What Fluids Can Be Used With Liquid Cold Plates in Electronics Cooling Systems

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Liquid cooling systems transfer heat up to four times better than an equal mass of air. This allows higher performance cooling to be provided with a smaller system. A liquid cooled cold plate can replace space-consuming heat sinks and fans and, while a liquid cold plate requires a pump, heat exchanger, tubing and plates, there are more placement choices for cold plates because they can be outside the airflow. [1]

One-time concerns over costs and leaking cold plates have greatly subsided with improved manufacturing capabilities. Today's question isn't "Should we use liquid cooling?" The question is "What kind of liquid should we use to help optimize performance?"

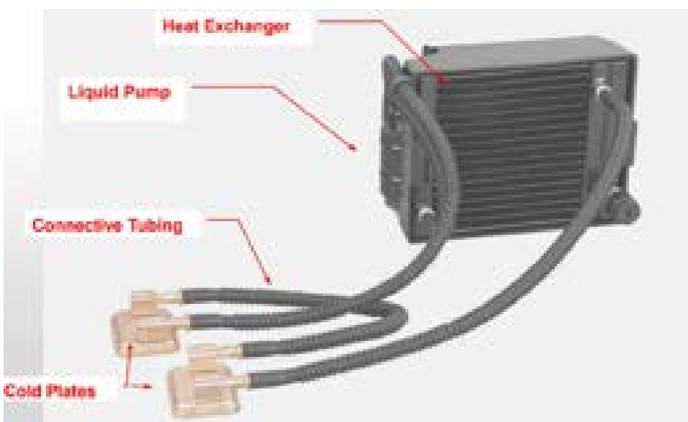

Figure 1. A Liquid Cooling System for a Desktop PC with Two Cold Plates. [2]

For liquid cold plates, the choice of working fluid is as important as choosing the hardware pieces. The wrong liquid can lead to poor heat transfer, clogging, and even system failure. A proper heat transfer fluid should provide compatibility with system's metals, high thermal conductivity and specific heat, low viscosity, low freezing point, high flash point, low corrosivity, low toxicity, and thermal stability. [3]

Today, despite many refinements in liquid cold plate designs, coolant options have stayed relatively limited. In many cases, regular water will do, but water-with-additives and other types of fluids are available and more appropriate for certain applications. Here is a look at these coolant choices and where they are best suited.

Basic Cooling Choices

While water provides superior cooling performance in a cold plate, it is not always practical to use because of its low freezing temperature. Additives such as glycol are often needed to change a coolant's characteristics to better suit a cold plate's operating environment.

In fact, temperature range requirements are the main consideration for a cold plate fluid. Some fluids freeze at lower temperatures than water, but have lower heat transfer capability. The selected fluid also must be compatible with the cold plate's internal metals to limit any potential for corrosion.

Table 1 below shows how the most common cold plate fluids match up to the metals in different cold plate designs.

	Technology	Water	Glycol/Water	Deionized Water	Oil	Dielectric Fluids (e.g. [illegible])	Polyalphaolefin (PAO)
Standard	Copper Tube Cold Plate	X	X	X	X	X	X
	Stainless Tube Cold Plate	X	X	X	X	X	X
	Aluminum [illegible] Cold Plate		X		X	X	X
Extended Surface	Copper [illegible] Cold Plate	X	X	X	X	X	X
	Aluminum [illegible]		X		X	X	X
	Alum [illegible] Cold Plate		X		X	X	X

Table 1. Compatibility Match-ups of Common Cold Plate Metals and Cooling Fluids [1]

The choices of cold plate coolants will obviously have varied properties. Some of the differences between fluids are less relevant to optimizing cold plate performance, but many properties should be compared. Tables 2 and 3 show the properties of some common coolants.

Properties of Typical Electronic Coolants

Coolant	Thermal Conductivity (W/m-K)	Thermal Expansion Coefficient (K⁻¹)	Specific Heat (J/kg-K)	Boiling Point (°C)	Freezing Point (°C)	Reference Temperature (°C)
Water	[illegible]	[illegible]	[illegible]	100	0	25
Ethylene Glycol/Water (50%)	0.404	[illegible]	3341	[illegible]	-34	25
Propylene Glycol/Water (50%)	0.382	[illegible]	[illegible]	[illegible]	-28	25
3M™ Novec™ HFE-7100 (HFE)	[illegible]	[illegible]	[illegible]	61	[illegible]	25
R-134a	[illegible] Liquid/vapor	N/A	1400	-26.1	[illegible]	25

Table 2. Comparisons of Properties of Typical Electronic Coolants. [4]

Properties of Typical Electronic Coolants

Coolant	GWP (GWP)	Flashpoint (°C)	Vapor Pressure (kPa)	Dielectric Constant (@1kHz)	Prandtl Number	Liquid Density (kg/m³)	Reference Temperature (°C)
Water	0	None	3.2	78.5	6.2	997	25
Ethylene Glycol/Water (50%)	Low	111	3.3	N/A	29	1076	25
Propylene Glycol/Water (50%)	Low	99.1	N/A	N/A	46	1034	25
3M™ Novec™ HFE-7500	210	None	5.5	7.4	N/A	1640	25
R-134a	1300	None TGP	665.6	9.5	N/A	1210	25

Table 3. Comparisons of Properties of Typical Electronic Coolants. [4]

An excellent review of common cold plate fluids is provided by Lytron, an OEM of cold plates and other cooling devices. The following condenses fluid descriptions taken from Lytron's literature. [5]

The most commonly used coolants for liquid cooling applications today are:

- Water
- Deionized Water
- Inhibited Glycol and Water Solutions
- Dielectric Fluids

Water – Water has high heat capacity and thermal conductivity. It is compatible with copper, which is one of the best heat transfer materials to use for your fluid path. Facility water or tap water is likely to contain impurities that can cause corrosion in the liquid cooling loop and/or clog fluid channels. Therefore, using good quality water is recommended in order to minimize corrosion and optimize thermal performance.

If you determine that your facility water or tap water contains a large percent of minerals, salts, or other impurities, you can either filter the water or can opt to purchase filtered or deionized water. [5, 6]

Deionized Water – The deionization process removes harmful minerals, salts, and other impurities that can cause corrosion or scale formation. Compared to tap water and most fluids, deionized water has a high resistivity. Deionized water is an excellent insulator, and is used in the manufacturing of electrical components where parts must be electrically isolated. However, as water's resistivity increases, its corrosivity increases as well. When using deionized water in cold plates or heat exchangers, stainless steel tubing is recommended. [5, 7]

Inhibited Glycol and Water Solutions – The two types of glycol most commonly used for liquid cooling applications are ethylene glycol and water (EGW) and propylene glycol and water (PGW) solutions. Ethylene glycol has desirable thermal properties, including a high boiling point, low freezing point, stability over a wide range of temperatures, and high specific heat and thermal conductivity. It also has a low viscosity and, therefore, reduced pumping requirements. Although EGW has more desirable physical properties than PGW, PGW is used in applications where toxicity might be a concern. PGW is generally recognized as safe for use in food or food processing applications, and can also be used in enclosed spaces. [5, 8]

Dielectric Fluid – A dielectric fluid is non-conductive and therefore preferred over water when working with sensitive electronics. Perfluorinated carbons, such as 3M's dielectric fluid Fluorinert™, are non-flammable, non-explosive, and thermally stable over a wide range of operating temperatures. Although deionized water is also non-conductive, Fluorinert™ is less corrosive than deionized water. However, it has a much lower thermal conductivity and much higher price. PAO is a synthetic hydrocarbon used for its dielectric properties and wide range of operating temperatures. For example, the fire control radars on today's jet fighters are liquid-cooled using PAO. For testing cold plates and heat exchangers that will use PAO as the heat transfer fluid, PAO-compatible recirculating chillers are available. Like perfluorinated carbons, PAO has much lower thermal conductivity than water. [5, 9]

Conclusion

Water, deionized water, glycol/water solutions, and dielectric fluids such as fluorocarbons and PAO are the heat transfer fluids most commonly used in high performance liquid cooling applications.

It is important to select a heat transfer fluid that is compatible with your fluid path, offers corrosion protection or minimal risk of corrosion, and meets your application's specific requirements. With the right chemistry, your heat transfer fluid can provide very effective cooling for your liquid cooling loop.

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