Open Standards Harmonization Working Group*:

Open Specification for a Liquid Cooled Server Rack - Progress Update

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DRAFT

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Disclaimer:

This Document does not imply specific guidance from the authors (the working group members) but is intended to be informational only and the reader is suggested to perform their own research to create their own conclusions for implementation or supplier engagement. Any indication of preference of any kind due to the inclusion or exclusion of any details or suppliers is unintentional.

Input:

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Disclaimer:

Please note the disclaimer at the beginning of this document. Any installation of a liquid cooling system needs validation, and the integrator cannot assume that following these guidelines is a replacement for that validation.

Introduction/Scope:

Although liquid cooling of servers is not new, its uptake has been slow. There are many liquid cooling solution providers, but each solution is unique and proprietary. The purpose of an open specification for a liquid cooled rack is to hasten the adoption of liquid cooling with a multivendor solution.

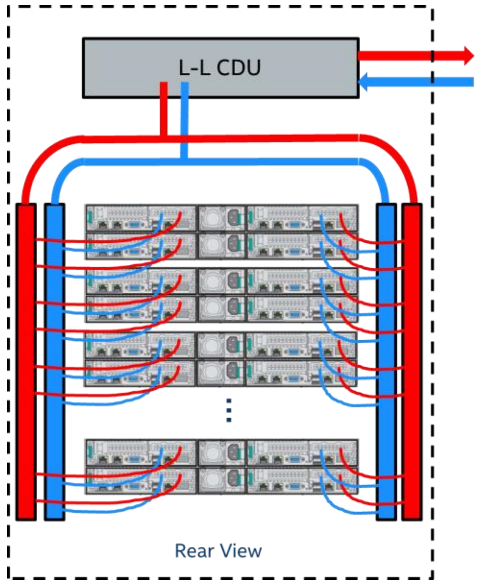
Liquid cooling is not intended as a replacement for air cooling, but is intended as a path for higher density, improved efficiency, and increased performance. Liquid cooling may be deployed when air cooling is insufficient to meet cooling requirements, to increase rack density or for heat capture, and to reduce total cost of ownership.

This specification focusses on the rack design and is intended to be compatible with open rack specifications/standards such as the Open Compute Project (OCP), Project Scorpio, and Open19.

The specification does not include the heat exchange configuration within the IT equipment (e.g. servers). These details will be left to solution providers as long as their design is compatible with the rack specification. Likewise the design of the cooling distribution unit (CDU) is not included. The CDU can be at the rack, row, or room level as long as it provides liquid compatible with the rack. Compatibility is driven by the wetted materials, the transfer fluid, connectors, and operating conditions. This will allow innovation and competition in the market while allowing multiple generations of IT equipment hardware to benefit from the same rack infrastructure. Owner/operators will not be tied to one vendor during IT refresh cycles.

In the context of this specification, the liquid cooling loop consists of a secondary fluid pumped through a rack manifold from a CDU. The heat exchangers within the IT equipment are connected to the rack manifold via either rigid or flexible tubing and quick connects.

Figure 1. Liquid Cooled Rack System Diagram (Diagram courtesy of Intel)



The scope of this project is to develop an open specification for the secondary fluid (closed loop between the CDU and the IT equipment), manifolds, tubing, quick connectors, and the operating conditions. It does not include the CDU or the heat exchangers in or on the IT equipment. The goal is the ability of IT equipment from multiple vendors to "plug and play" in the same rack (meeting the open specification).

Background:

The initiative to develop an open specification for liquid cooling is part of a larger initiative to harmonize international open standards in order to facilitate trade and energy efficiency. The U.S. Department of Energy (DOE) and China's Ministry of Industry and Information Technology (MIIT) are supporting this bilateral initiative to increase efficiency in data centers. The Lawrence Berkeley National Laboratory (LBNL) and China Institute of Electronics (CIE) steer this initiative and coordinate the contributions of industry stakeholders. A small working group of influential potential users/buyers of warm liquid cooled equipment that are active in open standards organizations was formed. The small group is collaborating to develop an open specification that can be presented to their respective open standards organizations for adoption. A hierarchical framework was developed that acknowledges that there are multiple paths to follow to achieve liquid cooling from computer room air handlers (CRAHs), to in-row coolers, to in-rack solutions such as rear door heat exchangers, to cooling at the server or chip level, to immersion cooling. The initial focus was to develop an open specification for a warm liquid cooled rack providing a water based fluid to individual servers. Ideally the specification would be compatible with server rack designs promulgated by multiple open standards organizations such as Project Scorpio (China), the Open Compute Project (OCP), and Open19. Following the framework mentioned above, additional open specifications could be developed for other liquid cooling solutions such as immersion cooling in the future.

Working Group Members:

The working group includes staff from the following organizations:

- Lawrence Berkeley National Laboratory
- China Institute of Electronics
- Tencent
- Baidu
- Alibaba
- Intel
- Facebook
- LinkedIn
- Google
- Microsoft

Goal:

The project goal is to develop and promulgate an open specification for a non-proprietary multi-vendor platform (rack) for warm liquid cooled servers (and other IT equipment) compatible with existing open rack standards.

Rationale:

Many vendors have entered the market with liquid cooling solutions, however most/all are proprietary and generally non-compatible with each other. This is acceptable for some homogeneous compute environments, but less acceptable for non-homogeneous compute environments where standard multi-vendor solutions are strongly preferred. Buyers in the market would benefit from greater standardization. The hypothesis is that incompatible proprietary systems are a market barrier that will continue to inhibit adoption of warm liquid cooling.

Progress and Focus:

The working group has focused on the following specifications:

1. The wetted material list (all components must be compatible with this list)
2. Water based transfer fluid quality and treatment
3. A universal (multi-vendor) quick connect
4. General operating specifications

Challenges:

The working group has grappled with numerous challenges:

1. The chemical compositions of water based transfer fluids (e.g. anti-freeze solutions and corrosion/biological inhibitors) are generally proprietary and it is assumed that you cannot mix one with another (if you had pre-charged servers from different manufacturers they may not be compatible in the same system).
2. Likewise quick connects are generally proprietary and if we don't standardize on a single quick connect, it will be difficult to replace servers with others having a different connection (like mixing the electrical plugs of European and US servers).

Proposed Solution:

This document is a preliminary outline for an open specification which can be used to engage suppliers to create the basis for a secondary liquid cooling loop integrated into standard IT equipment (e.g. server) racks. Any proposed solution that does not meet all the specifications outlined should clearly state the exception(s) and its/their justification. All users of this document must conduct their own evaluation for suitability to their needs.

Wetted Material List:

All wetted components (server heat exchangers, connectors, tubing, manifolds, CDUs, etc.) must be made from material included in the wetted materials list. Additional materials will require evaluation and validation relative to compatibility with the wetted material list and the selected transfer fluid. All wetted materials must be compatible with each other and the transfer fluid selected under the operating conditions outlined (e.g. temperature).

Table 1. Common Wetted Materials*

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

* *Double check with your fluid treatment supplier to confirm compatibility of all components. This list does not guarantee material fluid compatibility but is guidance on which materials to expect to come in contact with the fluid. The user must ensure that they fully understand the wetted materials in their specific fluid loop and that any materials in the fluid loop have been validated to be compatible with the fluid and with the other materials in the loop at the operating conditions specified.*

Table 2. Wetted Materials to be avoided

The list below specifies which materials are recommended to be avoided. These material are known for promoting or encountering corrosion. In addition to the materials below, any materials which are not known to be compatible with the fluid or to other materials in the fluid loop at the operating temperatures should be avoided unless validated for compatibility.

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

Transfer Fluid:

The water based transfer fluid will be selected by the customer (e.g. data center owner/operator) and must meet the quality and treatment requirements including compatibility with the wetted material list. IT components could be pre-charged (e.g. with antifreeze) for shipping, or filled on-site. Pre-charging could limit the options available to the customer or increase the procurement logistics and cost. Alternatively, the IT equipment fluid could be added (or replaced) on-site. Fluid maintenance would be as required by the manufacturer. If the added components to the water based transfer fluid materially change the pumping and thermal characteristics, additional evaluation and validation will be required. The use of a non-water based transfer fluid, for example a non-conducting fluid, will require evaluation and validation. A universal transfer fluid specification available from multiple vendors would be preferable and may be developed in the future.

Table 3: 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	

Table 4. Fluid Thermo-physical Properties

Parameters	Value	Source	Comments
Freezing protection (°C)	As required for charged shipping		Specific value is application dependent and not set in open specification
Thermal conductivity at 50 °C (W/mK)			**Dependent variables**. To be provided by fluid supplier in data sheet. Values will be used to fine tune design and to monitor fluid integrity.
Specific heat at 50 °C (kJ/kg-K)			
Viscosity at 50 °C (cP)			
Volume expansion from -40 to 90 °C (%)			
Vapor pressure	< water vapor pressure at all temperatures		Concern with evaporation of additives. To be provided by fluid supplier in data sheet
Flash point or fire point *	None		This requirement is to avoid any product regulatory risk
Toxicity& Environment Compliance	Non-toxic and environmentally benign		This requirement is to avoid any product regulatory risk & global adoption of fluid

* Pure glycol fluid can have a flash point temperature value documented in the Safety Data Sheet (SDS). Once mixed with water in certain percentages, there is no specific flash point for the mixture. Need to make sure the percentage of water is more than needed to avoid any flash point.

Table 5. Fluid Quality

Values other than "required" in the table below represent the makeup water quality prior to adding inhibitors, biocides or Glycol. When additives are included, several of the parameters may change.

Parameters	**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

Quick connects:

A universal quick connect interface is being developed by Intel in conjunction with several suppliers for use in the open specification. The quick connect must be designed to allow removal and replacement of IT equipment without shutting down liquid flow to other components. The Universal quick connect requirements will specify the interface dimensions for interchangeability and will define minimum performance for a no drip fluid coupling for use in the secondary cooling loop (e.g. connections between the manifold and a server). Ideally the quick connect will be available from multiple suppliers soon. There is interest in blind-mating connections (e.g. the liquid connectors that would be mounted so as the server slides into the rack, the connections would engage) that may be a future enhancement to the specification.

<u>Figure 2. Schematic of Universal Quick Connect</u>

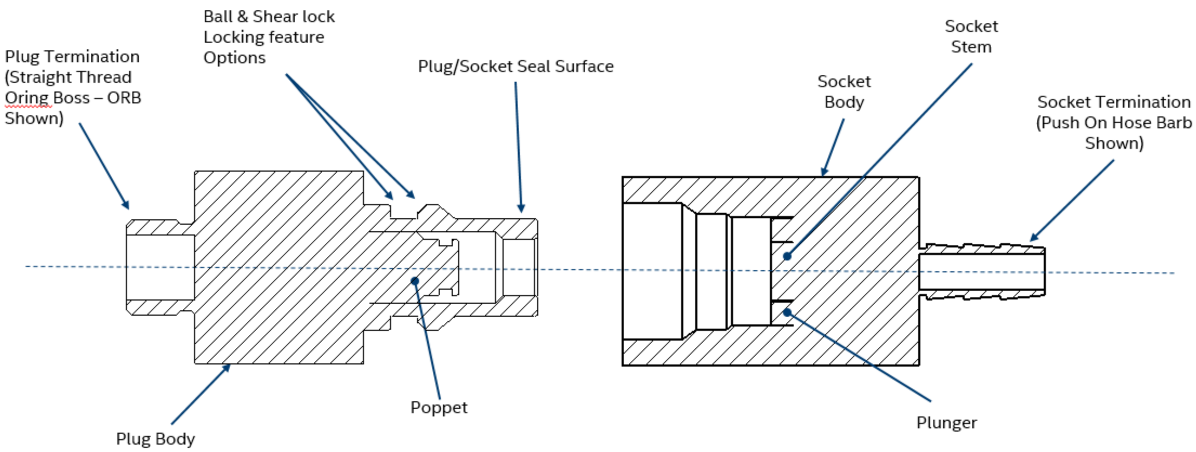


Table 6. Draft Universal Quick Connection Performance Requirements

Parameter	6.35 mm	9.53 mm	12.70 mm
Maximum operating pressure	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°C – 115°C		

Other specifications and operating conditions:

The solution inside or associated with the IT equipment (e.g. the CDU heat exchanger) would be left to the vendor. Ideally there will be multiple solutions and all will be compatible with the liquid cooled rack infrastructure. This specification stops at the connection to the IT equipment. Temperature and pressure ranges, along with deltas must be established to assure that a connected server, compatible with the specification, has adequate transfer fluid flow. If the server's operating conditions are different, further evaluation and validation will be required. While the specification does not require a minimum percent of cooling attributable to liquid cooling, this must be considered in the design. Ideally all the heat would be removed by the liquid and there would be no fan driven air cooling. However, many systems do not meet that ideal, and leaving the specification flexible on this parameter allows for their use. This specification does not include the CDU which could be at the rack, row, or room level. The wetted materials in the CDU must be included in the wetted material list or further evaluation and validation will be required. The CDU will need to provide the flow and pressure characteristics specified at the rack/server level. Sizing of the manifolds and tubing will depend on the power density of the IT equipment and the rack as a whole. The user will need to specify the rack power capacity (the heat load). If the load increases beyond the specified capacity, the manifolds may require replacement with a larger size (as well as other upstream components such as the CDU). Design guidance is provided below.

Manifold Design Considerations

- Manifold cross section large enough to keep maximum velocity less than 1.0m/s.
- Maximum pressure drop of manifold supply and return at maximum flow rate less than 1/40th pressure drop of individual IT equipment cooling loops. This will ensure uniform flow rates through all loops on the manifold.
- Maximum of 10% pressure drop variation between all cooling loops at design flow, otherwise provide balancing valves to ensure every loop received the correct fluid flow.
- Compare overall pressure drop of entire manifold assembly (from secondary inlet to secondary return) to CDU pump capability to ensure sufficient flow to all IT equipment loops.
- Compare CDU capacity and approach temperature to loop power and flow rate requirements.

- Ensure sufficient primary supply flow to CDU to achieve required approach temperature based on secondary flow rate and power.
- Confirm flow rate of each loop matches IT equipment cooling requirements based on the manifold supply liquid temperature.
- Confirm secondary return temperature does not exceed maximum allowed fluid temperature for every component in the loop (CDU, Tubing, QD, etc…).

Tubing Design Considerations

- Placeholder

Operating Temperature Considerations

The typical operating temperature for the secondary fluid can range between a low of 2degC per ASHRAE W classes to a high as 60degC or more depending on the power captured in the IT by the secondary fluid and the fluid flow rate. For higher operating temperatures compatibility with all system components must be checked - the maximum allowable hot fluid temperature must be limited by the lowest 'maximum' temperature of any components. 60degC allows for ASHRAE W4 primary (facility) water, a 2degC approach in the CDU, and up to a 13degC delta T.

Operating Pressure Considerations

Typical operating pressure for the secondary loop is up to 60PSI depending on the pump performance of the CDU. Typically all components must be able to withstand up to 3x the operating pressure in order to be qualified for use in liquid cooling per IEC standards.

Filtration Considerations

Maintaining fluid quality is critical for liquid cooling applications reliability and performance. A fluid loop has two main components which will drive filtration requirements, the fluid connectors and the heat exchangers. The appropriate filter is driven by whichever requires the smallest particle size. Some of the considerations for filter selection are filter particulate size, the filter effectiveness and the resulting pressure drop through the filter. In general it is desirable to use the largest filter possible to minimize pressure drop, but an application also requires a filter small enough to block the desired size and percentage of particulates. The maximum particulate size specified is 50 micron, however system components may have looser or more stringent requirements. If a different specification is adopted care must be taken to assure future system changes adhere to the adopted specification.

Other Considerations

Other design considerations include:

- Approach Temperatures for Heat Exchangers
- Liquid Cooling Guidelines (Class W1 – W5)
- Facility Water System (FWS) Loop
- Corrosion
- Fouling
- Scale
- Microbiologically induced corrosion
- Flammability

It is recommended that the latest edition (current is 2nd edition 2013) of the ASHRAE Liquid Cooling Guidelines for Datacom Equipment Centers be consulted when designing a liquid cooling system.

Appendix 1

Open Standards Framework and high level specification for Liquid Cooled Data Centers

(Framework and high level specification developed by Chinese working group members.)