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ATS's maxiFLOW™ heat sinks with an integral push-pin mounting system chosen one of the EDN Hot 100

Norwood, MA, November 21, 2011 – Advanced Thermal Solutions, Inc. (ATS) announced today that their maxiFLOW™ heat sinks, with integral push pin mounting, has been given the 2011 hot 100 award from Electronic Design News The award underscores ATS's commitment to innovations in thermal management.

Each heat sink comes with a pair of durable plastic or brass push. The pins run through opposite corners of the heat sinks and mount securely into 3.00 mm holes in the PCB laid out in industry standard patterns. Plastic pins are lighter and non-electrically conductive; brass pins have added strength and durability for more rugged applications or thicker devices. An integral spring on each pin provides approximately 2 lbs of retention load, depending on the height of the component and the PCB thickness.

The patented ATS maxiFLOW sinks feature a low profile, spread fin array that maximizes surface area for more effective convection (air) cooling in the restricted airflow conditions typical of today's condensed electronic packages. The heat sinks are fabricated from light weight, extruded aluminum which minimizes thermal resistance from the base to the fins. They have a protective green anodized surface.

Tests on maxiFLOW heat sinks with an airflow rate of just 100 lfm (linear feet per minute) show that device junction temperatures (Tj) can be reduced by more than 40 percent below the temperatures achieved using conventional straight-fin heat sinks.

The push pin mount maxiFLOW heat sinks are available in sizes ranging from 37.4 x 37.5 x 10.0 mm (L x W x H) up to 41.4 x 45.75 x 24.5 mm (L x W x H). Each maxiFLOW heat sink is provided preassembled with a Chomerics T766 phase change thermal interface material (TIM) for improved component-to-sink thermal transfer. The pad is centered on the base of the sink.

More information on push pin heat sinks is found on http://www.qats.com or by calling 781-769-2800.

Miniature-Scale Refrigeration

for Thermal Management

Looking back at "A History of the Internet: 1962-1992", the world's computer hosts have gone from 10,000 to over one million, computers are nine orders of magnitude faster and network bandwidth is twenty million times greater [1]. Since truncated at 1992, let's fast forward to today where we are seeing ever increasing demand for unlimited data promotions, upload and download drag races, increased bandwidth "how-tos" and challenging package requirements. These conditions have added stress to electronics and systems in addition to integrated circuitry's ever- increasing power and functionality. Such electrical engineering advances have occurred while thermal engineers are seeing the maximum allowable temperatures remaining the same or even decreases specified, as temperature is a key proponent for reliability. This has produced an increased focus on thermal engineering and maintained the non-commoditized market for thermal solutions of high capacity computing. Even with the great strides that have been made in the design of heat sinks, such as the maxiFLOW™ created by Advanced Thermal Solutions, there could come a point where effective refrigeration systems will be the only option. While commercial refrigeration cooling systems are available, smaller scale refrigeration units for electronics haven't been widely studied. This article will discuss the advantages and limitations along with experimentation results from testing a miniature-scale refrigeration system.

How is miniature defined? For the purpose of this article, and experimentation already performed, a miniature-scale refrigeration system will be defined as a system in which the heat exchangers have a maximum height of 45 mm (1-U rack) and the compressor has a maximum volume of 1000 cm^3. A schematic of the system is shown in Figure 1.

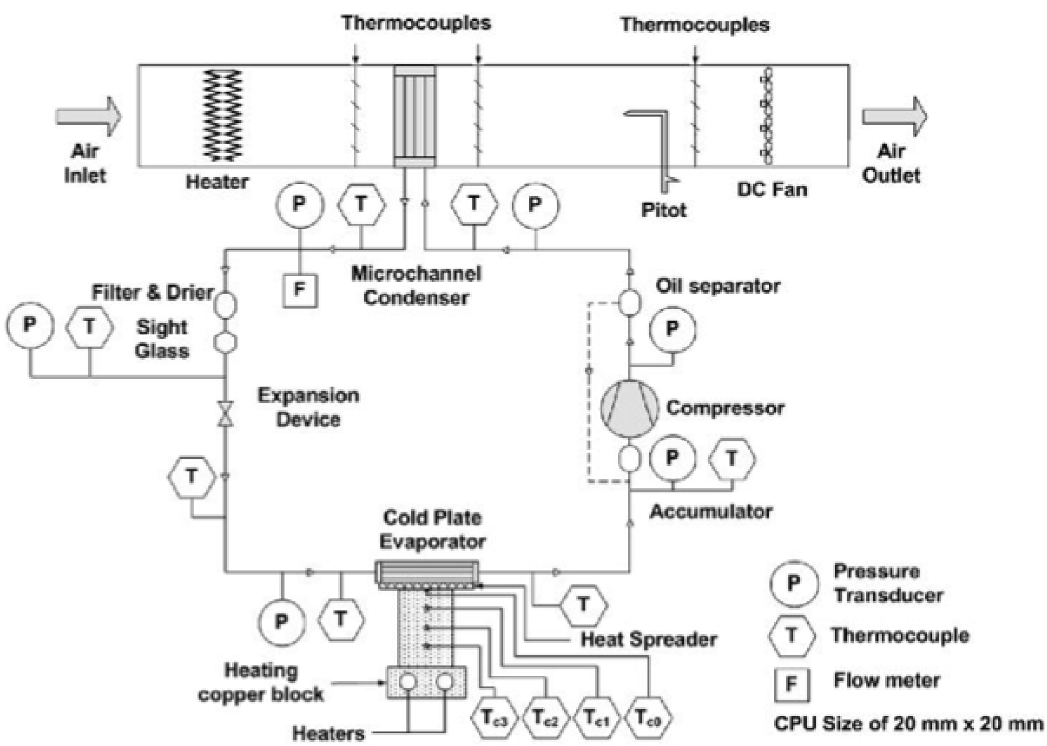

Figure 1. Miniature Scale Refrigeration System [2]

When discussing the benefits of deploying a reliable refrigeration system, we expect to maintain junction temperatures at or below the maximum limits when the system is operating at its maximum designed ambient temperatures. Based on the results of Trutassanawin [2], it was found that the chip heat dissipation rate of micro-refrigeration systems can be up to 14 times higher than that of the conventional air-cooled heat sinks and the overall system thermal resistance can be approximately 3 times lower. [3] The cooling capacity of a micro-refrigeration system is a function of the overall system thermal resistance, and for a given temperature difference between the chip surface and the surrounding air. It is defined as the following:

$$Q_{CPU} = \Delta T_{chip\text{-}air} / R_{\theta,sys} = (T_{chip} - T_{air}) / R_{\theta,sys} \quad (1)$$

Where Q_{CPU} is the heat generation rate of the CPU, T_{chip} is the surface temperature of the CPU, and T_{air} is the bulk temperature of the ambient entering the condenser. In some cases, negative values of thermal resistance can be introduced, such that despite ambient air temperature, devices will be able to run at lower operating temperatures, resulting in higher efficiency and reliability. Alternately, devices may be able to run at higher frequencies or perform more functions handling the increased heat dissipation capability. From experimentation, results showed that the system in the figure above was able to dissipate CPU heat fluxes of approximately 40–75 W/cm^2 and keep the junction temperature below 85ºC for a chip size of 20 mm^2. The performance of the Miniature-Scale Refrigeration System (“MSRS”) was characterized by the Coefficient of Performance (COP) of the refrigeration cycle and the COP of the overall system according to the following definitions:

$$COP_{refrig} = Q_{evap} / W_{comp} \quad (2)$$

$$COP_{MSRS} = Q_{evap} / W_{elec} \quad (3)$$

Where the overall system work, W_{elec}, includes the power consumed by the evaporator and compressor and related fans. The overall system performance depends on compressor efficiency and evaporator temperature. If the overall compressor isentropic efficiency decreases, the electric power consumption increases and, thus, the COP decreases. At a given inlet air temperature, the system COP increases as the evaporator temperature increases, since the compressor power consumption decreases toward lower pressure ratios while the cooling capacity slightly increases. The compressor used in the experiments was not designed for the given electronics cooling application, and its calculated overall isentropic efficiency was only between 25% and 60%. In general, overall isentropic compressor efficiencies between 50%–70% can be achieved for small and medium-scale compressors of 3 to 10 kW cooling capacity [2].

Refrigeration systems must often be used in varying atmospheric conditions; therefore, variations in heat flux from the device will be present and, as with any refrigeration system, condensation can present itself on the outer surface of the evaporator. Furthermore, compressors are not currently designed specifically for electronics cooling, and so for testing: the originally designed units (engineered to run at much higher pressure ratios and much lower evaporator temperatures) promoted overheating, re-expansion processes and eventual flow losses occurred in the compressor. To address these issues, it has been suggested that during future development of these systems, an automatic expansion device is needed to accurately control the expansion process, i.e., the mass flow rate as a function of the heat load fluctuations of the microprocessor or its temperature. By maintaining the refrigerant evaporator temperature slightly above the dew point temperature of the surrounding air, the system control should prevent condensation at the evaporator [2]. The type of refrigerant is also a point of concern, as its physical properties and operating pressures determine its evaporating temperature and its capacity to transport heat. Operating pressure range, heat capacity, atmospheric disruption potential, explosion hazard and corrosion potential make some fluids inappropriate for some applications. R-134a and R-404a are common refrigerants currently in use in high power electronics cooling applications.

Today, reliable vapor compression driven cooling subsystems can be designed and manufactured for use in high performance electronic applications. Vapor compression refrigeration offers several important advantages. These include low mass flow rate, high COP, low cold plate temperatures and the ability to transport heat away from its source. Also, a wide variety of vapor compression refrigerant fluids have been well studied and are commercially available, including water, alcohol, butane and ammonia [4].

Processor frequencies are increasing along with board densities, while spatial constraints are remaining the same, or shrinking. Refrigeration cooling can emerge as a practical solution to advanced electronic cooling challenges. Refinement of vapor compression cooling techniques are sure to unlock a new era of electronics where the use of ultra-high performance semiconductor devices are designed specifically for low temperature operation and are readily available. Any system, especially a refrigeration one, must be efficient and reliable. With all the benefits inherent in a refrigerated system, these same advances create challenges for installation within practical electronic applications. Concerns with leakage, compressor failure and cold plate blockage, maintenance and energy consumption, as mentioned, are issues that need to be addressed. These areas continue to be driving factors for cost, as additional commitment is warranted to make these advanced thermal solutions widely accepted. Even with a high efficient refrigeration system, its efficiency is constrained by the efficiency of the compressor and the Carnot efficiency of the unit operating between the processor temperature and the ambient. This creates a large amount of energy wasted, with its direct result on the increase of carbon footprint. This is certainly in contrast to where the industry is going.

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LED Heat Transfer

and Cooling Technology Options

LED lighting is one of the fastest growing market sectors across the globe. There are two primary areas that make LED's attractive as the replacement for standard lighting that we have enjoyed for decades. These are: (1) energy savings and (2) easier control in managing the response of the light. The energy savings is certainly attractive and has become the strongest driver behind the LED appeal. As shown in Figure 1, on the visible light range, an LED is about three times more efficient than the comparable incandescent light.

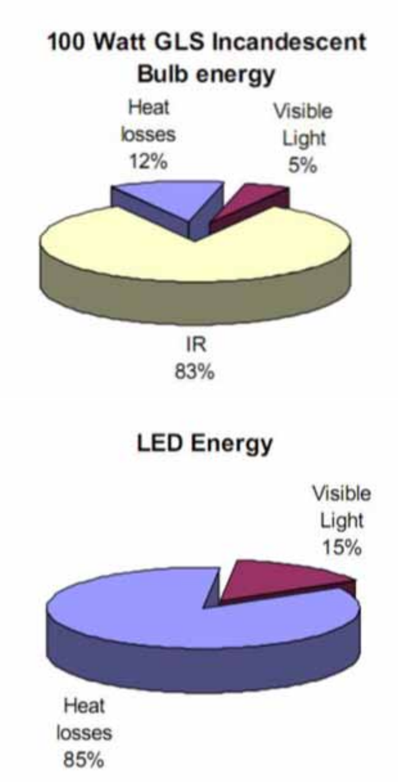

Figure 1: Power Usage of LED and Incandescent Light Bulb, [1]

LEDs still generate heat and need to be cooled, but the light output for the same power is more effective than the standard lighting technology that has been utilized for many years.

Role of Heat and LED Response

The combination of the generated heat and the control of the response time bring the issue of cooling into the forefront of LED lighting. As stated above, ease of control of the light output makes LEDs an attractive proposition for many applications that range from cosmetic to industrial to home and street lighting applications. Since LEDs are semiconductor devices, their light output is directly impacted by temperature. Figure 2, [1], clearly demonstrates how the relative Light Output (LOP) is impacted by temperature.

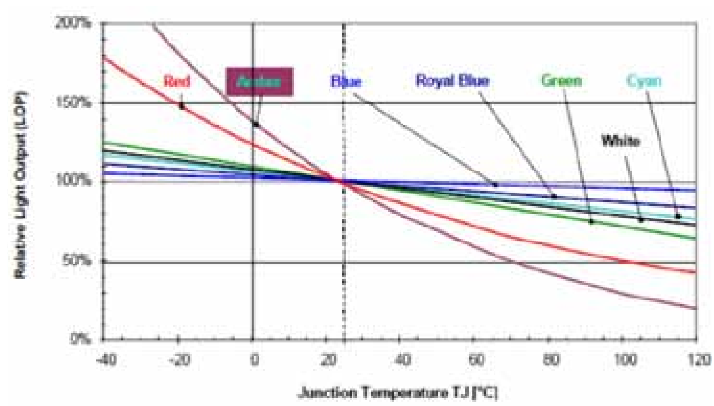

Figure 2: Effect of LED Junction Temperature on Light Output of an LED, [1]

For Amber and Red lights, for the full range of temperature that one commonly designs lights for, one notices a large swing in the relative light output. The only color that is least impacted is the Blue, where the changes are in the few percentage points, as compared to the other colors. This swing in light output is distinctly measureable and visible even in lower temperature ranges that are most commonly seen in diverse deployment sites.

Clearly, like any other semiconductor device, the expected life of an LED device is highly temperature dependent. Figure 3, [2], clearly shows the important role temperature plays in maintaining a higher life of the LED.

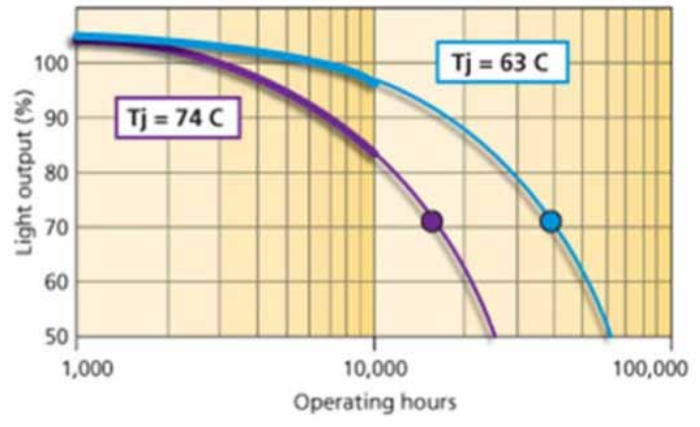

Figure 3: Useful Life of High-Brightness White LEDs at Different Operating Temperatures, [2]

Figure 3 clearly shows that, if the device junction temperature is reduced by 11ºC, the expected life is increased by 35,000 hours. In addition, by increasing the LED temperature, several key characteristics may become more notable. The temperature increase has a direct effect on the LED's forward voltage that causes it to decrease, i.e., they can increase the load on other components that drive the LED, resulting in their temperature increase. The temperature increase will cause the wavelength change, as shown in Figure 4, [1]. The change in the wavelength can cause an orange LED light to appear as red or white LEDs to appear with a tint of blue. Similar to any other semiconductor device, if the thermal situation is not managed, it will cause a catastrophic failure for the LED. Therefore, the combination, of the expected life and the control on the color display of the LEDs, places the thermal management at the center of LEDs' successful launch, irrespective of the deployment site.

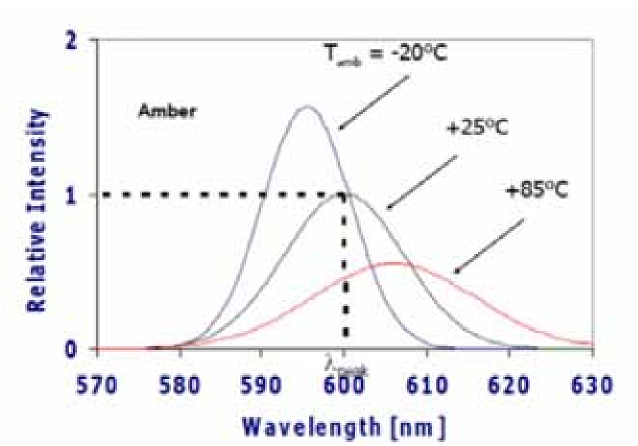

Figure 4: Effect of Temperature on Wavelength Emitting From an LED, [1]

Understanding LED Heat Transfer

Although the LED function has not changed, LED packaging has gone through a major change over the past several decades. The packaging changes have had a dramatic improvement on the LEDs' thermal performance. This is illustrated in Figure 5, [3], where we clearly see that the change of packaging of the semiconductor has reduced the thermal resistance by orders of magnitude.

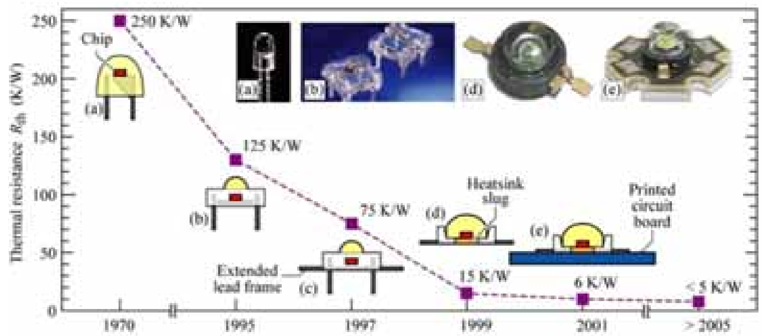

Figure 5: LED Packaging Trend and the Reduction of Thermal Resistance, [3]

Since the top surface of the LED is covered by its lens and must be exposed for emitting the light, the typical construction of today's LEDs strives to transfer the heat as efficiently as possible from the backside of the device to the Printed Wiring Board (PWB) that it resides on, as in Figure 6, [4,5]. This is typically accompanied by a heat slug, where the die resides, that is interfaced to the PWB.

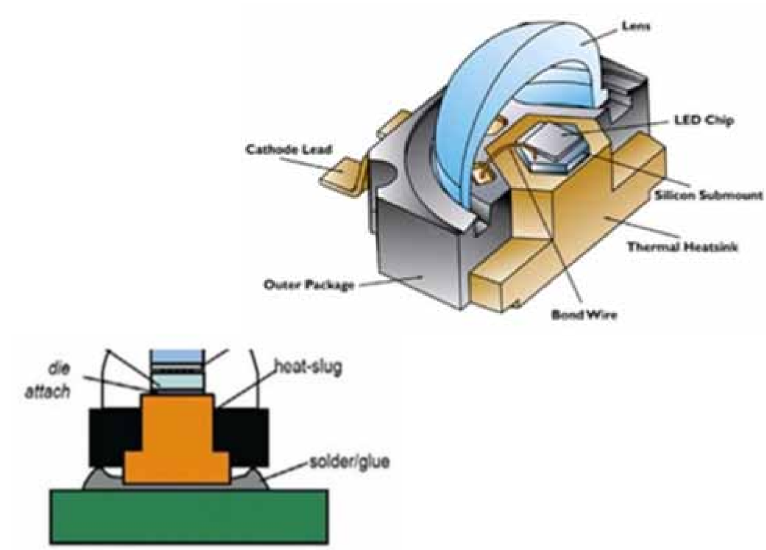

Figure 6: LED Packaging – Use of Heat Slug to Carry the Heat from the Semiconductor Device to the Printed Wiring Board (PWB), [4 & 5]

Many efforts are put in place to minimize contact resistance between the heat slug and the PWB. These measures include: interface material, soldering (as long as there is electrical isolation) or, more recently, constructing the whole LED structure on the PWB. In this process, there are several options for taking the heat from the LED to the non-component side of the PWB: use of filled vias, heat slugs within a PWB, a copper layer, graphite foam and others. Irrespective, once the heat has entered into the PWB, it is transitioned to the backside (non-LED side) for dissipation into the ambient by natural convection or active high (or higher) capacity cooling system.

Cooling Options

Similar to any other semiconductor device, the cooling options are as broad as the application for the LED: these range from a simple copper plate, or a heat sink, to spread and dissipate the heat to a sophisticated cooling system that may contain liquid or refrigerants. These can be broadly divided into two categories of passive and active systems. The passive systems, by definition, have no active components, i.e., a heat sink. An active component, e.g., a fan-cooled heat sink or TEC (thermo-electric device – typically referred to as Peltier device or semiconductor refrigerator) has a part or parts that could fail and/or which require maintenance. The active systems typically have a component that requires power to assist with the cooling – this can be a fan, pump, TEC or any such device or process that assists with cooling. Yet, there are some distinct criteria for the selection of the cooling system. These include:

1. Effectiveness of cooling. Would it yield the desired junction and temperature uniformity across an array of LEDs?
2. Cost effectiveness. Is it a cost effective solution, such that the combination of the LED(s) and the cooling system makes the deployment of the system economically feasible?
3. Suitability for the deployment site.
Would it meet acoustic requirements of the deployment site?
4. Powerconsumption.Would power consumption of the cooling system mitigate any savings that may be attained by deploying LEDs vs. traditional lighting systems?
5. Reliability.How reliable is the cooling system, and would it require regular maintenance?
6. Environmental friendliness. What is the carbon footprint of the cooling system–from deployment to disposal?

Considering the criteria stated above, the simpler the cooling system, the more desirable its deployment. That is, if we can provide the required cooling and uniformity of temperature with a simple copper or aluminum plate, assuming that weight is not a huge issue, it will be the most desirable solution. Of course, because of the required higher illumination, the power dissipation is higher; therefore, the cooling system must be changed to meet the performance requirements.
A very important factor is Item 3 (above). Would the cooling system be suitable for the site at which the LED will be deployed? Imagine, for example, that an LED streetlight has an active cooling system. The system has a fan that may fail due to time and temperature. For the LED to function properly, the fan needs to be replaced and there needs to be intelligence in the street light to let a central office know that the fan has failed so that they can shut that LED off until a repair is made. The combination of the fan, intelligent system and maintenance, would possibly render the LED not cost effective for deployment. It would suggest, in this example, that designers strive to come up with a passive cooling system instead.
Thanks to the advance of technology, the market is rich with a variety of active cooling options that have already been deployed successfully in the electronics industry [6]. One example of an active system is the use of synthetic jets to generate airflow in LED housing. Figure 7 shows one such example, where a Nuventix Synjet™ is used for cooling the LED.

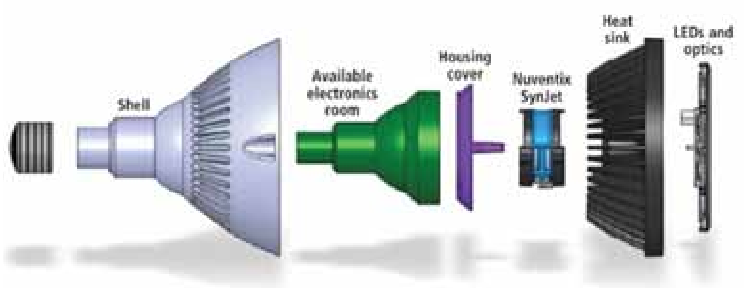

Figure 7: Use of Synthetic Jet for Cooling of High Power LED, http://www.ledsmagazine.com/features/8/6/10

Although the Synjet does not have a blade, as do traditional fans, it is able to develop air movement by creating oscillation via a diaphragm, Figure 8.

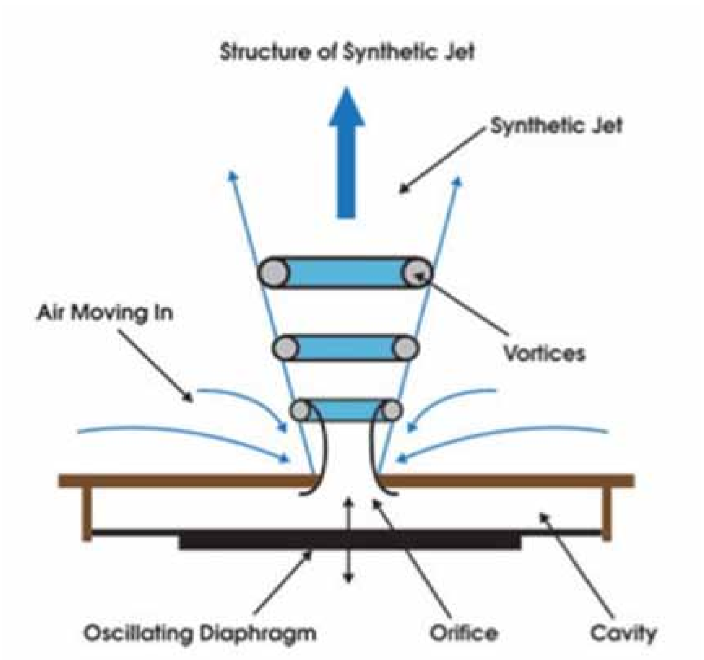

Figure 8: Cross Section of a Synthetic Jet Showing an Oscillating Diaphragm for Creating Air Movement, http://www.photonics.com/Article.aspx?AID=35531

The cooling options, in broad categories, include:

• Piezo-Fans. These are recommended for more local cooling for lower power applications, as these devices create local flow and improve the heat transfer coefficient over natural convection-cooled LEDs.

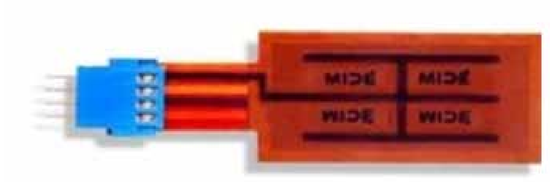

Figure 9: Piezo Fan for LED Cooling - http://www.prweb.com/releases/2009/12/prweb3281304.htm

• Fan-sink. These devices require the application of a fan affixed to the top of a heat sink, which, in turn, is attached to the backside of the PCB housing the LEDs.

• Jet impingement. In this configuration, air is directed on the hotspots on the backside of the LED array, to provide more effective cooling than fan-sink.

• Liquid cooling. Here, a cold plate is attached to the PCB carrying the LEDs and it is then connected to a liquid loop that contains a reservoir with a liquid-to-air heat exchanger and a pump. The typical application of such systems is that of very high power lighting to which such an elaborate cooling system merits deployment.

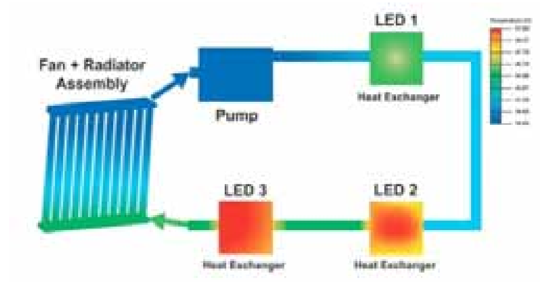

Figure 10: Schematic of Liquid-cooling system for an LED Display Application http://www.eetasia.com/ART_8800480649_480700_NP_6ab3f0d2.HTM

• Refrigeration. In this solution, a refrigeration cycle is used for cooling of the LEDs, whereby the evaporator of the refrigeration cycle is placed on the backside of the PCB housing the LEDs. Similar to liquid cooling, the application of such elaborate systems is application dependent and depends on the justification of the use of LED vs. other light-emitting sources.

There are two important factors that all designers involved in LED lighting need to put at the forefront of their design process: these are contact and spreading resistances. From the cooling standpoint, contact resistance where the LED contacts the PWB or the LED-PCB contacts the cooling system, irrespective of its type (active or passive), it must remain minimal. Use of gap fillers, improved fabrication processes (e.g., flatness), different manufacturing processes, such as an integrated construction of the LED and cooling system, will be pivotal for thermally challenging lighting systems. A good designer will further investigate to ensure that all contact resistances on the path of the heat transfer from semiconductor to the final ambient are minimized to ensure least-hindered flow of heat and minimization of temperature gradients underneath of the LED.

Since we are dealing with discrete heat sources that are attached to larger heat sinks or coldplates, spreading resistance will play a major role in effective thermal management. Often, depending upon design and materials selection, spreading resistance is the dominant hindering parameter to the flow of heat. Regretfully, its minimization is often overlooked by many designers, and the result is that it often leads to a more complex cooling system than what may be required. Understanding the flow of heat from the source to the sink (e.g., ambient), and minimization of the spreading resistance, could often be the difference between a simple heat sink and a more elaborate cooling system.

In conclusion, an LED, or correctly stated, solid-state lighting, is identical to any other electronics device whose longevity and proper operation directly depend on its junction temperature and how it is thermally managed. The cooling technologies for LED thermal management are readily available on the market, and have been deployed across different market sectors in the electronics industry. There is no new heat transfer phenomenon that has not been dealt with before. The challenge that a designer or producer of such product has is the alignment of the cooling system/solution with the deployment-site requirements and its marketplace acceptance. Imagine, when you come to an office or a room in your house where LED lighting is deployed and the room is saturated with fan or synthetic jet acoustic noise. The noise from the PC or the HVAC is uncomfortable enough, now consider what it is like to have 12 LEDs that are cooled by air-movers. Therefore, the challenge confronting the LED lighting designers is not the cooling technology – that is readily available – but, it is the packaging of the cooling technology that will render the LED light or lighting-system a more viable choice, once compared with other available lighting options.

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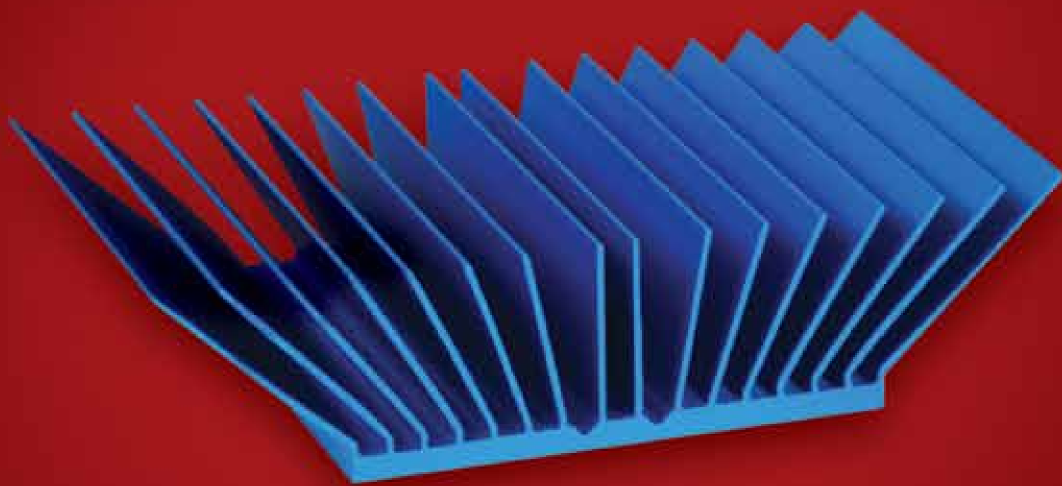

Cooling High Power Electronics

With Microchannels

In recent years, as computing power densities have continued to increase, it has come to the point where the traditional air cooling solution is becoming less and less able to keep up with today's power dissipation requirements. No single technology has yet been declared the frontrunner in the race to keep the next generation of computers cool, but liquid cooling and the use of microstructures in heat exchangers have been the subject of much exploration.

One strategy developed by Cooligy, a subsidiary of Emerson Network Power, is a closed loop liquid cooling solution for CPUs [1]. As a closed loop system, the Active Micro-Structure Cooling System, as it is called, comprises a pump, CPU cold plate, radiator and a system fan. One of the notable features of the system is that the cold plate uses microchannels to enhance heat transfer from the CPU to the working fluid. The system is illustrated in Figure 1.

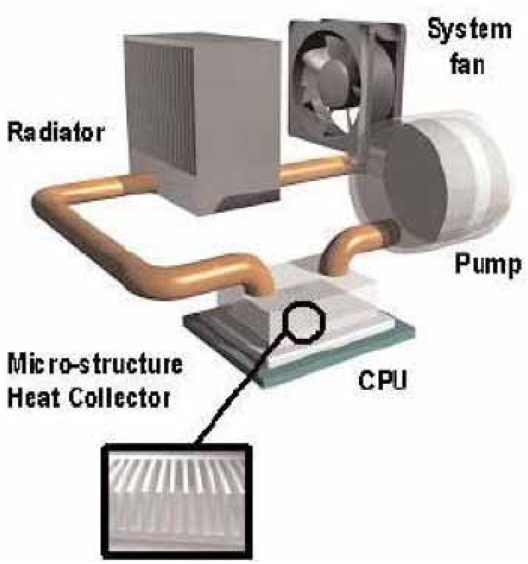

Figure 1 - Schematic of the Active Micro-Structure Cooling System [1]

The idea of using a heat exchanger with very small surface features is not new, but this has not been in widespread use because of deployment challenges, such as high pressure drop and the difficulty of manufacturing such small channels. Microchannels are usually less than 200 microns in width [2], and the fins that form the channels are tall and thin, giving a high aspect ratio. In the Cooligy heat exchanger, the channels are around the width of a human hair, or 100 microns. The small size of these features gives a large amount of surface area for heat transfer while maintaining a small package size.

Common methods of fabricating microchannels have been micro-milling, skiving, photo etching (on silicon) and EDM, but these processes are still relatively expensive for production quantities [3]. Cooligy claims that high volume production of their microchannel heat exchanger has been made feasible through the use of a chemical etching process and the implementation of manufacturing in low-cost labor regions of the world.

Modern CPUs can dissipate heat with an average density over 100 W/cm^2, with localized "hot spots" of over 500 W/cm^2. With the high rate of heat transport enabled by microchannels, the heat exchanger can outperform solutions such as heat pipes and vapor chambers, which are effective up to about 200 W/cm^2 [4]. In fact, the Active Micro-Structure Cooling System is claimed to be able to handle local hot spots of up to 1000 W/cm^2.

Microchannels increase heat transport partly by packing a relatively large amount of surface area into a small volume. However, microchannels also owe their high heat transport ability to the fact that the heat transfer coefficient increases as the hydraulic diameter decreases, represented by equation 1 [5], where D_h is hydraulic diameter, Nu_{Dh} is the Nusselt number based on the hydraulic diameter, and k is the thermal conductivity of the fluid.

$$h = \frac{Nu_{D_h} \times k}{D_h} \qquad (1)$$

This equation is for heat transfers for internal laminar flows, and illustrates the fact that in a microchannel, where the effective hydraulic diameter is very small, the heat transfer coefficient, h, gets larger. Of course, as the channels get smaller, the pressure drop across them increases, so it is important to realize that there are tradeoffs for every approach.

At the present time, most of the commercially available liquid coolers do not use microchannels, instead having water passages with hydraulic diameters of several millimeters. Webb compared one such example, the Thermaltake "Bigwater 735" heat exchanger, to a microchannel heat exchanger with a channel hydraulic diameter of 0.491 mm [6]. The microchannel heat exchanger was a copper design with skived fins, which is referred to as "Fin-H", shown in Figure 3. Overall dimensions of the Thermaltake heat exchanger are 77X70 mm, while the microchannel heat exchanger has a channel area of 25X20 mm.

Figure 2 - Thermaltake "Bigwater 735" Heat Exchanger With 4.5X10mm Channel [6]

Figure 3 - "Fin-H" Copper Microchannel Heat Exchanger [6]

Webb tested both heat exchangers with a power input of about 110W, but the water inlet and outlet temperatures are not given. It can be seen in Figure 4 that the pressure drop across the microchannel heat exchanger is much higher than across the standard heat exchanger. With microchannels, however, the required flow rate is also much less compared to a traditional cold plate, illustrated in Figure 5. The "Fin-H 2-Pass" may be ignored, as Webb later found the 1-Pass design to be sufficient for his tests.

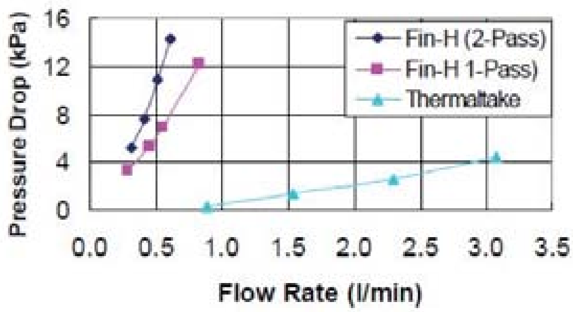

Figure 4 - Pressure Drop vs. Flow Rate for Microchannel and Standard Heat Exchangers [6]

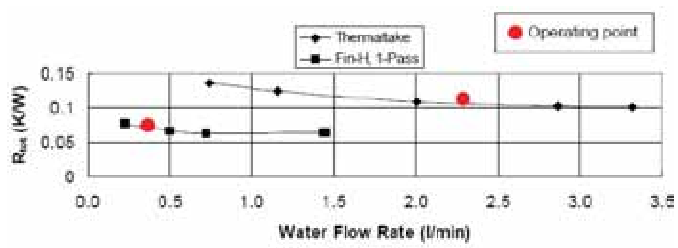

Figure 5 – Overall Thermal Resistance vs. Water Flow Rate for Microchannel and Standard Heat Exchangers [6]

Webb does not make clear how the indicated "operating points" were selected, but at those points, the microchannel heat exchanger has a 29% lower overall thermal resistance than the standard heat exchanger while using about 16% of the water flow rate. When taking into account the higher pressure drop, the pumping power ratio (volume flow rate X pressure drop) for the microchannel heat exchanger was measured to be 75% less than the standard heat exchanger.

Cooligy claims that pump research in the past few years has yielded pumps that can deliver the required pressure and flow with high reliability. In addition, it is claimed that the working fluid in Cooligy's system is less viscous than competitors' glycol solutions, reducing the required pumping pressure. The Active Micro-Structure Cooling System uses near-pure water as the working fluid because common coolant solutions, such as those based on propylene glycol, have lower specific heat and lower thermal conductivity compared to water. For instance, a 50% water/glycol solution has about 30% less thermal conductivity compared to pure water at room temperature [7].

Because the working fluid does not contain an anti-freeze agent, the system is designed to be able to cope with the expansion of the coolant if it should freeze. Particular attention was also paid to materials used in the system, to ensure long term reliability. Because it is a closed loop system, materials must be chosen that will not corrode and will not introduce foreign particles into the coolant during the life of the system. Exactly what materials were used remains proprietary information of Cooligy. Eventually, it is inevitable that small particles will enter the coolant, and because the heat exchanger has such small channels, it will be susceptible to clogging. Such factors must be taken into account when evaluating the lifespan of any liquid cooling system.

While detailed reliability data is not given by Cooligy, the lifetime of the system is described as 5 years in Table 1 below (Temperature not given). Non-stop operation for five years is a little less than 44,000 hours. This can be contrasted with the MTBF of a typical 92X92mm axial fan which might be used in an air cooled application. These are commonly rated around 70,000 hours at 40ºC [8]. A competing closed loop liquid cooling solution by CoolIT Systems specifies their pump with a 50,000 hour MTBF [9], which is on the same order as the Cooligy system. So ultimately, the reliability of a liquid cooling system may be a concern, but depending on the application, the cooling capability of a liquid cooling system may make it an acceptable trade-off.

Liquid cooling systems still have to prove themselves, as the issue of coolant leakage is a real concern. It is possible for systems to use dielectric fluids so that circuits will not be damaged if a leak occurs, but that does not alleviate the sudden loss of heat transport. Factory sealed systems like the Active Micro-Structure Cooling System aim to minimize the possibility of leaks, but careful installation and periodic system checks will be required for best results. Serviceability is not mentioned by Cooligy, but often it is the case with a sealed system that when it fails, the entire system needs to be replaced.

Cooligy does describe a test setup that was constructed to measure the performance of the microchannel cooling system. The CPU was simulated by a copper block with embedded cartridge heaters, and the entire system was placed in a wind tunnel. With the wind tunnel providing about 0.014-0.017 m^3/s of air flow to cool the heat exchanger, the system was able to achieve an impressive sink-to-ambient resistance of R_{sa}<0.1 ºC/W. The test results and system specifications are summarized in Table 1.

Thermal Performance	
Rs-a, C/W	0.1
Airflow	32-35 cfm
Average heat flux	150 W/sq cm
Power	235 W
Peak heat flux	250 W/ sq cm
Ambient temp, C	25 C
Tj max	<85 C
Mechanical	
Radiator volume	90 x 140 x 40 (mm)
MCP size	35 x 25 x 20 (mm)
Pump size	60 x 60 x 80 (mm)
Storage	-40 to 50 C
Acoustics	<45 dB at 1m
Reliability	5 Yrs

Table 1 - Cooligy Active Micro-Structure Cooling System Specifications [1]

Liquid cooling and the use of microstructures that enhance heat transfer may be two technologies that will play a major role in allowing the clock frequency in many ASICs and CPUs to increase. Companies such as CoolIT seem to agree, with their production of a factory sealed liquid cooling system that also uses a microchannel heat exchanger [10]. CoolIT claims to have reached a thermal resistance of only 0.05 oC/W with some systems, which allows the use of CPUs with very high power dissipation.

As these and other advanced cooling techniques become more and more common, they will demonstrate their performance, reliability and value. It will be interesting to see which technologies prove themselves and become more prevalent than others.

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Understanding Cold Plate Manufacturing

for Deployment in Electronics Equipment

The most important rule in the thermal management of electronics devices is to design cooling systems to maintain the device junction temperature below a set limit called maximum junction temperature. It has been shown that for every 10ºC reduction in junction temperature, the life expectancy of the device will double. The most common and economical method for cooling devices is air cooling. However, to deal with increasingly amplified heat rejection issues, more and more engineers are turning to liquid cooling. Liquid cooling is defined as a single-phase liquid, mechanically pumped through a cold plate where the fluid absorbs the heat [1]. The liquid then flows through a liquid-to-air/liquid heat exchanger where the heat is dumped to another fluid, typically facility water or air. Figure 1 shows an example of a forced liquid cooling system with the ambient air as the final heat sink.

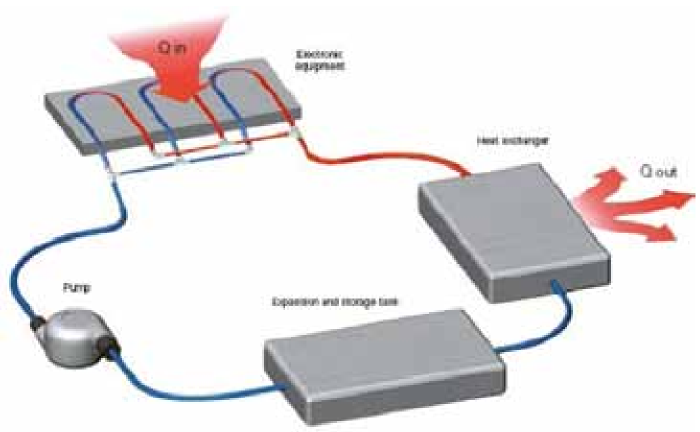

Figure 1.- Typical Schematic of a Forced Liquid Cooling System [2]

Cold plates are generally made of Copper. Copper offers an excellent thermal conductivity of 398 W/m.K, but has a significantly higher cost than aluminum and comes with a higher weight for the same volume [3]. Liquid cold plates can be generally classified into two types, those using a discrete tubing assembly for the liquid pathway and those which have an internal fluid pathway construction. The use of a discrete tubing assembly offers the advantages of having known physical parameters for the tube, specifically of material, temper, strength, wall thickness and usually a plethora of readily available commercial fittings which can be applied to the in and out ports of the cold plate. Most commonly used is copper tubing which offers low cost, a wide range of fluid compatibility, is easily formed and provides low cost fittings which can be soldered or crimped to the tubing. Internal fluid pathway construction is usually a lot more expensive, and care must be taken with cooling fluid selection, but can offer improved thermals in some applications.

DISCRETE TUBING COLD PLATES

Cold pates with tube sub-assemblies have the benefit of having the cooling liquid flow through a known strength pipe, which eliminates the possibility of any internal leaking, which is always a concern on internal fluid cold plates. Also, copper piping can be used in an aluminum cold plate, saving weight and greatly improving corrosion resistance.

Snake on a Plate: This process is seldom used today. This is where the tube is laid on a flat plate and can be welded or soldered to the plate.

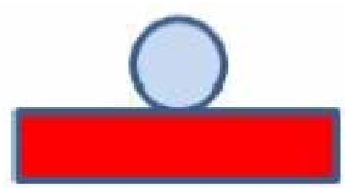

Figure 2.- Typical Image of Snake on a Cold Plate [4]

Crimped Extrusion: A plate is extruded with two fins that are crimped around the tubing, offering low cost but limited thermal, and each size/shape must be tooled.

Figure 3.- Typical Image of Crimped Extrusion Cold Plate [4]

Half Buried: Just as it sounds, the tube is buried half way into the cold plate; this is often done where the plate may be of limited thickness and strength. The tube is best soldered to the cold pate, providing some level of mechanical strength

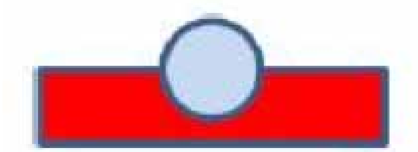

Figure 4.- Typical Image of Half Buried Cold Plate [4]

Buried Tubing: Buried tubing parts offer economical, outstanding high pressure and high reliability paths for the cooling fluids. Tubes are then set into the cold plate, which is often aluminum for weight and cost savings.

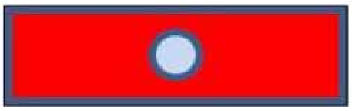

Figure 5.- Typical Image of Buried Tubing Cold Plate [4]

Flat Exposed Buried Tubing: Round tubing is formed into a D– shaped tube and the flat side of the tube is flush with the surface of the cold plate; this gives greater area for thermal transfer directly to the tube.

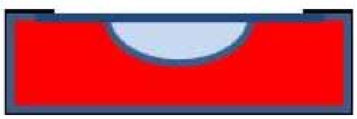

Figure 6.- Typical Image of Flat Exposed Buried Tubing Cold Plate [4]

Flat Exposed Flat Tubing: Larger section rectangular tubing is used in the cold plate for maximum thermal transfer area. Internal fins provide better heat transfer to the fluid. Internal ribbing provides added structural strength so that the flat tubing does not distort when exposed to high pressure.

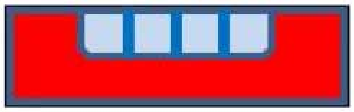

Figure 7.- Typical Image of Flat Exposed Flat Tubing Cold Plate [4]

Sandwich Construction:
The two sides of the cold plate are machined and then bolted together with or without a sealing gasket or compound in between. This requires that the cold plate be thick enough for the bolts or screws that will hold it together. If gasketed, it must be acceptable that the two sides be thermally isolated from each other (the gasket is a good insulator) and that the parts have sufficient intrinsic strength to be bolted together.

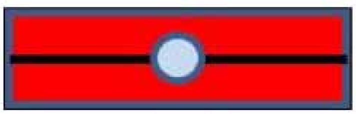

Figure 8.- Typical Image of Sandwich Construction Cold Plate [4]

Soldered: The cold plate sides are held together by solder, which typically will have a melting point of 400ºC. The solder also provides a metallurgical joint to the tubing,

INTERNAL FLUID PATH COLD PLATES

Brazed: there are three common types of brazed plates, Vacuum, Dip and Controlled Atmosphere. All internal fluid path cold plates need to be carefully pressure tested to make sure that parts are completely sealed. Internal fluid leakage from one cooling path to another inside the cold plate usually cannot be detected and some level of internal leakage should be allowed on the thermal design. **Vacuum Brazed**: The cold plate halves are machined, then assembled with braze sheet in between (similar to a solder pre-form sheet). Parts are then heated to near melting point at around 1100ºC, the braze melts and the parts are cooled. The vacuum means that no air pockets or contaminants will be trapped and a solid metallurgical joint is made. The metal, however, is now dead soft and usually distorted in the oven; parts must be straightened and drawn back to hardness. This means that parts need to be final machined after all these processes, basically double machining. Parts can be very thin-walled and this is good in applications where weight is important, such as aircraft parts. The big drawback is that this is a very expensive process, limited by the number of parts that can be fitted into the oven (which can have up to a 12 hour cycle) and multiple machining steps are required.

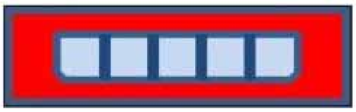

Figure 9.- Typical Image of Internal Fluid Path Brazed Cold Plate [4]

Dip Brazed: Parts are assembled with braze sheet and then dipped in molten salt at 1100ºC to assemble. Aluminum has a near-neutral buoyancy in molten salt, so the parts will not sag at elevated temperatures. Once the parts are withdrawn, the salt crystallizes and must be washed out of the heat sink, tubing, fine features and fin spacing. Often, the salt cannot be washed out. Parts are soft temper and must be drawn back to temper. Similar to vacuum brazing, a solid metallurgical joint is made, but pockets of embedded salt are trapped inside the joints. In high moisture environments (like the Navy), dip brazing is not commonly allowed.

Controlled Atmosphere: Parts are assembled with braze sheet and heated in an inert atmosphere, then cooled. This is how aluminum automobile radiators are made on conveyorized lines. These are low cost if you have huge volume and thin walled parts. Most cold plates have heavy walls for heat spreading and part mounting and not the needed volumes.

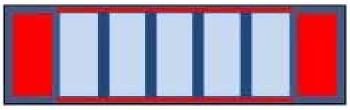

Figure 10.- Typical Image of Internal Fluid Path Dip Brazed Cold Plate [4]

Deep Drilled: Deep drilled parts, which process is similar to gun drilling, allow solid parts to have simple cooling channels added. The channels are usually at right angles and will have a higher fluid backpressure due to the 90 degree joints, but in those cases where high performance cooling is not needed; they can be a high strength solution.

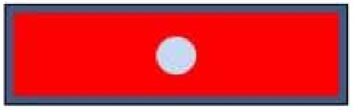

Figure 11.- Typical Image of Internal Fluid Path Deep Drilled Cold Plate [4]

Some of the typical cold plates in industry are shown below. Figure 12 shows a typical cold plate manufactured by vacuum brazing for military applications.

Figure 12.- Picture of a Vacuum Brazed Cold Plate for Military [5]

Figure 13 shows a cold plate for cooling multiple IGBT applications.

Figure 13.- Picture of a Cold Plate for IGBT [5]

Figure 14 shows typical cold plates for electronics cooling applications.

Figure 14.- Picture of Two Cold Plates for Electronics Cooling [5]

Figure 15 shows two pictures of thin walled cold plates for aerospace applications.

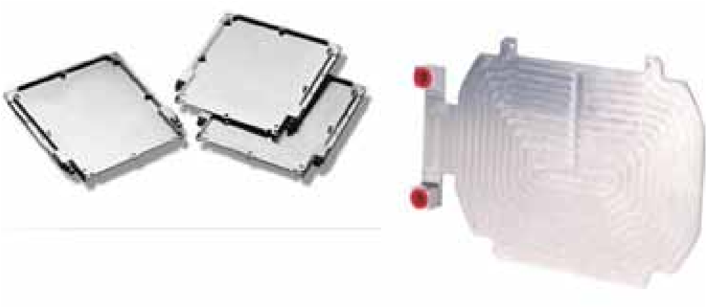

Figure 15.- Picture of Two Thin Walled Cold Plates [5]

This article has provided an overview of both of the major types of available cold plates: discrete tubing and internal fluid; in the process, delving into their individual manufacturing techniques. Additionally, some of the typical industrial cold plate applications are highlighted. Hopefully, the reader has gained an appreciation for cold plate technology, which can be both a complex and a delicate process and one that requires considerable knowledge and experience.

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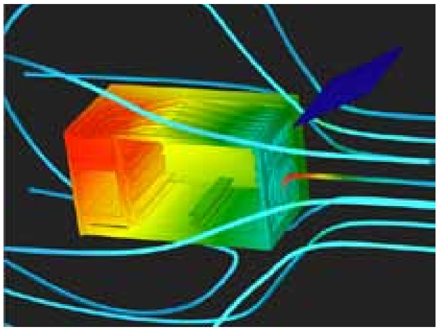
Cooling News

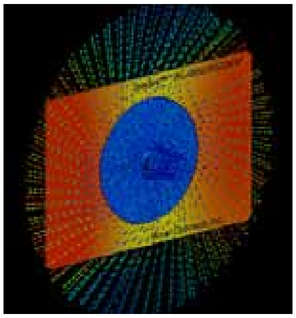
New Products, Services and Events from around the Industry

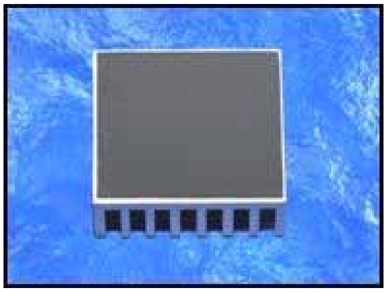


New Visualization Tools for CFD
Daat Research has released new visualization tools for its award winning Coolit family of CFD thermal software for electronics. One tool is Solution Volume Visualization, using color fog. Typically, fog depicts temperature or pressure variations and its opacity can be controlled, allowing the user to view obscured objects. When combined with sectional view planes, fog helps the user to quickly analyze complex spatial distributions. A second powerful tool is Automatic Flow Visualization and Animation. Based on previously available streamrods and streamribbons, the new one-click option automatically distributes injectors throughout the solution field and injects particles that show flow direction, velocity and swirl, as well as the local value of a scalar variable, such as temperature, at the particle's location.

Gap-Filler Pad is Ultra Conformable
Gap Pad VO Ultimate, from Bergquist, is a robust, highly compliant product that is ideal for both small and large gap designs. The Fiberglass carrier on one side of the material allows ease of rework, excellent handling characteristics and puncture resistance. Additionally, the Fiberglass carrier has a slight inherent tack, minimizing any shifting during assembly. The conformable and elastic nature of Gap Pad® VO Ultimate allows excellent interfacing and wet-out characteristics, even to surfaces with a high degree of roughness or uneven topography. As to the construction of Gap Pad® VO Ultimate, one side has high inherent tack, while the other side has minimal tack. This combination is useful for manual and automated processes..

Mini Compact Fans Provide High Performance
Cooltron has released a new line of mini compact fans, available in six models and outfitted with Cooltron's state-of-the-art hydro bearing technology. The fans provide a high level of performance, despite the small dimensions. The smallest fan measures only 15mm by 6mm and comes with 0.44 CFM airflow and 19.3 dBA noises. With low energy-consuming design and micro fan technology, the fans have passed rigorous reliability verification and are ideal for the new generation of handheld electronics, such as smartphones, PDAs, tablets, laptops, etc. Other applications include power tools, portable stereo systems, medical equipment and security surveillance.





Spot Cooling from New Vortex Tubes

A maintenance-free solution to a variety of industrial spot-cooling problems is available using vortex tubes from Exair Corp. Independent laboratory tests certify that the tubes meet safety, health and environmental standards of the EU. The tubes are utilized to cool electronic controls, machining operations, gas samples, and environmental chambers. The rapidly rotating air from the tubes converts an 80-100 PSIG compressed air supply into a stream of air whose temperature can be as cold as −50°F (-46°C). The tubes have no moving parts and are constructed of corrosion-resistant stainless steel. They are available in three sizes and in a range of forms that include an adjustable spot cooler, cabinet cooler, cold-gun air coolant, component cooler and a mini cooler.

Credit-Card Sized Forced-Air Heat Sink

Thinner than a credit card, the Thin-Sink from Novel Concepts is a forced-convection (fan-cooled) heat sink. It has a volumetric cooling efficiency 25 times greater than today's best microprocessor heat sinks, and cools 25 times more heat per cubic centimeter. The fan-cooled heat sink fits inside small electronic devices such as notebooks, monitors, and tablets, and cools ICs, semiconductors, LEDs, and other microelectronic heat-generating devices. The product technology can be fabricated in almost any shape or size, and be incorporated within existing structures, such as circuit boards or enclosures. The fan and motor rotates a thin toroid (circular fan disc) that generates an axial-to-radial fluid flow field across a heat sink. The local radial velocity near the toroid's perimeter is about 12.6 m/s. The volumetric cooling efficiency is 0.081 W/°C/cc. The device consumes only 0.031 W of electricity and produces a sound level of 34 dBA.

High Thermal Conductivity Mounting Tape

MH&W International has introduced Keratherm® KL 90 highly thermally conductive, double-sided adhesive tape, which provides 1.4 W/mK of thermal conductivity – nearly three times higher than other thermal tapes – for more effective heat transfer from hot components to heat sinks. The new tape's thermal impedance is just 208°C-mm2/W (0.32°K-in2/W). Keratherm KL 90 tape consists of a ceramic-filled acrylic adhesive film that provides exceptional bonding properties, and replaces the use of mechanical fasteners, reducing costs and assembly time. A Fiberglass-reinforced version, KL 91, is available for applications requiring higher levels of ruggedness, peel strength and conformability to irregular surfaces. Both Keratherm KL 90 and KL 91 mounting tapes are silicone-free, eliminating any contamination concerns.