A Top-20 Supercomputing Facility Rethinks its Cooling Efficiency with Fluid-Submersion Cooling

Figure 1: 42U CarnotJet rack and pump module at TACC

Figure 2: Perspective view of servers installed in system

Introduction

Despite recent gains in data center cooling efficiency – hot and cold aisles, air-side economization, in-row cooling – air cooling remains inherently inefficient as a cooling medium. In mid-2010, Green Revolution Cooling (GRC) partnered with Texas Advanced Computing Center (TACC) and the National Science Foundation (NSF) to study the long-term plausibility of fluid submersion cooling for OEM servers in data centers. GRC deployed the CarnotJet system, a proprietary fluid submersion cooling system that utilizes low-cost, dielectric fluid coolant, on an unconditioned loading dock adjacent to Ranger in April 2010. Questions posed before the install included: Could submersion cooling be efficient and reliable? Could it make sustained over-clocking of CPUs possible? Could this pave the way for future large-scale deployment of fluid cooling?

System Design

The CarnotJet system consists of three components: a 42U rack filled with dielectric fluid (resembles a vertical cabinet tipped on its back), a pump module, and a control system. The pump module circulates coolant in the rack via natural and forced convection, dissipating server heat. Hot coolant is carried out of the rack to the pump module where the heat is rejected to water. Servers must have fans removed, thermal grease replaced with Indium foil, and hard drives encapsulated to be submerged.

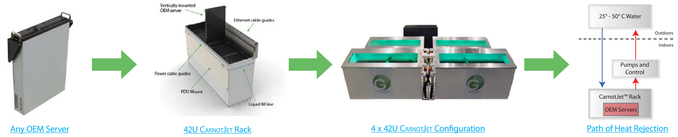

Figure 5: Full system view of CarnotJet fluid submersion cooling system

Figure 3: Dell servers installed in CarnotJet system

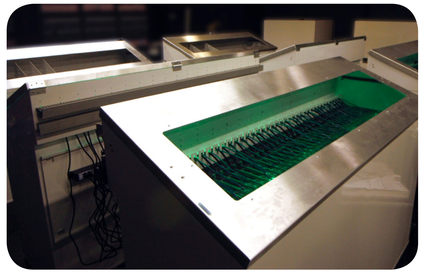

Figure 4: Example of six-rack system installation

Results

Cooling Efficiency

The installation at TACC has consistently used 6 Watts or less of cooling power for every 100 Watts of IT since April 2010.

System has consistently shown reductions in total power usage of ~40% compared to the same hardware cooled by air. Installed on an unconditioned loading dock, system displays efficient cooling even when ambient air temperature is well over 100°F.

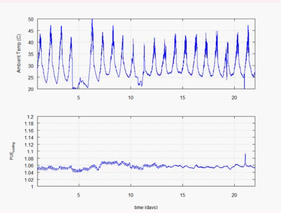

Figure 6: Measured system efficiency compared to ambient outdoor temperature.

PUEcooling = (server power + cooling power) / server power.

Server Efficiency

Server and power supply fans are removed as they are rendered obsolete in a fluid submersion environment. Depending on server manufacturer and model, fan removal results in 10-25% reduction in server power. This allows more energy to be spent on compute rather than cooling. Fans may be reinstalled if servers are reconditioned for air-cooled environment.

Table 1: Increase in server fan power use as a function of increase in ambient temperature, as compared to the CarnotJet™ system. Baseline: Dell 1U server (R410), one 4-core CPU (E5520), 4 GB RAM, 1 HDD.

Server Model	*Power Reduction*
IBM x3550 1U server	10.3% at 100% CPU
Dell 1950 1U server	27% at idle

Table 2: Increase in server fan power use as a function of increase in ambient temperature, as compared to the CarnotJet™ system. Baseline: Dell 1U server (R410), one 4-core CPU (E5520), 4 GB RAM, 1 HDD.

	Idle		100% CPU	
	W	%Δ	W	%Δ
CarnotJet	67.9		126.6	
air @ 27°C	68.9	1%	137.7	9%
air @ 29°C	71.5	5%	139.4	10%
air @ 33°C	75.8	12%	144	14%
air @ 35°C	80.5	19%	148.4	17%

Overall Performance

Since installation, the CarnotJet system has produced significant energy savings while demonstrating the ability to sustain dramatic performance increases.

Table 3: TACC total data center efficiency. Unit = $\frac{\text{Power}}{\text{Server Power in an Air-Cooled System}}$

System Element	*Current System*	*GR Cooling*
Server	1.0	.85
Power Distribution Losses	.02	.02
Cooling	.4	.06
Total	1.42	.93

The system has also shown the ability to sustain over-clocking of CPUs more than 30% past the base rate.

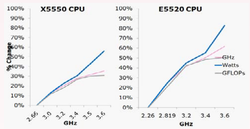

Figure 7: X5550 over-clock to 3.6 GHz vs. its 2.66 GHz base (+35%); E5520 over-clock to 3.66 GHz vs. its 2.26 GHz base (+62%).

Future

Drawing on the experience of this installation, GRC and TACC are in talks to produce *Jalapeno*, a two-rack system with 130 kW total capacity (65 kW of compute per rack) sometime in 2012. To upgrade the existing system, a more robust pump module will be installed and connected to multiple racks to drive circulation of the dielectric fluid. By installing extremely dense servers, TACC and GRC will be able to leverage the efficiency of fluid submersion cooling on a larger scale.

Green Revolution Cooling (GRC)

Produces a groundbreaking cooling system for OEM servers that uses total submersion in dielectric fluid. Introduced at **SC'09**, Green Revolution Cooling's CarnotJet™ system continues to lead the way in next-generation data center cooling efficiency.

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Texas Advanced Computing Center (TACC)

Home of the Stampede, Ranger, and Lonestar 4 supercomputers, the Texas Advanced Computing Center at The University of Texas at Austin is on the forefront of academic supercomputing research.

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