Critical Liquid Cooling Considerations in Electronics – Technical Guide for Connectors

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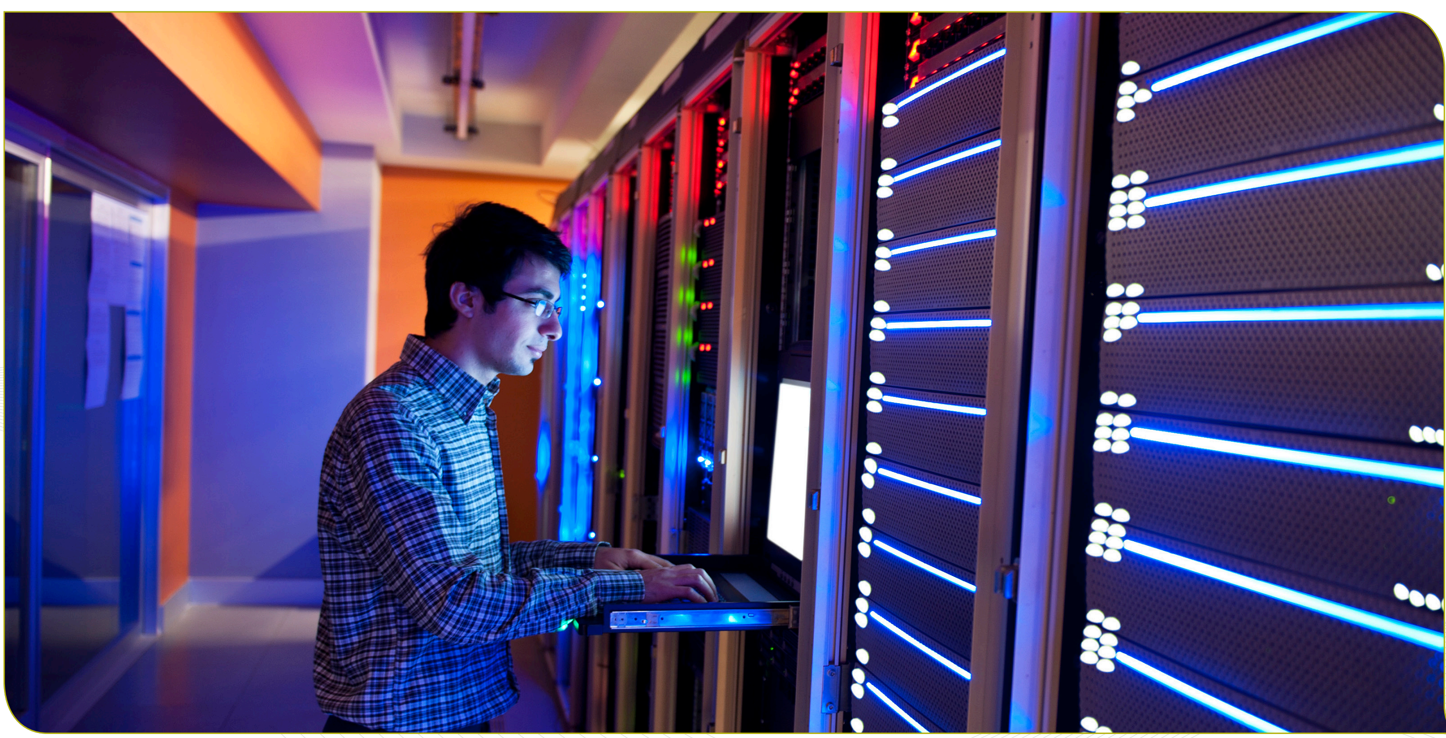
As data centers and high performance computing continue to drive demand for higher densities and increased efficiency, liquid cooling is expanding as a method of thermal management. System and Information Technology Equipment (ITE) providers must now work to incorporate fluid handling components alongside critical electronic equipment. Connectors are crucial to the safe and reliable operation of liquid cooling systems; however, the appropriate specifications for these components are often poorly understood.

Well-designed fluid connectors used in liquid cooling:

- Easily facilitate connection, disconnection and rerouting of fluid though computing clusters.
- Support 100% uptime during installation, reconfiguration and maintenance.
- Allow secure, efficient, reliable and leak-free management fluids within the liquid cooling system.

In specifying connectors for a liquid cooling system, the following characteristics and performance parameters are useful in ensuring the components will functionally optimally relative to overall system requirements particularly in HPC and data center environments.



PERFORMANCE CHARACTERISTIC	DESCRIPTION AND ASSOCIATED CONSIDERATIONS
CONNECTOR TYPE	
Consider space constraints, required force-to-connect, ease of use, and ability to confirm a secure connection along with other baseline performance parameters like pressure, flow and durability.	
Quick disconnects (QDs)	Increasingly used in liquid cooling; easier to install/uninstall than other fluid handling connectors like ball-and-sleeve; look for components designed specifically for use in liquid cooling applications vs. adapted from other industries (e.g., automobile) where drip-free performance is less critical and the seals and internal valves were not designed for the low-pressure/high-flow applications of HPC environments
Socket/plug; male/female; body/insert	Connector halves fit together by one side inserting into the other; intuitive to use; as with all fluid connectors, requires force to connect, which increases as the system pressure increases
Latched	Integrated thumb latches can ease connection/disconnection by allowing one-handed operation; audible “click” confirms full connection; enables hot swapping
Blind mate	Requires a separate retention mechanism, such as a server blade latch; releasing force disconnects the QD; works best in difficult to see/access locations like the backs of server racks; enables hot swapping
QDs with elbows, swivel joints	Integrated swivel joints and elbows eliminate tube kinking and allow easier connection and disconnection in tight spaces by orienting latches (if equipped) for easy access
CONNECTOR MATERIALS	
Consider chemical compatibility, materials in contact with coolant (wetted materials like valves, seals, connector body), pressure, temperature, reliability, weight	
Metal	Durable, withstands rough handling, perceived higher-end aesthetics, good flammability ratings usually more expensive and heavier than plastic, susceptible to corrosion—coolant system maintenance critical for lasting leak-free performance
Plastic	Lightweight, compact, allows unique geometries for flow path, usually less expensive than metal, engineered polymers offer more than sufficient strength and durability in low-pressure (<200 PSI), moderate-temperature (<80°C) applications such as liquid cooling for electronics; good flame retardance—seek materials that adhere to UL94
Combination: metal/plastic	Combines the strength of a metal exterior with high-performance engineered polymer components inside; the rugged exterior withstands physical abuse while robust engineering-grade thermoplastics resist corrosion and optimize flow

Connectors should be tested to ensure functionality and performance specific to the defined application requirements. CPC offers transparency regarding test methods and results for its liquid cooling connectors through validation reports available on the CPC website. Also, CPC has extensive experience and in-house expertise in developing reliability and test programs to meet specific customer needs.

PERFORMANCE CHARACTERISTIC	DESCRIPTION AND ASSOCIATED CONSIDERATIONS
FLOW RATE, PRESSURE AND PRESSURE DROP	
Consider flow across the entire liquid cooling system and at each cooling stage (e.g., server, rack, cluster, Coolant Distribution Unit)	
Flow rate	Flow rates are typically low at the server (e.g., 0.5 l/min) and much higher at the CDU (up to 70 l/min.); actual-use flow rates that exceed the connector's maximum flow rate capacity can lead to seal failure or accelerated part erosion
Connector size	Specify appropriate connector size(s)—hydraulic diameter—from server to CDU; connector sizes can range from 1/8 inch at the server to 1 inch at the CDU; QDs of the same size can deliver significantly different flow performance. Example: a newer 1/8-inch quick disconnect showed a 23% better flow rate (flow coefficient: CV=0.37) than other currently available 1/8-inch connectors, reducing pressure drop through the connector by ~34% and lessening cooling system burden; also consider physical space available at the front or back of server to ensure adequate room for connections, disconnections and ongoing use
Pressure	Operating, break and safety burst pressures should all be assessed. Operating pressure defines the usual and customary pressure ranges during regular system use. Break pressure indicates the point at which a component no longer maintains pressure, which is a higher threshold than safety burst pressure.
Pressure drop	Both flow rate and connector size affect pressure drop; calculate pressure drop throughout the system, which typically involves many connector types/sizes operating in parallel and in series. To calculate the pressure drop for a given flow rate through a QD, use the following equation: $Q = Cv\sqrt{\Delta P}$ **Q** = volumetric flow rate in gallons per minute **Cv** = flow coefficient of the connector **ΔP** = pressure drop in PSI (Δ between the upstream pressure and the down¬stream pressure) **S** = specific gravity of fluid
STOP-FLOW/DRIPLESS PERFORMANCE	
Consider the level of tolerance for coolant escape at disconnection. Most HPC manufacturers and data center operators want no coolant to be present at disconnect—a performance requirement that is now achievable. Materials, seals, valve type and overall connector design impact the level of coolant present at disconnection.	
Straight-through connectors	Neither connector half features a valve necessitating flow stop prior to disconnection
Single shut-off valve	One side of the QD contains a valve
Double shut-off valves	Both QD halves contain valves; poppet valves trap a small amount of liquid within the coupling body that can drip when disconnected
Flush-face valves	Most dripless/drybreak/non-spill QDs feature flush-face valves that allow no more than a coating of coolant on valve surfaces
Seal type	Many QDs feature O-rings; some connectors feature multilobed seals that offer better shape retention over time, protection against leakage, greater resistance to debris or foreign contaminants, and require less force to connect

PERFORMANCE CHARACTERISTIC	DESCRIPTION AND ASSOCIATED CONSIDERATIONS
RELIABILITY QDs purposely designed for liquid cooling applications help system and thermal management designers enhance usability, develop more efficient systems and deliver long-term, leak-free performance; seek manufacturer-provided validation reports that specify test protocols and results; types of testing include:	
Helium vacuum leak test	Verifies sealing performance at specific temperatures
Elevated temperature burst test	Demonstrates adequate safety margins above rated operating pressure at higher than ambient temperatures
Creep rupture test	Demonstrates safe use at continuous higher-than-rated pressures and temperatures (e.g., 180°F) for an extended period (e.g., 7 days)
Flow rate test	Determines CV values
Drip leak testing and spillage testing	Under specific temperature and pressure conditions, measure evidence of drip leaks during simulated use conditions or spillage at disconnection
Disconnect under flow	Quantify resistance of connectors to water hammer and fluid acceleration caused by disconnecting units under flow
Cycle testing	Verifies connector sealing performance after repeated connection/disconnection cycles; some manufacturers conduct 10,000 cycles to validate leak-free performance
Connect force testing	Characterize the force to connect with varying pressures in the disconnected body and insert prior to connection

For more information, visit:
cpcworldwide.com/liquid-cooling.

Contact CPC at:
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Or by contacting one of our liquid cooling engineers at:
Ask Our Engineers.

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