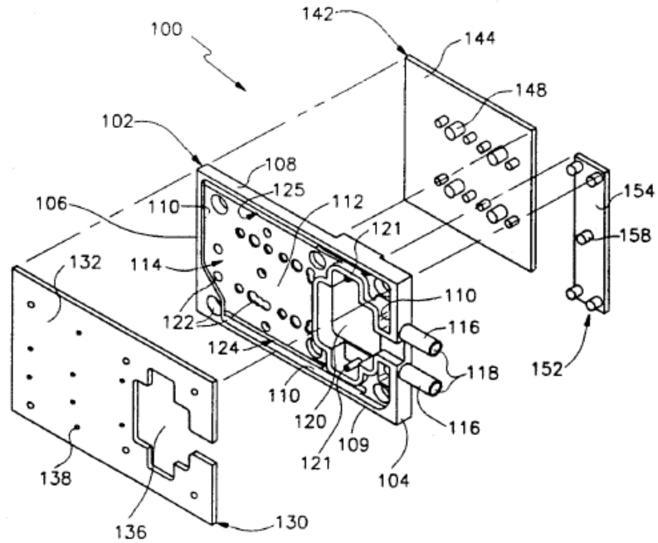
This invention features a coolant management system for cooling electrical components. The coolant management system consists of a heat transfer plate with a high thermal conductivity that is mounted to hot electronic components, and a coolant management system that directs coolant against the first heat transfer plate. The heat transfer plate is ideally made of copper. The coolant management system has a lower thermal conductivity than the heat transfer plate, and is preferably made from molded plastic material. When the heat transfer plate is attached to the coolant management system, a coolant cavity of desired flow characteristics is formed between them. The composite liquid cooled plate can accommodate a second heat transfer plate that can be attached to the coolant management system to form a second coolant cavity. With this option, the two coolant cavities may permit coolant flow between them via a fluid conduit.

The composite liquid cooled plate is easily manufactured and particularly lightweight. By restricting the use of copper or other material with a high thermal conductivity to only those areas of the plate requiring thermal conduction, the plate remains relatively lightweight and compact in size.

The invention also provides an optimized cooling path to direct coolant to areas requiring the greatest heat transfer. Therefore, if several electronic components are to be cooled, the plate may be configured to account for the individual cooling requirements of each electronic component. The coolant management system has coolant flow channels to direct coolant against the plate underneath "hot" components, thereby providing a short conduction path between "hot" components and the coolant.

A further advantage can be achieved in enhancing the final package design by first determining the layout of the device to be cooled and then routing the channels of the liquid cooled plate to areas that require the greatest heat transfer.

The following figures show the schematic of patent awarded to Lovgren, et al.



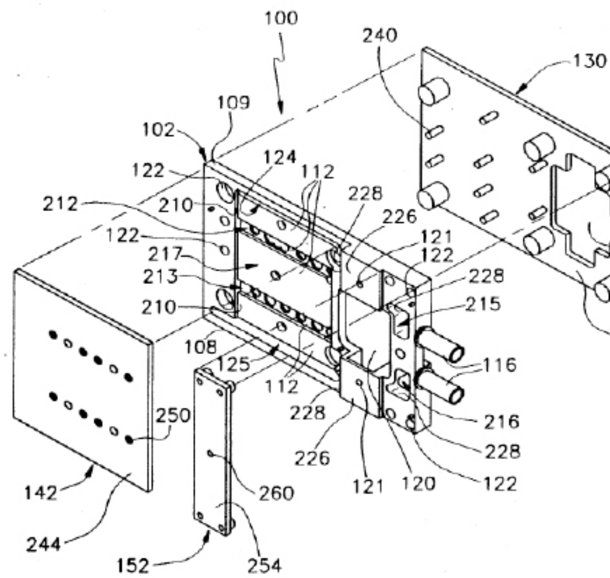
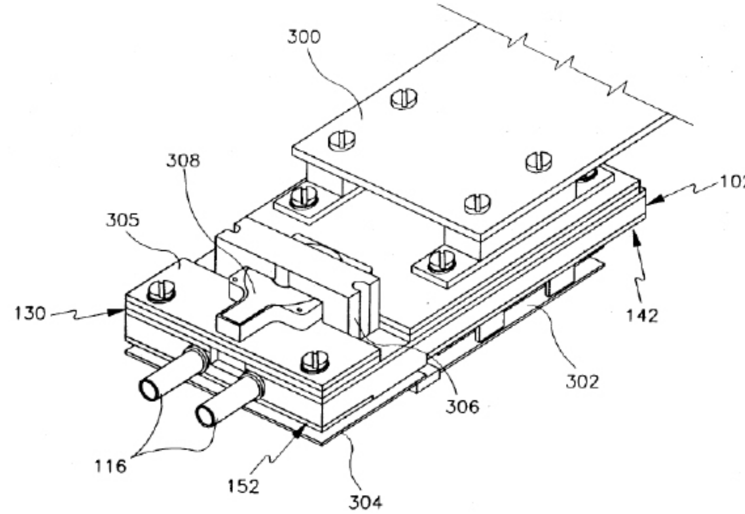


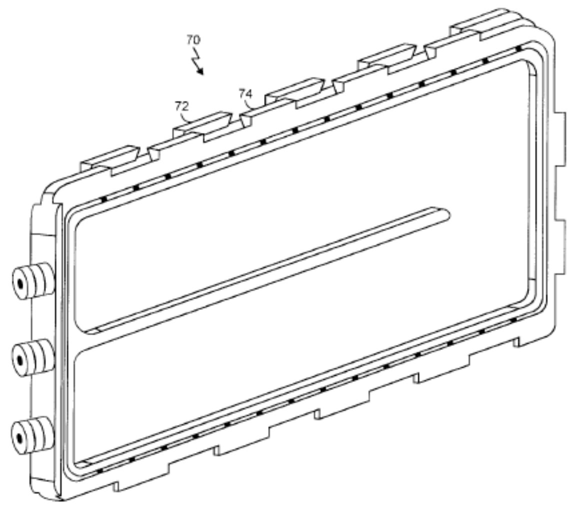
Fig.



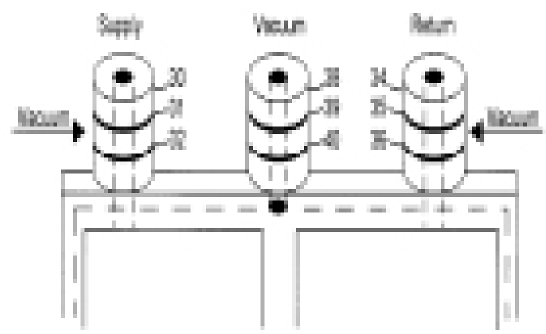
LIQUID COOLING APPARATUS FOR USE WITH ELECTRONIC EQUIPMENT

5,871,042, Gutfeldt, et al.

Electronic devices can generate heat and often require cooling in order to be maintained at an optimum operating temperature. Some liquid cooling designs are known and references are made to devices described in U.S. Pat. Nos. 4,109,707,4,938,279; 4,879,632; 4,997,032; 5,000,256; and 5,040,051. These devices typically use a plastic bag or some other container in which a cooled liquid is circulated. When the container is close to the electronic equipment, the equipment is cooled and can be maintained at an optimum operating temperature.

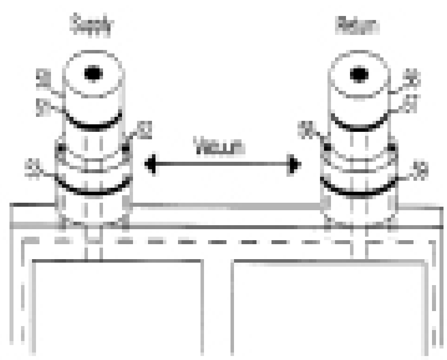


Electronic equipment such as printed circuit boards tends to have sharp protrusions including edges and soldered connections. Moreover, it is known that electronic equipment is very sensitive to liquids because liquids can corrode or short out the electronic components. However, many conventional containers employ membranes such as thin plastic that can easily tear. In conventional devices, a physical inspection is required to determine whether a leak has occurred. A limiting factor of current liquid cooling devices is that they do not offer adequate protection against leaks to prevent damage from occurring to the electronic components.



The goals for this invention are to overcome these limitations and to provide an apparatus that offers the benefits of liquid cooling along with an access method to for detecting leaks in the cooling device before damage takes place, and a way to protect the electronic components from any leakage.

The invention overcomes the identified problems. An exemplary embodiment of such a liquid cooling device includes a frame adapted to fit in a chassis with electronic equipment. An inner container and outer container are attached to the frame. A liquid inlet is disposed in the frame and has an opening in liquid flow communication with the inner container. A liquid outlet is disposed in the frame and has an opening in liquid flow communication with the inner container. A vacuum outlet is disposed in the frame and coupled to a space between the inner container and the outer container.



In one set up, a detector is coupled to the vacuum outlet and configured to detect air and/or liquid escaping from the vacuum outlet. In another set up, dual films may be sealed to one another with inlet, outlet and vacuum fittings, dispensing the need of a frame.

LIQUID COOLING OF REMOVABLE ELECTRONIC MODULES BASED ON LOW PRESSURE APPLYING BIASING MECHANISMS

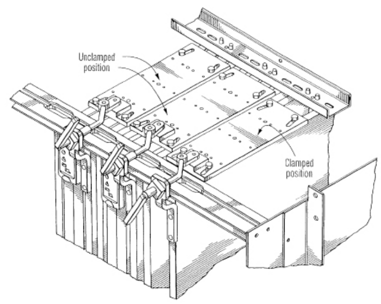
6,393,853 Bl, Vukovic, et al.

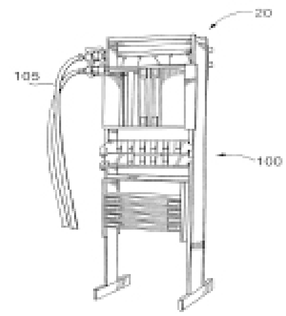
This invention addresses the liquid cooling of removable electronic modules. It describes an apparatus for cooling an electronic module in a shelf unit comprising a cold plate and a mechanism for moving cold plates toward and away from the module into operating and released positions, respectively, relative to the module when in place there, such that:

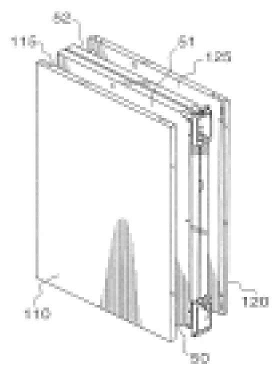
- when the cold plates have moved toward the module into the operating position, a surface of each said cold plate comes into heat transferring relationship with an associated surface of the module so that, in use, as a coolant flows through each cold plate, heat is transferred from the module to the coolant in each cold plate, and

- when the first and second cold plates have been moved away from the module into the released position; the module is spaced from the cold plates to enable the module to be readily removed from between the cold plates.

The invention is designed for electronic shelf unit used in the communications industry, but here it is populated with electronic modules. These modules are removable and supported by the shelf unit, the shelf unit comprises an apparatus for liquid cooling of an electronic module in a shelf unit. The system contains a biasing mechanism to provide pressure capable of forcing the first and second cold plates toward the module to provide close heat transferring relation between the plates and the module as the cooling liquid flows. A travel stop mounts the first and second cold plates together, and a spring is positioned between the first and second cold plates so that the spring force applies pressure forcing the first and second cold plates toward the module. In addition, the invention offers a fast, easy, drip free removal and replacement of liquid cooled high power electronics equipment.







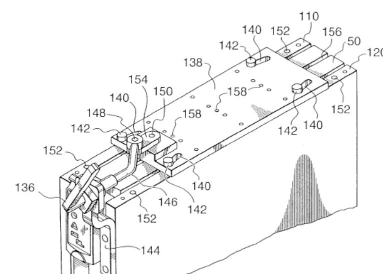
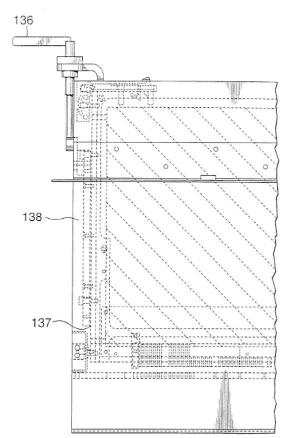


FIG. 3



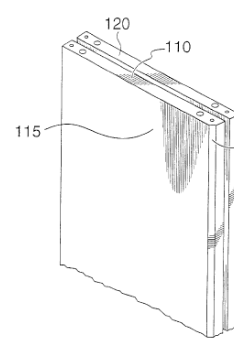


FIG. 5a

METHOD AND APPARATUS FOR COOLING ELECTRONIC COMPONENTS

6,580,609 B2, Pautsch, G.W.

Demand for higher performance supercomputers continues to create challenging thermal and packaging design environments for today's computer packaging engineers. As the performance of CRAY supercomputers continues to grow exponentially, in general agreement with Moore's law (Bar-Cohen, et al, 1988), the thermal and packaging solutions continue to become more complex. The increase of supercomputer performance over the last 30 years was initially achieved with an increase in the complexity of the computer's CPU by increasing the number of ICs within the CPU. The next step in performance was achieved by adding more gates per IC and increasing the clock rate. Performance was further increased by the paralleling of CPUs and then the scaling of groups of CPUs.

In order to continue on the path of Moore's law, we are again pushing the IC technology and ultimately the performance of each individual CPU. One technology that hasn't been able to keep pace with the ICs is printed circuit board (PCB) technology. The demands for component placement and IC net routings have exceeded the current state of the art in PCB technology.

One solution to this problem implements a multi-chip module with thin film routing layers (MCM-D) for the packaging of these high performance chip sets. This high density packaging design is, however, capable of producing heat fluxes on the ICs and MCM that approach values of 50 and 15 W/ cm^2, respectively. The control of the IC's junction temperature is important for its reliability and for the performance of two communicating devices. The amount of induced leakage "noise" that exists on an integrated circuit is also a function of its temperature.

A number of cooling methodologies have been described by

- Bar-Cohen, A., "Thermal Management of Electronic Components with Dielectric Liquids", JSME International Journal, Series B, vol. 36, No., 1993.
- Simons, R. E., "Bibliography of Heat Transfer in Electronic Equipment", 1989, IBM Corporation)
- Incropera, F. P., "Convection Heat Transfer in Electronic Equipment Cooling", Journal of Heat Transfer, Nov. 1988, Vol. 110/1097.
- Bergles, A. E., "Liquid Cooling for Electronic Equipment", International Symposium on Cooling Technology for Electronic Equipment, March 1987.

Studies by

- Chu, R. C., and Chrysler, G. M., "Electronic Module Coolability Analysis", EEP-Vol. 19-2, Advances in Electronic Packaging-1997 Volume 2, ASME 1997.
- Nakayama, W., "Liquid-Cooling of Electronic Equipment: Where Does It Offer Viable Solutions?", EEP-Vol. 19-2, Advances in Electronic Packaging-1997 Volume 2, ASME 1997.

However, there are indications that these approaches are no longer capable of satisfying today's high density packaging requirements (Chu and Chrysler, 1997), (Nakayama, 1997). As heat flux continues to increase, the most promising methods are those that utilize direct liquid cooling with dielectric fluids.

Direct liquid cooling circumvents the problems of high thermal interface resistance associated with conventional technologies and is capable of providing very high heat transfer rates (Bar-Cohen, 1993). A number of such direct liquid cooling techniques are described in "Thermal Management of Multichip Modules with Evaporative Spray Cooling," by G. W. Pautsch and A. Bar-Cohen, published in ASME Advances in Electronic Packaging 1999, EEP-Vol.26-2, 1453-1463, the discussion of which is incorporated herein by reference. That paper concluded that the method of choice for cooling high heat flux electronic components is described as "High Density, Pressure Atomized Evaporative Spray Cooling". This condition occurs when a fluid is sprayed on a surface at a rate that maintains a continuously wetted surface, whose temperature is less than 25°C above the saturation temperature of the thermal coolant. This method, with the selection of an appropriate fluid, such as Fluorinert™ FC-72 which has a boiling point of 56°C at standard atmospheric conditions, allows one to maintain high heat flux components at operating temperatures below 85°C. Each of the above cooling approaches has its deficiencies. What is needed is a system and method for cooling electronics components that addresses these deficiencies.

To address the problems stated above, and to solve other problems, a system and method for cooling electronic components is described herein. An enclosure is provided which includes a plurality of a first set of electronic components, cooling means for cooling a gas, and distribution means for directing the gas across the electronics components and the cooling means, where the distribution means forms a closed system limiting the transfer of the gas both into and out of the distribution means.

Several options for the enclosure are as follows. For instance, in one option, the cooling means includes a cooling coil and means for directing water through the cooling coil. In another option, the enclosure further includes means for spray evaporative cooling over a second set of electronic components. In yet another option, the first set of electronic components is low power components and the second set is high power components. In yet another embodiment, a system includes a chassis with one or more modules with a plurality of electronic components, where the chassis forms a closed internal system. The system further includes a gas distribution member positioned within the chassis and configured to direct a chilled gas toward the electronic components. A gas cooling device is positioned within the chassis and configured to cool the gas after the gas has been heated by the electronic components. Several options for the system are as follows. For instance, at least one of the modules includes a mechanical subsystem having multiple electronic modules and at least one fluid conditioning unit, and optionally at least one of the modules includes a spray evaporative cooling assembly. In yet another option, the gas cooling device includes a heat exchanger

In another set up, a system includes a chassis with one or more modules containing one or more electronic modules and at least one fluid conditioning unit, and at least one of the electronic modules includes at least one spray evaporative cooling assembly. The system further includes a gas distribution member positioned within the chassis and configured to direct a chilled gas toward the electronic components. The system further includes a gas cooling device positioned within the chassis that is configured to cool the gas after it has been heated by the electronic components.

Several options for the system are as follows. In one option, at least one spray evaporative cooling assembly and the at least one fluid conditioning unit form a closed system. In another option, the chassis forms a closed internal system. In another option, at least one fluid conditioning unit includes at least one pump and a heat exchanger. The spray evaporative cooling assembly, in another option, includes a fluid charged with a non-corrosive, inert gas, for example Nitrogen.

A method of cooling an electronics enclosure is provided in which air is forced over a first set of electronic components, cooling these components, heating a liquid to a temperature near its boiling point, directing the heated liquid against a second set of electronic components where at least portion of the heated liquid vaporizes, drawing the vapor and the heated liquid away from the electronics components, condensing the vapor back into liquid, and cooling the air and recirculating the air through the enclosure, where the air is maintained within the enclosure in a closed system.

Several options for the method are as follows. In one option, the method further includes recirculating the liquid, where the liquid and vapor are maintained within the enclosure in a closed system. In another option, the method further includes filtering the liquid, or charging the liquid with a non-corrosive gas. In another option, the heated liquid is directed against a second set of electronic components having a higher power than the first set of electronic components.
In yet another embodiment, a method of cooling an electronics enclosure having a plurality of electronics components includes directing a gas over electronic components to cool them, cooling the gas within the electronics enclosure, and recirculating the gas within the enclosure, where the air is maintained within the enclosure in a closed system.

Several options for the method are as follows. For instance, in one embodiment, cooling the gas includes passing the gas through a water cooled heat exchanger. Optionally, recirculating the gas includes directing the gas up sides of the enclosure to air plenums at the top of the enclosure. The method further optionally includes funneling the gas across heat sinks thermally coupled with the electronic components.