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The Facility Perspective on Liquid Cooling: Experiences and Proposed Open Specification

SC18 Birds of a Feather

November 13, 2018

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Agenda

- Overview of warm water liquid cooling
- Introductory remarks from panelists (strategies and lessons learned)
- Overview of open specifications for liquid cooled rack
- Panel and audience discussion

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Warm Liquid Cooling - Overview

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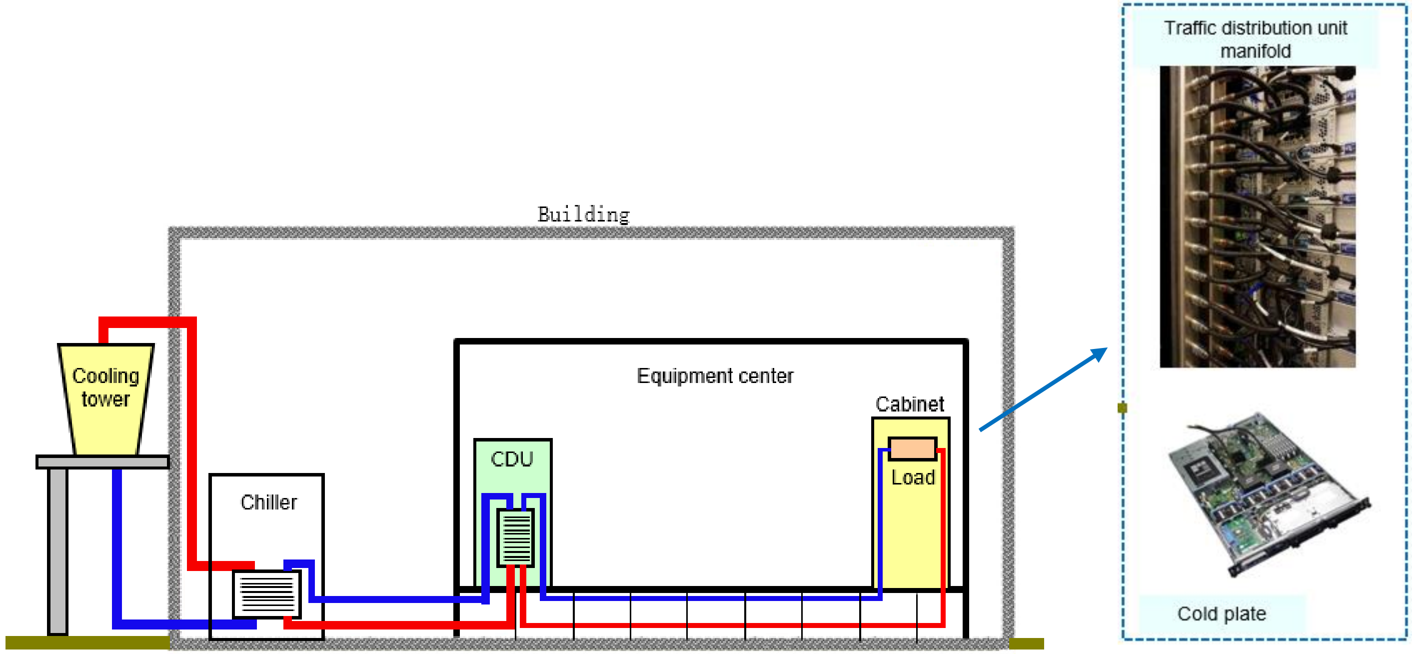
Liquid Cooling Solution



Typical liquid cooled equipment room, with external coolant distribution units (CDUs)

For most locations these data centers may be operated without chillers in a water-side economizer mode

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

(1.5 m^3)

Water

=

(5,380 m^3)

Air

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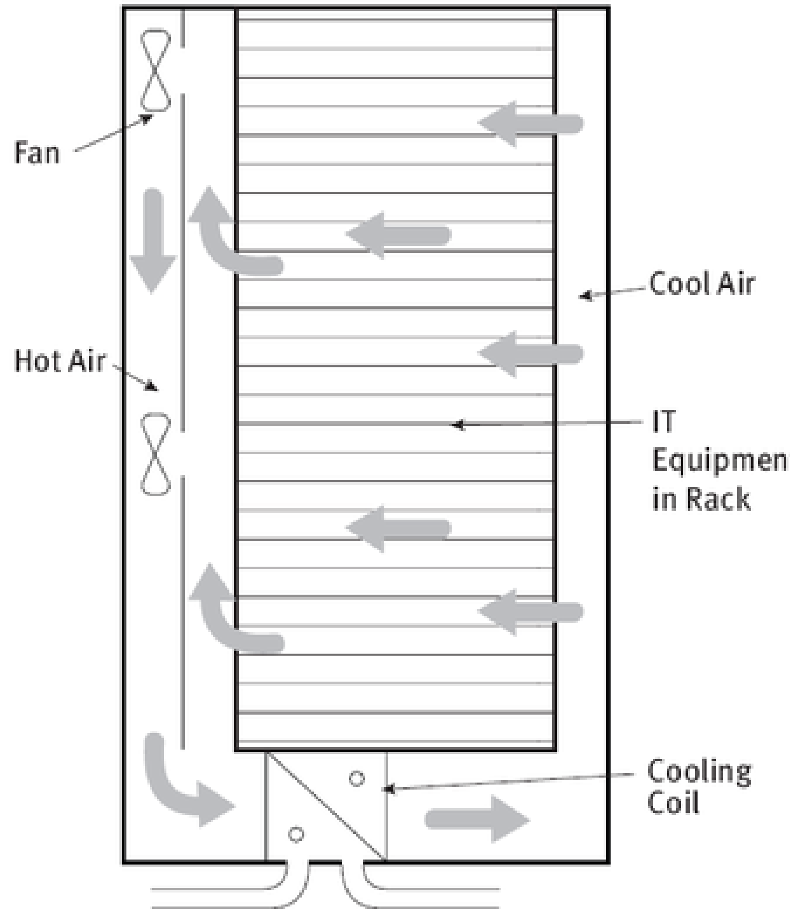
Why Liquid Cooling?

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

Heat Transfer		Resultant Energy Requirements			
Rate	ΔT	Heat Transfer Medium	Fluid Flow Rate	Conduit Size	Theoretical Horsepower
10 Tons	12°F	Forced Air	9217 cfm	34" Ø	3.63 Hp
		Water	20 gpm	2" Ø	.25 Hp

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-Chip Cooling

Maui HPC Center Warm Water Cooling

IBM System x iDataPlex

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

Water inside

Dry Coolers, 10 kW each compared to 100 kW Chillers

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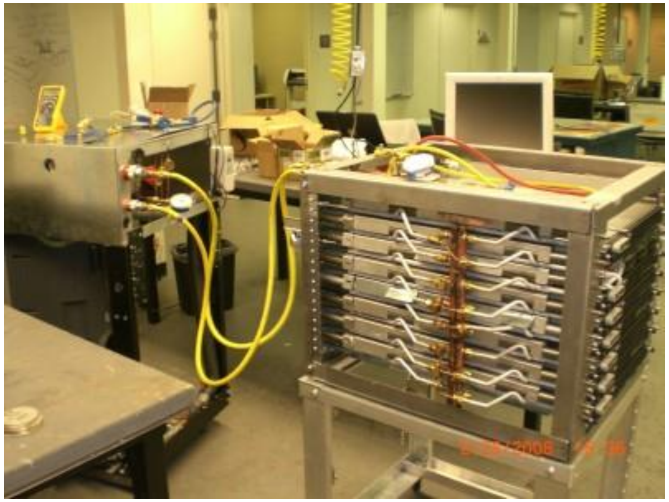
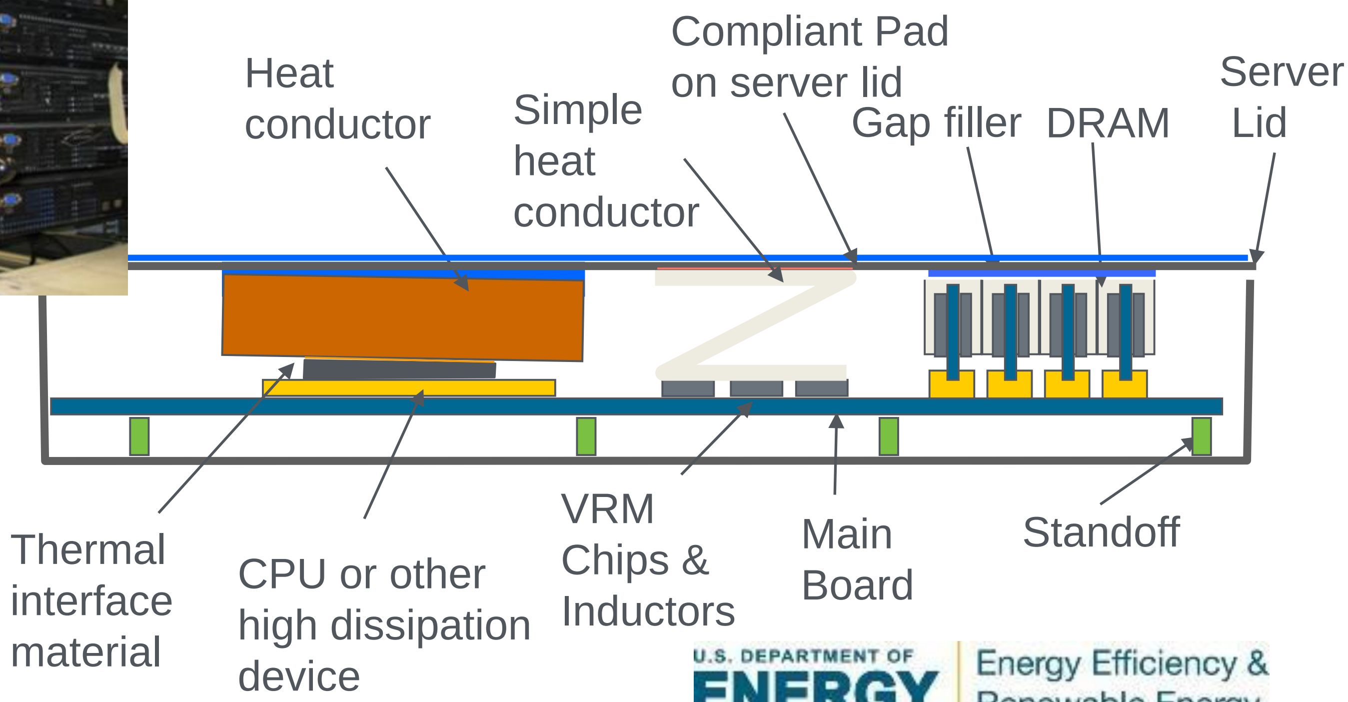
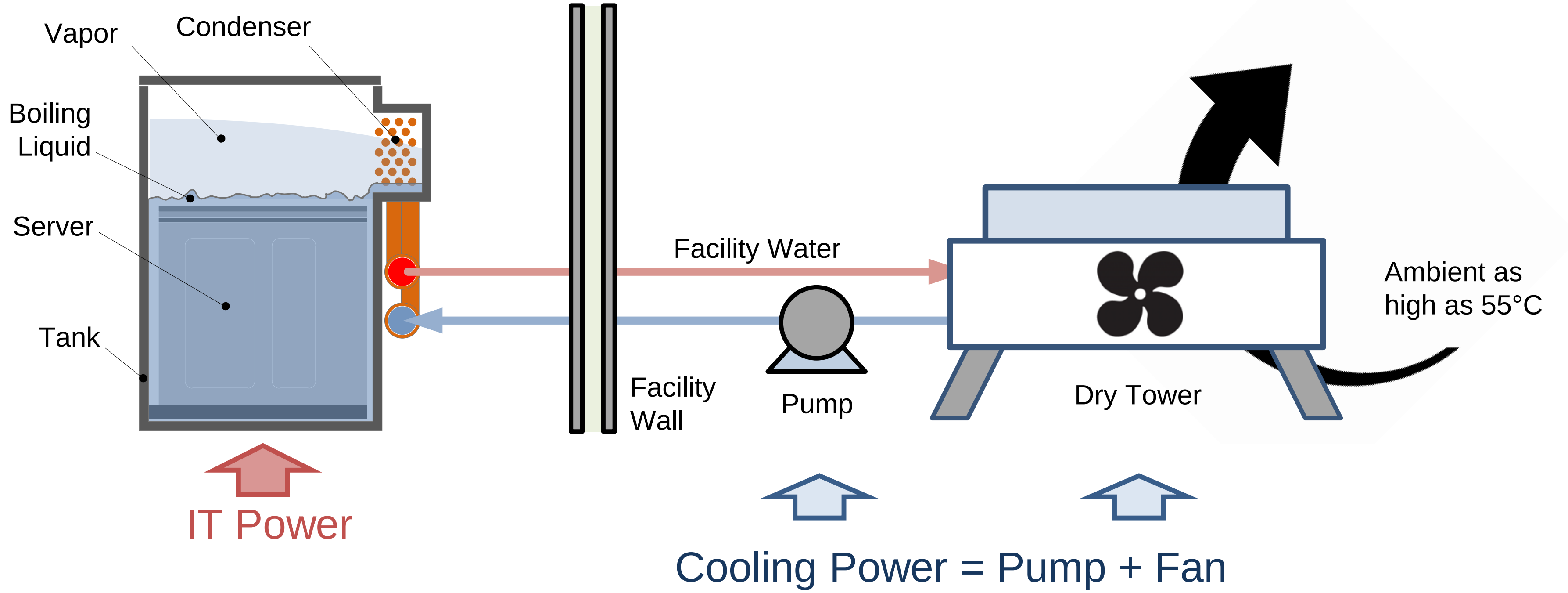
Liquid On-Board Cooling

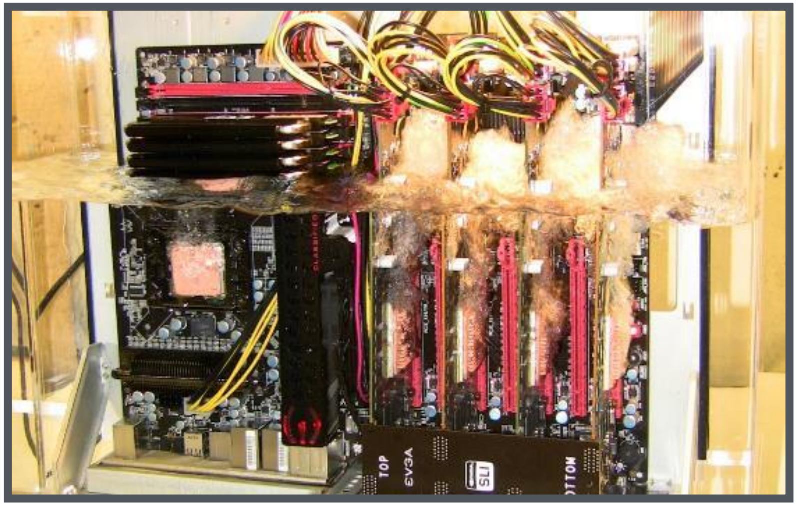
- Heat exchanger plate covers top of server and heat risers connect to the top plate
- Server fans are removed





Liquid Immersion Cooling





Computer in glass tank

No longer requires:

- chillers
- cooling towers
- water use
- raised floors
- computer room air conditioners
- earplugs!

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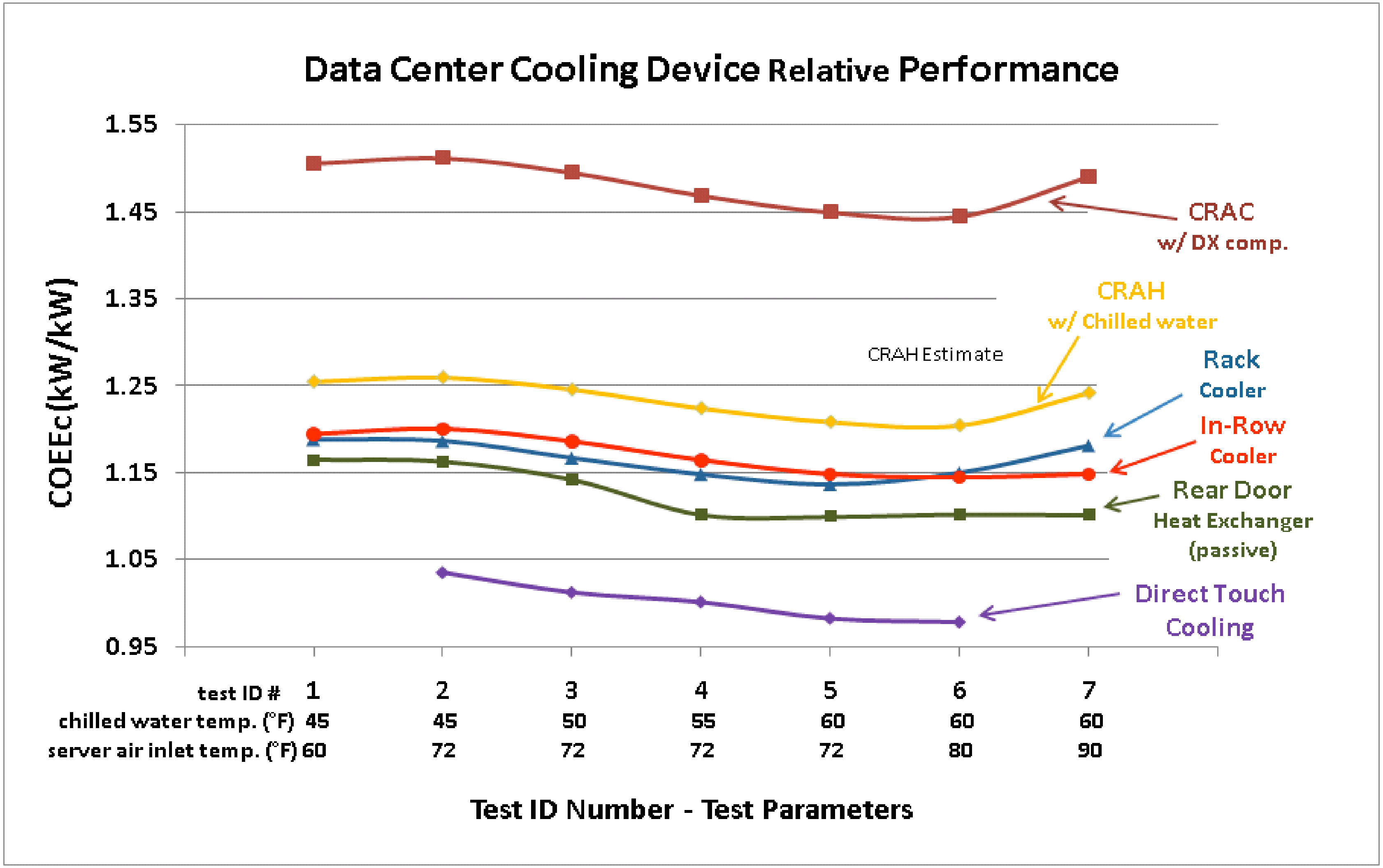
"Chill-Off 2" Evaluation of Liquid Cooling Solutions



“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
- Panelists to describe transition

No or minimum compressor cooling

Cooling tower and HX = Water-side Economizer

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ASHRAE Design Reference Conditions - 2015

Liquid Cooling Classes	Typical Infrastructure Design		Facility Supply Water Temperature
	Main Heat Rejection Equipment	Supplemental Cooling Equipment	
W1	Chiller/Cooling Tower	Water-side Economizer (With Drycooler or Cooling Tower)	35.6°F to 62.6°F
W2			35.6°F to 80.6°F
W3	Cooling Tower	Chiller	35.6°F to 89.6°F
W4	Water-side Economizer (With Drycooler or Cooling Tower)	N/A	35.6°F to 113°F
W5	Building Heating System	Cooling Tower	>113°F

Defines interface between Facility and IT

- Allows a common design basis
- Provides guidance in system, loop & infrastructure design

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 (NREL’s data center adds heat to campus heating loop)

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Find Resources at the Center of Expertise

https://datacenters.lbl.gov/

Introductions from Panelists

- Anna Maria Bailey, LLNL
- David Grant, ORNL
- Herbert Huber, LRZ
- David Martinez, SNL

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Introduction of Open Specifications for Liquid Cooling

Dale Sartor, P.E.
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Liquid Cooled Rack Standard

- While liquid cooling potential is understood, uptake is slow
- Most solutions are unique and proprietary
- Needed:
  - Multi-source solution
  - Reusable rack infrastructure
- Users can drive faster technology development and adoption

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International Open Data Center Specifications

- Target Organizations:
  - The Open Compute Project (OCP) – US
  - Open Data Center Committee (ODCC)/Scorpio Project – China
- Collaborators:
  - Facebook
  - Google
  - Intel
  - Microsoft
  - Baidu
  - Alibaba
  - Tencent
  - YOU

- Chinese team developed high level framework (White Paper)
- US team (+ Baidu) developed draft rack specification

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Goal for Liquid Cooled Rack Specifications

- The Working Group focused on:
  - Water based transfer fluid: quality, treatment and compatibility
  - Wetted material list (OK and not OK)
  - Universal (multi-vendor) quick connectors
  - Operating conditions (e.g. supply pressure, temperature)
- Goal:
  - A liquid cooled rack specification that could accommodate multiple vendors and provide an infrastructure for multiple refresh cycles with a variety of liquid cooled servers/suppliers.
- Challenges
  - Proprietary nature of both the chemical compositions of water based transfer fluids and the quick connects
- Next step
  - Seeking broader input (e.g. via EEHPCWG) and working with OCP

Common Wetted Materials List

Material	Description/Comment
Brass	
Stainless Steel (series 300 and 400)	
Copper	
Nickel Plating	
Chrome Plating	
Polyphenylene sulfide (PPS)	Thermoplastic
PTFE	Seals
EPDM	Hoses, seals, O-rings
Nitrile	rubber
Polysulfone	
Nylon 6	
Expanded Polythene	Foam
PPO, Polyphenylene oxide	Thermoplastic
PVC	Plastic
Nickel-Chromium	
Viton	o-rings
Delrin, Acetal, Polyacetal	
Grease	PFPE/PTFE or suitable for vacuum systems
BCuP-2, 3, 4, 5	Brazing material
TF-H600F	Brazing material
B-Ni-6	Brazing material
B-Ag-8a	Brazing material

Wetted Materials to be Avoided

Material	Description/Comment
Aluminum	
Zinc (including brazing material)	
Lead	Be aware of regulatory requirements as well as fluid compatibility requirements

Fluid Operating Ranges

Parameter	Value	Source	Comments
Shipping Temperature Range	-40C to 75C		-40C condition is typical for shipping and storage. Some OEMs may prefer to ship the assemblies pre charged with liquid.
Operating Temperature Range	2C to 60C		Assumes ASHRAE W4, 2degC approach in CDU and up to a 13degC delta T
Life	10+ years		End users/integrators responsible for checking water quality parameters at regular time intervals (quarterly/monthly) per supplier requirements.
pH	7 to 10.5	ASHRAE guidelines	

Fluid Quality

Parameter	Value	Source	Comments
Corrosion inhibitor	Required	ASHRAE	
Biocides	Required	ASHRAE	
Sulfides	<1 ppm	ASHRAE	
Sulfate	<10 ppm	ASHRAE	
Chloride	<5 ppm	ASHRAE	
Bacteria	<100 CFU/mL	ASHRAE	
Total hardness (as CaCO3)	<20 ppm	ASHRAE	
Conductivity	0.20 to 20 micromho/cm based on water	ASHRAE	
Total suspended solids	<3 ppm	ASHRAE	
Residue after evaporation	<50 ppm based on water	ASHRAE	
Turbidity	<20 NTU (nephelometric)	ASHRAE	
Maximum Particulate size	50 microns		In some cases a bypass filter is used to remove smaller particulates

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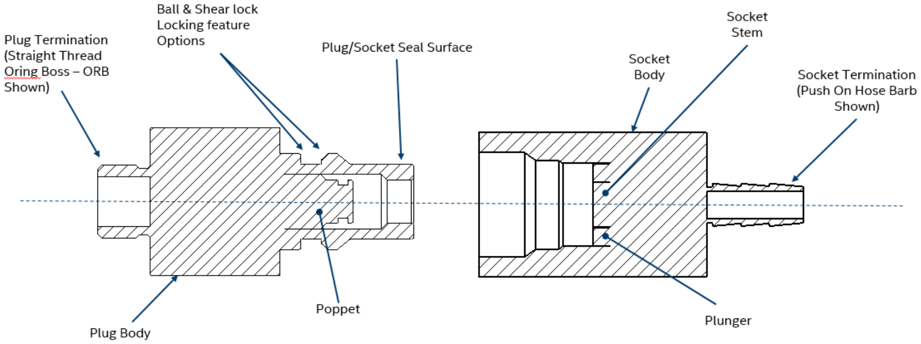
Quick Connect



Parameter	6.35 mm	9.53 mm	12.70 mm
Operating pressure	Up to 60 psi (TBD)		
Minimum Cv	0.33	1.1	1.9
Flow Rating	At least 0.75 GPM	At least 1.7 GPM	At least 3.0 GPM
Operating temperature	2 – 70 °C		
Shipping temperature	-40 – 115°C		

Other Specifications & Operating Conditions

- Manifold Design Considerations
- Tubing Design Considerations
- Operating Temperature Considerations:
  - 2°C (per ASHRAE W classes) to 60°C or greater
- Operating Pressure Conditions:
  - Up to 60psi depending on pump performance of the CDU.
- Filtration Considerations:
  - Maximum particulate size of 50 micron
  - System components may have looser or more stringent requirements (bypass filter)
- **Consult ASHRAE Liquid Cooling System Guidelines for Datacom Equipment Centers when designing liquid cooling system.**
- **Users/integrators must validate their own design**

Websites

Access the current liquid cooled rack specification (DRAFT) here: https://datacenters.lbl.gov/resources/open-specification-liquid-cooled-server

Additional information: https://datacenters.lbl.gov/industry-driving-harmonization-international-data

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Next Steps

- Provide input tonight
- Provide input on draft specification document
- Join the EEHPCWG effort (contact Dale or Natalie)
  - Will feed into procurement specification working group as well as Open Compute Project (OCP) activity
- Join OCP activity – Advanced Cooling Solutions (ACS)
  - Rear door cooling
  - Cold plate cooling (heat exchanger(s) in IT device)
  - Immersion cooling
  - ➢ Membership not required to participate

Questions to Panelists and Open Discussion

Questions

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