Improving Liquid Cooled Server Efficiency with Larger Connectors and Design Improvements

We know that switching from air cooling to liquid cooling in a data center improves efficiency because water is better at carrying away heat than air. Anyone who has walked into a beer cooler at 45°F and jumped into a mountain stream at 45°F will tell you that the liquid sucks away heat faster.

This article explores ways to enhance liquid cooling efficiency that may not have been previously considered. Improving the efficiency of the cooling system begins by reducing the pressure drop in the cooling lines from the CDU (Coolant Distribution Unit) to the server and back, so that the pump in the CDU doesn't have to work as hard and uses less power. Note that this article dives into some technical details, but the key takeaway is that there are opportunities to dramatically improve the efficiency in cooling AI data centers.

Some servers have a low pressure drop of less than 5 psi, while others exceed 20 psi. This 15 psi difference *represents a waste of power.* A typical CDU has a water pumping efficiency of 25%, so the power required for liquid cooling a 1 MW cluster can decrease by 10 kW by using a low-pressure drop server, thereby decreasing the PUE (Power Usage Effectiveness) by .01

PUE savings, assuming 1.5lpm/kW of cooling, 15 psi less pressure drop, 25% CDU efficiency

$$\frac{1.5 \cdot \frac{\text{lpm}}{\text{kW}} \cdot 15 \cdot \text{psi}}{25\%} = 0.01$$

The pressure drop in a server includes the cold plates, the fittings and manifolds inside the server and the quick disconnects. Typical cold plates have less than 2 psi (14 kPa) of pressure drop. This is the system payload. All the other pressure drop in the system is parasitic load that should be reduced as much as possible.

For example, Chilldyne's Nvidia GPU installation at the Texas Advanced Computer Center (TACC) has less than 4 psi of pressure drop for the whole server including cold plates, tubing and quick disconnects. The same server with other liquid cooling may have 20 psi of pressure drop.

An easy way to improve efficiency is to use a larger fluid connector. If we have a 10 kW server, that is liquid cooled with 12 lpm of water or PG25, we can figure out the power savings by using a larger connector. Some vendors use a universal quick disconnect that is made by a number of vendors. If we switch from a UQD04 (1/4") to a UQD06 (3/8"), We can save 66 watts of CDU power. Assuming the bigger connector costs $15 more per set, ($30 total) and that electricity costs $.05 /kWhr, the savings pays for the larger connector in about 1 year.

We further cover the technical details and proof points with our analysis on the next page.

Power savings using larger fluid connector we assume a 10 kW server with 12 lpm of cooling water

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$SG := 1$

$Cv4 := 1.15$ For UQD04.

Cv values found on Staubli website: Universal Quick Disconnect UQD & UQDB

Flow rate $Q := 12 \cdot \frac{liter}{min}$ $Q = 3.17 \frac{gal}{min}$

Pressure drop $\Delta P := 2 \cdot \left[\frac{\left(\frac{Q}{\frac{gal}{min}} \right)^2}{Cv4^2} \cdot SG \right] \cdot psi$ $\Delta P = 15.197\, psi$ $\Delta P = 31.03\, in\_Hg$

Power consumption and cost of power at $.05/kwhr for 5 yrs)

$\frac{Q \cdot \Delta P}{.25} = 83.826\, W$ $\frac{Q \cdot \Delta P}{.25} \cdot 5 \cdot yr \cdot \frac{.05}{1000 \cdot W \cdot hr} = 183.7$

$Cv6 := 2.5$ For UQD06.

Pressure drop $\Delta P2 := 2 \cdot \left[\frac{\left(\frac{Q}{\frac{gal}{min}} \right)^2}{Cv6^2} \cdot SG \right] \cdot psi$ $\Delta P2 = 3.216\, psi$ $\Delta P2 = 6.566\, in\_Hg$

CDU Power $\frac{Q \cdot \Delta P2}{.25} = 17.738\, W$ Power Cost $\frac{Q \cdot \Delta P2}{.25} \cdot 5 \cdot yr \cdot \frac{.05}{1000 \cdot W \cdot hr} = 38.87$

Payback time based on estimated cost delta for 1 server set, 2 Male +2 Female

$\Delta cost := 30$ $\frac{\Delta cost}{\frac{Q \cdot \Delta P}{.25} - \frac{Q \cdot \Delta P2}{.25}} \cdot \frac{(1000 \cdot W \cdot hr)}{.05} = 1.036\, yr$ $\frac{Q \cdot \Delta P}{.25} - \frac{Q \cdot \Delta P2}{.25} = 66.1\, W$