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Better cooling for high-power devices

Ditch the old liquid cold plate — this new system exploits the heat of vaporization

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Thermal management of high-power electronic devices has always been a challenge, and traditional cooling methods have not kept pace with the needs of applications requiring smaller footprints and higher output.

While air-cooling has been the method of choice for lower-power devices, the amount of space required is not conducive to a small footprint.

Water-cooling methods have several inherent downsides with high-power electronics. Conductive water can destroy a computer and cause life-threatening, catastrophic failure in a 10,000-A inverter. Water systems are also prone to thermal stack-up, where water flowing from one cold plate to the next picks up heat, providing less cooling as it flows.

Parker's Advanced Thermal Solutions Business Unit has developed a two-phase liquid cooling system said to be the world's first commercialization of the technology. We believe it will revolutionize the way high-power electronic devices are cooled, allowing platforms to have twice the power density in half the space.

Theory of operation

Parker's Vaporizable Dielectric Fluid (VDF) system offers a significantly more efficient method of heat transfer without the risk of electrical shorting due to a fluid leak.

Key components of the closed-loop system include the dielectric fluid, liquid cold plates, and a low-flow-rate pump. Noticeably absent from this system is a compressor.

Dielectric fluid

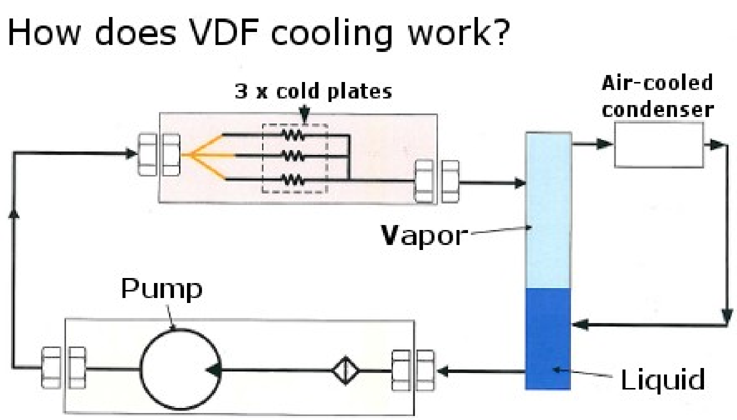
While most VDFs are suitable, Parker selected R134a, as it is a commonly used refrigerant found in most refrigerators and automobiles, is fully dielectric, flashes to gas at typical ambient temperatures, does not react with metals, and is intrinsically non-harmful. Newer fluids are being developed that have similar characteristics but better global warming ratings. Such fluids are expected to be a drop-in replacement.

Liquid cold plates

Typically designed for the component that will rest on top of it, cold plates are usually made from aluminum or copper. Unlike water-cooled systems, a VDF cold plate may be made from metals different from other parts of the system, as VDFs do not cause galvanic reactions. The direct contact between the plate and the heat-generating device allows for latent heat transfer, with the heat being carried away by the vaporizing fluid travelling through the plate. Multiple cold plates may be built into the system either in series or parallel to accommodate different components within the device.

Low-flow-rate pump

Specially adapted from pumps Parker had developed for aerospace and automotive applications, the unique, hermetically sealed pump employs the gear-pump method of flow management, where a turning gear within the pump's body uses displacement to create flow and suction to move the fluid.



The pump moves the fluid as a liquid through the loop at a pressure just above the levels where at ambient temperature the fluid would flash to gas. As it enters the cooling plate the fluid absorbs the heat from the component, causing some fluid to vaporize. The amount of fluid that vaporizes is directly proportional to the amount of heat to be transferred, which is then taken downstream in a two-phase liquid/gas mixture and away from the component, as illustrated in the VDF Cooling Loop diagram.

An important characteristic of this system is that the pressure and temperature are allowed to "float" relative to ambient conditions. This makes the system self-optimizing, so as heat loads increase, more fluid vaporizes, taking away more heat. Stack-up problems are eliminated because every cold plate's temperature is roughly the same regardless of where it is in the system, as the vaporization temperature is constant while the amount of vaporization is variable.

System advantages

Parker's new two-phase liquid cooling system offers a number of distinctive benefits.

VDF heat transfer efficiency is significantly greater than water, requiring less fluid, smaller line sets, and lower pump rates. The same dissipation rates provided by a 3 liter/min water flow can be achieved by a .05 liter/min VDC flow, allowing for a smaller system.

A smaller pump also consumes less power, which can be parasitically drawn from the system it is cooling rather than its own power source, which helps free up more area.

The system is virtually maintenance-free. The VDF is non-corrosive, requires no filtering, and is not subject to freezing. The low-power pump utilizes a brushless DC motor rated to provide 50,000-hr L10 continuous-duty life. The hermetically sealed assembly is designed to be leak-proof, but should a leak occur, the non-conductive fluid will not damage the electronic components. Dry-break connectors make for easy plug-and-play, field-replaceable modules needing minimal or no device downtime for scheduled maintenance or failure replacement.

Ramifications for the future

While VDF cooling offers more flexibility and performance for high-power electronics, certain applications are better suited than others. While standard box-type electronic devices might benefit, air-cooled heat-sink methodologies might still be the most cost-effective choice. VDF cooling will offer significant advantages for applications that:

- Are low-weight/small size-driven
- Have a propensity for high cyclical loads
- Call for more power output from a given device package (e.g., increased switching frequency or difficulty in paralleling devices)
- Require thermal and electrical contact
- Feature multiple loads in the cooling loop connected in series
- Need easy field-service via quick dry-break connectors
- High-voltage applications that use de-ionizing cartridges

Specific industries that are expected to benefit from Parker's new two-stage cooling system include:

- Hybrid and electric vehicles
- Industrial-power electronics
- Power transmission and distribution
- Alternative power generation
- Marine and rail propulsion
- Medical equipment
- Motor controls
- Telecommunications
- Military

The new cooling system developed by the Advanced Thermal Solutions Business Unit drew on core competencies from several of the company's divisions, including aerospace, electromechanical, flow control, refrigeration, and tubing and fittings. Featuring a number of proprietary and patent-pending elements, the first commercial applications are expected to go on-line in the summer of 2009.