The Impact of Ambient Conditions on Liquid Cooling

With a growing number of sophisticated computing and energy operations occurring in potentially harsh environments, it's important to understand how ambient conditions affect liquid cooling systems and their components.

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ADVANCING TECHNOLOGIES, HEAT, AND ENVIRONMENTAL EXPOSURE

Computing demands continue to grow across a wide range of applications and operating environments. Artificial Intelligence (AI), 5G, blockchain, IoT, streaming entertainment, self-driving technologies, and videoconferencing all require high computational loads, which generate heat.

These operations increasingly take place in smaller edge computing data centers placed in or near cities to lower data latency and transport costs by moving processing closer to end users. In fact, more than 75% of data will be created and processed outside the traditional data center or cloud by 2025, according to Gartner, a technology research consultancy.

Unlike climate-controlled hyperscale computing centers situated in remote areas, edge facilities are subject to localized conditions including fluctuating temperatures and humidity levels and airborne contaminants. Just opening the door to service the hardware inside can expose it to ambient factors.

Other modern technologies like electric vehicle fast-charging stations and green energy equipment (e.g., massive wind turbines) also generate high heat—and their outdoor locations can impact their liquid cooling systems and overall function, too. Understanding the environmental extremes under which liquid cooling systems operate is essential to specifying the optimal components for those systems.

ENVIRONMENTAL FACTORS IMPACT COMPONENT SELECTION

For every application, systems designers must carefully consider the potential impact and interrelationship of local temperature, humidity, and air quality on liquid cooling systems and the components that support them.

FACTOR 1: TEMPERATURE

High external temperatures make it more difficult to keep devices and equipment properly cooled. This increases requirements for cooling rates, coolant distribution, pump power, and energy consumption. In the event of a cooling system breakdown, hardware may reach its peak operating temperature more quickly.

Low temperatures can affect coolant viscosity, reducing flow, affecting internal pressure, restricting pump efficiency, and reducing cooling effectiveness. Depending on the coolant properties, low temperatures may result in the entire liquid cooling system freezing up. Extreme cold is also associated with drier air, and an increased potential for static electricity.

Some environments may require dedicated HVAC systems to control air temperatures surrounding the equipment, including space heaters to mitigate cold, air conditioning units to combat heat, or both.

To help ensure reliable performance, liquid cooling systems must be designed to handle operational temperature ranges. In the edge computing example, a facility located in Minneapolis, Minnesota, in the United States, could face seasonal variations of as much as 175°F (97°C), factoring in recorded lows of -60°F (-51°C) and highs of 115°F (46°C).

From a component standpoint, therefore, it is prudent to consider materials with high insulating properties that are designed to deal with extreme heat or cold. Polymers like silicone, polysulfone (PSU), polyvinyl chloride (PVC) and polyether ether ketone (PEEK) offer excellent thermal properties. They also remain dimensionally stable through extreme temperature changes.

5G relies on edge computing facilities

FACTOR 2: HUMIDITY

High relative humidity increases the potential for condensation. Liquid coolant at a temperature lower than ambient air may result in external condensate on tubing, connectors, and other system components, creating risk of exposing electronic components to moisture.

Liquid cooling systems operating in high humidity may require insulation to avoid condensation on metal piping and components. Or design engineers may choose to specify components made of polymer materials like PSU, PVC or PEEK, which are less prone to condensation.

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Versatile polysulfone (PSU) provides excellent performance in many challenging environments. PSU is lightweight, dimensionally stable, and resistant to galvanic corrosion.

On the other end of the scale, low humidity increases the risk of static electricity disrupting performance. Over time, arid conditions can lead to drying and cracking of component materials (e.g., some elastomer O-ring seals, tubing or plastics), which can increase the potential for liquid coolant leaks.

Under low-humidity conditions, metals are more likely to react with ionic activity in the dry air, which may be suppressed using insulation. Polymers generally have low ionic properties and are less reactive electrically. However, there are hundreds of polymers available offering a wide range of performance characteristics. The chart that follows offers considerations that link to application conditions.

FACTOR 3: AIR QUALITY

Air quality is influenced by humidity, geographic location and human activity. Though small edge data centers, for example, are often housed in preassembled and pretested enclosures, opening a door for routine maintenance can expose equipment to dramatic changes in temperature, humidity, and airborne particulates. The conditions in Singapore, Dubai, New York City, Stockholm all differ.

In lower humidity zones, greater attention should be given to possible air quality issues. Dry air movement is more likely to stir up dust, lint, and other particles that can negatively impact the reliability and life expectancy of equipment.

Depending on the level of ambient exposure, devices or equipment operating in coastal cities might encounter salt air. This can promote corrosion of all sorts of critical system components, from hard drives and circuit boards to cooling system infrastructure.

For system components, metals and polymers offer different levels of resistance to potential airborne contaminants. Coatings or insulation may be applied to some components to enhance durability. Choose carefully and test all materials to ensure they can withstand field conditions.

CHOOSING THE RIGHT CONNECTORS FOR LIQUID COOLING APPLICATIONS

Ambient conditions are only one factor to consider when selecting quick disconnects (QDs) or other system components. For example, the liquid coolant that will perform best in a given application may interact with certain commodity plastics, making metal or engineered thermoplastic QDs a better option. (For more information, see CPC Tech Guide 5012, "Liquid cooling and the chemical compatibility imperative.")

COMMON MATERIALS USED IN LIQUID COOLING CONNECTORS

POLYMERS	EXAMPLES	CHARACTERISTICS RELATIVE TO AMBIENT CONDITIONS	BENEFITS & USES
COMMODITY PLASTICS	HDPE, POM, PP, PS, PVC	High temperatures (above 180°F) may cause thermal degradation and shrinkage. Potential ignition under extreme heat. Low condensation issues. Non-reactive to water or salt air. Airborne pollutants may cause degradation.	Cost effective. Reliable in temperature-controlled applications.
ENGINEERED THERMOPLASTICS	PEEK, PEI, PESU, PSU	Excellent thermal properties. Dimensionally stable through extreme temperature changes. Flame retardant. High resistance to water absorption and corrosion. Non-reactive to water or salt air. High resistance to salt air, chemical pollutants.	Reliable performance under the most extreme conditions.
ELASTOMERS	CR, EPDM/ EPM, FKM, HNBR, silicone	Good thermal properties. May be modified to enhance high- or low-temperature performance. Resistant to condensation and corrosion. Potential reactivity to pollutants; may be reduced through modification.	Moderate cost. Adaptable to most application environments.

METALS		CHARACTERISTICS RELATIVE TO AMBIENT CONDITIONS	BENEFITS & USES
METAL ALLOYS		Metal alloys combine durability and excellent thermal properties. All have condensation potential, which may be lessened with insulation. Airborne pollutants or salt air are potentially corrosive to metals; however, corrosion resistance can be enhanced for some alloys as noted below.	Metal components can perform well in all environments, with proper treatment to resist condensation and corrosion.
ALUMINUM		Galvanic corrosion potential increases in the presence of copper components, especially in high humidity. Anodization reduces corrosion potential.	Lightweight, easy to machine, cost effective, compatible with other aluminum components in the cooling loop.
BRASS		Nickel or chrome plating reduces galvanic corrosion potential.	Cost-effective. Compatible with copper and water.
STAINLESS STEEL		Passivation increases corrosion resistance.	Highest durability and stability in all conditions. Compatible with other materials like aluminum and brass.

Materials of construction offer insight into how a given QD might perform under various environmental conditions. As always, components should be fully performance-tested within the parameters for the finished application.

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