Liquid in the Rack: Liquid Cooling Your Data Centers

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Agenda

• Introduction to Liquid Cooling
• NREL Case Study
Benefits of Liquid Cooling

- Higher compute densities
- Higher efficiency

➤ Vision: Eliminate compressor based cooling and water consumption
Moving (Back) to Liquid Cooling

- As heat densities rise, liquid solutions become more attractive
- Volumetric heat capacity comparison:
  - Water: (1.5 m³)
  - Air: (5,380 m³)

Image: 400 Gallon pool = ~ 190,000 cubic foot blimp
**Why Liquid Cooling?**

- Liquids can provide cooling at higher temperatures
  - Improved cooling efficiency
  - Increased economizer hours
  - Potential use of waste heat
- Reduced transport energy:

<table>
<thead>
<tr>
<th>Heat Transfer</th>
<th>Resultant Energy Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rate</td>
<td>Heat Transfer Medium</td>
</tr>
<tr>
<td>10 Tons</td>
<td>Forced Air</td>
</tr>
<tr>
<td></td>
<td>Water</td>
</tr>
</tbody>
</table>
For most locations data centers may be operated without chillers in a water-side economizer mode.
In-Rack Liquid Cooling

• Racks with integral coils and full containment:
Rear-Door Heat Exchanger

• Passive technology: relies on server fans for airflow
• Active technology: supplements server fans with external fans in door
• Can use chilled or higher temperature water for cooling

Photo courtesy of Vette
Liquid On-Board Cooling
Example: Maui DOD HPC Center Warm Water Cooling

IBM System x iDataPlex

- 90% water cooled
- 10% air cooled
- Cooling water temperature as high as 44°C

Dry Coolers, 10 kW each compared to 100 kW Chillers
Liquid Immersion Cooling

Computers in glass tank

Cooling Power = Pump + Fan

No longer requires:
- chillers
- cooling towers
- water use
- raised floors
- CRACs
- earplugs!
“Chill-Off 2” Evaluation of Liquid Cooling Solutions

Data Center Cooling Device Relative Performance

- CRAC w/ DX comp.
- CRAH w/ Chilled water
- Rack Cooler
- In-Row Cooler
- Rear Door Heat Exchanger (passive)
- Direct Touch Cooling

Test ID Number - Test Parameters

<table>
<thead>
<tr>
<th>Test ID</th>
<th>Chilled Water Temp. (°F)</th>
<th>Server Air Inlet Temp. (°F)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>45</td>
<td>60</td>
</tr>
<tr>
<td>2</td>
<td>45</td>
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<td>60</td>
<td>90</td>
</tr>
<tr>
<td>7</td>
<td>60</td>
<td>90</td>
</tr>
</tbody>
</table>

COEEd (1.00-1.55)
“Free Cooling” w/ Water-Side Economizers

• Cooling without Compressors
• Easier retrofit
• Added reliability (backup in case of chiller failure)
• No contamination issues
• Put in series with chiller
• Uses tower or dry cooler

No or minimum compressor cooling

Cooling tower and HX = Water-side Economizer
Re-Use of Waste Heat

• Heat from a data center can be used for:
  – Heating adjacent offices directly
  – Preheating make-up air (e.g., “run around coil” for adjacent laboratories)

• Use a heat pump to elevate temperature
  – Waste heat from LBNL ALS servers captured with rear door coolers feed a heat pump that provides hot water for reheat coils

• Warm-water cooled computers are used to heat:
  – Greenhouses, swimming pools, and district heating systems
Resources: FEMP’s Center of Expertise in Data Centers

- [datacenters.lbl.gov](http://datacenters.lbl.gov)
- [datacenters.lbl.gov/technologies/liquid-cooling](http://datacenters.lbl.gov/technologies/liquid-cooling)

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Liquid in the Rack: Liquid Cooling Your Data Center

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NREL ESIF Data Center

• Showcase Facility
  – ESIF 182,000 ft.² research facility
  – 10,000 ft.² data center
  – 10-MW at full buildout
  – LEED Platinum Facility, PUE ≤ 1.06
  – NO mechanical cooling (eliminates expensive and inefficient chillers)

• Data Center Features
  – Direct, component-level liquid cooling, 24°C (75°F) cooling water supply
  – 35-40°C (95-104°F) return water (waste heat) is captured and used to heat offices and lab space
  – Pumps more efficient than fans
  – High-voltage, 480-VAC power distribution directly to high power density 60- to 80-kW compute racks

• Compared to a Typical Data Center
  – Lower CapEx—costs less to build
  – Lower OpEx—efficiencies save

• Integrated “Chips-to-Bricks” Approach

Utilize the bytes and the BTUs!
**Metrics**

\[
PUE = \frac{\text{"Facility energy"} + \text{"IT energy"}}{\text{"IT energy"}}
\]

Assume ~20MW HPC system & $1M per MW year utility cost.
**Metrics**

\[
PUE = \frac{\text{"Facility energy"} + \text{"IT energy"}}{\text{"IT energy"}}
\]

\[
ERE = \frac{\text{"Facility energy"} + \text{"IT energy"} - \text{"Reuse energy"}}{\text{"IT energy"}}
\]

Assume ~20MW HPC system & $1M per MW year utility cost.
Liquid Cooling – Considerations

- Liquid cooling essential at high-power density
- Compatible metals and water chemistry is crucial
- Cooling distribution units (CDUs)
  - Efficient heat exchangers to separate facility and server liquids
  - Flow control to manage heat return
  - System filtration (with bypass) to ensure quality
- Redundancy in hydronic system (pumps, heat exchangers)
- Plan for hierarchy of systems
  - Cooling in series rather than parallel
  - Most sensitive systems get coolest liquid
- At least 95% of rack heat load captured directly to liquid
Basic Hybrid System Concept

Heat In

95°F (35.0°C)

Dry Sensible Cooler

85°F (29.4°C)

Dry Loop
Sized for Water Savings

Condenser Water Pump

95°F (35.0°C)

Heat Exchange

75°F (23.9°C)

Process Loop

Wet Loop
Sized for Design Day
Thermal Duty

Wet Heat
Out

75°F (23.9°C)

Dry Heat
Out

Tower

21°F (9.4°C)
Basic Hybrid System Concept

“Wet” when it’s hot, “dry” when it’s not.
Improved WUE – Thermosyphon
Data Center Metrics

First year of TSC operation (9/1/2016–8/31/2017)

Hourly average IT Load
= 888 kW

PUE = 1.034
ERE = 0.929

Annual Heat Rejection

- Building Heat
- Cooling Towers
- Thermosyphon
Data Center Metrics

First year of TSC operation (9/1/2016–8/31/2017)

- **Hourly average IT Load** = 888 kW
- **PUE** = 1.034
- **ERE** = 0.929

**WUE = 0.7 liters/kWh**

(with only cooling towers, **WUE = 1.42 liters/kWh**)

Annual Heat Rejection

- **Cooling Towers**
- **Thermosyphon**
- **Building Heat**

Site Water Usage and Estimated Water Savings

- **Site Water Usage**
- **Estimated Reuse Energy Water Savings**
- **Estimated Thermosyphon Water Savings**
Cumulative Water and Cost Savings

Energy = $0.07/kWh
Water = $5.18/kgal

As of Jan 04, 2019 07:34 PM
Total TSC Heat Rejected = 8,469,782 kWh's
Total Water Saved = 2,780,123 Gallons
Total Operational Cost Savings = $7,691
Questions & Contact Information

• Questions?
• Contact Information:

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