Shrinking Data Center Size, Complexity, and Cost through Directed-Flow Liquid Immersion Cooling

Darwin Kauffman, CEO, LiquidCool Solutions
Gary Testa, CEO, Engineered Fluids
Other Companies are doing...

- **Cold Plates**
  Direct-to-Chip, Fluid-to-Chip, Spot Cooling

- **Back of Rack Cooling**
  Active Rack, Rear Door, Chilled Door Cooling

- **Two-phase Immersion**
  Novec, Passive 2-Phase, Spot-Cooling

**Cold Plates**
- Individual Heatsinks
- Board-Specific
- Individual Chip Fluid-cooling

**Back of Rack**
- Air is still only means to cool board/chip
- Limited by existing chip maximum temps
- Requires additional fans

**Two-Phase Immersion**
- Specialty fluids ($$$)
- Can Require Separate Cooling Coil
- Orientation sensitive
Liquid Cooling Approaches

Direct-to-Chip Cooling

The Pros:

• Improves cooling efficiency – better PUE
• Increases compute density in servers nodes

The Cons:

• Water is used at each server node and in data hall.
• Only a portion of the server components are cooled with liquid, fans still required.
Two-Phase Immersion

The Pros:

- Very effective at removing heat from CPU/GPU
- Provides excellent cooling energy efficiency
- Fans and air-cooling infrastructure are eliminated

The Cons:

- Two-phase fluid has high GWP, very expensive and volatile,
- Sealed enclosure contains coolant vapor under high pressure
- Micro-cavitation effects raise long-term reliability concern
- Requires water circulation in server enclosure
Liquid Cooling Approaches

Single-Phase Immersion

The Pros:

• Very effective removing heat from all electronics.
• Fans and air-cooling infrastructure are eliminated
• Non-volatile; low cost fluid
• Improved reliability and TCO

The Cons:

• Open tank designs
• Weight / large footprint
• Serviceability and fluid containment.
The right single-phase dielectric coolant for your solution makes all the difference:

- Safe for our environment, your equipment, and your people
  - Guaranteed materially compatible and non-destructive to metals, electronics, and most plastics
  - Never changes phase to gas thus eliminating high pressure, seal systems and gaseous vapor in IT room
  - 10 Year operational characteristics warranty, Biodegradable, Non-Toxic, Non-Allergenic, Not Flammable

- Eliminates all water from the IT white space
  - Reduce complexity, maintenance, and risk related to water in proximity to electronics
  - Eliminates server fans, CRACs, air handlers chillers, dehumidifiers, and filters
  - Immediate increase in server MTBF and eliminate a majority of scheduled maintenance.

- Requires very low flow rate (<.5 GPM per kW) and pressure (<5 PSI) for cooling infrastructure design
  - Reduction in liquid coolant piping infrastructure cost and complexity
  - Utilize off-the-shelf, low cost, highly reliable & redundant pumps
  - Typical pumping system requires only 3% of energy cooled (3kw to cool 1MW)

- Higher coolant supply temps (<130°F/54°C) and simple heat reuse
  - Use simple dry coolers with <15% active duty fans in most conditions (even humid locations) due to high coolant temps and coolant heat density.
  - Use of high efficiency, compact Liquid-to-Liquid HEX for heat transfer and reuse
<table>
<thead>
<tr>
<th>Characteristic</th>
<th>ElectroCool®</th>
<th>Mineral Oil</th>
<th>Fluorinated Fluids</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dielectric Strength (ASTM 1816)</td>
<td>60kV</td>
<td>25kV</td>
<td>40kV</td>
</tr>
<tr>
<td>Relative Heat Capacity ((\text{Air} = 1))</td>
<td>1410</td>
<td>1170</td>
<td>1360</td>
</tr>
<tr>
<td>Density ((\text{g/cm}^3 \text{ @ 20C}))</td>
<td>.80</td>
<td>.85</td>
<td>1.72</td>
</tr>
<tr>
<td>Flammability</td>
<td>Not Flammable</td>
<td>Flammable</td>
<td>Not Flammable</td>
</tr>
<tr>
<td>Environmental Impacts</td>
<td>GWP = 0</td>
<td>GWP = 0</td>
<td>GWP &gt; 9000</td>
</tr>
<tr>
<td>Worker Health and Safety</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Biodegradable and Nontoxic</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Characteristics are Standardized, Tested and</td>
<td>✓</td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>Guaranteed</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Material Compatibility Guarantee</td>
<td>✓</td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>Cooling Systems are Simple, Quiet, and Clean</td>
<td>✓</td>
<td></td>
<td>✓</td>
</tr>
</tbody>
</table>
LiquidCool’s Approach

LiquidCool Inc. combines:

• Total fluid immersion of server in 19 inch rack.
• A directed-flow fluid circulation system
• Uses ElectroCool - synthetic single-phase dielectric coolant specially engineered for cooling electronics

The Result:

LiquidCool’s Directed-Flow Total Immersion Cooling delivers all the benefits of other liquid-cooling approaches
How it Works

Directed-Flow makes the difference

With Directed-Flow

- Server and CPUs run much cooler
- Compute density can increase
- Cooling and energy efficiency can be optimized

Outgoing Warm Coolant

Incoming "Cool" Coolant

Incoming fluid FIRST directed to highest power components

LiquidCool sealed Server

34 granted patents
17 Additional patents pending
Total Immersion + Directed Flow means...

**CPUs operate up to 30 °C cooler compared to air cooling**

No rack fans + Cooler CPUs means...

**LiquidCool servers use up to 20% less power vs. equivalent air-cooled servers**

Source: LiquidCool “Server Power-to-Cool” whitepaper
LiquidCool Servers

Rack Server Systems for Data Centers

- Up to 96 servers per standard rack
- Up to 50kW of computing per rack
- Tailorable to OCP server configurations
Enterprise Installations

National Renewable Energy Laboratory
LSS server system tested for energy efficiency and heat recovery effectiveness in conjunction with the Wells Fargo IN² Program*
System now in operation in the NREL ESIF
- [https://www.nrel.gov/docs/fy18osti/70459.pdf](https://www.nrel.gov/docs/fy18osti/70459.pdf)
- Running OpenStudio tool suite for researchers

CBRE|ESI Smart Building Client Center
LSS server nodes installed at the CBRE|ESI Client Experience Center.
Three 2 socket servers running Vmware. SSDs and HDDs for storage
Two mission critical services.
- Smart Building systems
- Call center operations.
# The numbers

## Cooling System Specs

<table>
<thead>
<tr>
<th>Specification</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coolant Flow Rate (per kW)</td>
<td>0.3 - 0.5 GPM</td>
</tr>
<tr>
<td>Coolant Pressure</td>
<td>Less than 5 PSI</td>
</tr>
<tr>
<td>Coolant Volume (per CPU)</td>
<td>0.7 - 0.8 gallons</td>
</tr>
<tr>
<td>Coolant weight per Data Center Rack</td>
<td>450 – 700 lbs.</td>
</tr>
<tr>
<td>Weight of fully-populated 42U Rack</td>
<td>2900 – 3000 lbs.</td>
</tr>
<tr>
<td>Maximum Incoming Coolant Temperature</td>
<td>54°C (129°F)</td>
</tr>
<tr>
<td>Typical Partial PUE (per dielectric loop)</td>
<td>1.01 – 1.03</td>
</tr>
<tr>
<td>Heat Energy Recovery Effectiveness</td>
<td>90% - 95%</td>
</tr>
<tr>
<td>Heat Energy Reuse Temperature</td>
<td>Up to 60°C (140°F)</td>
</tr>
</tbody>
</table>
LiquidCool – OCP Concept

Olympus Server repackaged in LiquidCool enclosure

- Liquid tight enclosure with bulkheaded power, I/O, and UI features
- Fans eliminated at rear of chassis
- Space reserved for remote heatsink eliminated
- Shorter enclosure possible with a more compact power supply geometry

- Directed flow proportioning manifold added
- Fluid lines to/from manifold ports to LCS heatsinks for CPUs & PCIe cards added
Liquid cooling for OCP

Applying LiquidCool to GPU servers can dramatically increase rack density

Blockchain solution in Development

Overclocking GPU performance

Image Source: OCP Marketplace, opencompute.org
Summary

LiquidCool’s total liquid systems using Engineering Fluids coolant provides the ideal data center cooling technology

✓ High compute density
✓ Compatibility with standard server racks, including OCP designs
✓ High server reliability
✓ Highest PUE – 1.02
✓ Safe, effective, non-volatile, biodegradable coolant with zero Global Warming Potential
✓ No water inside racks and low-pressure fluid circulation prevent catastrophic failures
✓ Elimination of server and rack fans – lower ambient noise for storage