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Thermal Resistance Comparison

Thermal resistance is a key consideration when selecting a cooling system. AHRAE recently reported (1) that thermal resistance will need to be lower for future higher power, lower temperature CPUs and GPUs. Thermal resistance defined as the CPU temperature rise over the incoming water or air temperature divided by the chip power. This is reported as °C/watt. The temperature rise can be determined with the equation: $\Delta T = QR_\theta$ where Q is the power and R_θ is the thermal resistance.

If the thermal resistance of a liquid cooling system is 0.1 °C/watt, a 100-watt CPU would run 10°C warmer than the incoming water or air temperature, if the water was a 20°C, the chip would run at 30°C. Typical CPUs have a maximum temperature of about 85°C, if they get hotter than that, they slow down. People like to use warm water for cooling because it is cheaper and easier to use and, in some cases, you can reuse the heat from the computers. As the CPU power goes up a low thermal resistance becomes more important. For example, if a future 800-watt CPU is cooled with water from an outdoor radiator in a hot location where the cooling water is 60°C (140°F), we need a thermal resistance of 0.031 °C/watt or lower ((85°C-60°C)/800W). Here are some thermal resistance numbers with references for the various systems used today.

Technology	***State of the art thermal resistance for 1U server***
Air cooling	0.15 °C/watt @ 28 CFM air *(Dynatron A28)*
Oil Immersion (GRC, submer, DCX)	0.13 °C/watt *(Ref 2)*
Two Phase Immersion (3M, Allied Control)	0.06 °C/watt, Dries out at 20 watt/cm^2 *(Ref 3,4)*
Micro fin cold plate (Coolit, Asetek)	0.044 °C/watt at 0.5 lpm of 25% PEG 0.03 °C/watt at 1 lpm of 25% PEG *(Ref 5)*
Chilldyne	0.034 at 0.5 lpm of water 0.021 °C/watt at 1 lpm of water *(3rd party data)*

The cold plate data includes the thermal grease interface resistance of about 0.01 °C/watt. There are other considerations such as CDU approach, effectiveness and log mean temperature differential, but the thermal resistance calculation works over a range of power levels $\pm$50%.

At Chilldyne, we use pure water direct to the chip because it works the best. For instance, when the engineers at Chilldyne designed a rocket engine cooling system for a DARPA project where the heat flux is 100 times higher than for CPU cooling, flowing water was used.

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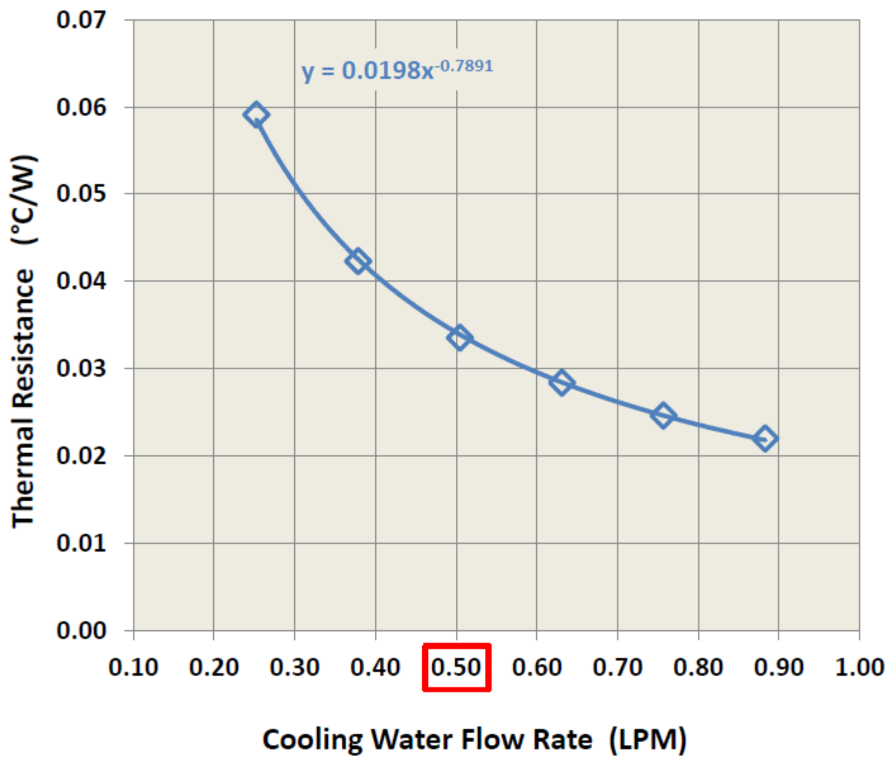
APPENDIX:

Third party test data for Chilldyne cold plate designed for 400 watt CPU. Cold plate temperature measured by thermocouple embedded in surface of simulated package made from a 47x47x13mm copper block with three cartridge heaters.



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