Why Fluidic Flow Dynamics Are Critical to the Design of Liquid Cooling in EV Charging Applications

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Compare relative heat transfer coeffficent and easily conclude liquid cooling with its exponential capacity is needed for DC fast and extreme fast charging systems.

Coolant	Flow type	h*	Efficiency
Gas	Free (e.g. heatsink)	2 to 25	Low
	Forced (e.g. fan)	25 to 250	
Liquid	Free (e.g. immersion)	50 to 1000	
	Forced (e.g. closed loop)	100 to 20,000	
	Phase change	2000 to 100,000	High

h* = convective heat transfer coefficient in Watts per square-meter Kelvin

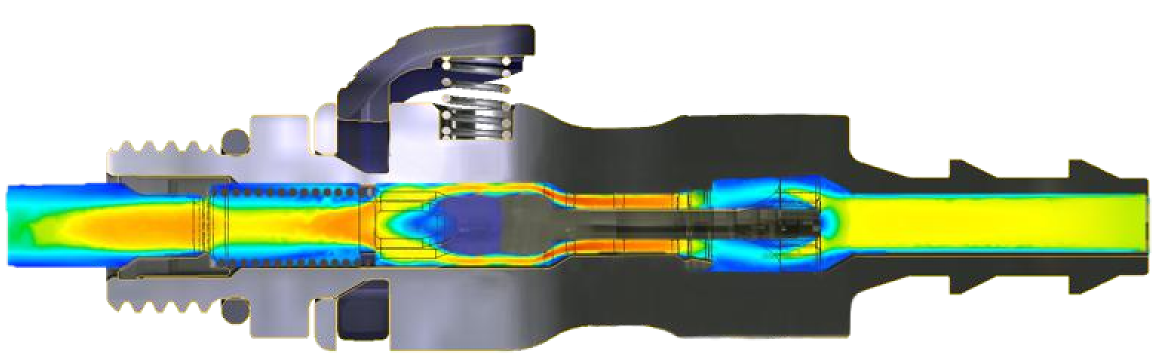
$$Cv = Q\sqrt{\frac{SG}{\Delta P}}$$

Evaluate connector performance via flow coefficient (Cv)

Cv value can vary widely based on the cooling fluid used and operating temperatures. Cv is a function of the volumetric flow rate (*Q*) of a fluid in its associated specific gravity (*SG*) passing across a connector that will result in a system pressure drop (ΔP) of 1 psi.

Measure volumetric flow rate (Q) and how efficient connectors enhance thermal management

Bernoulli's principle helps explain the effects of reistances and losses, demonstrating that a reduction in pressure correlates to an increase in fluid velocity and vice versa.



Specific gravity (SG) fluid property impacts connector requirements

High *SG* fluids have greater resistance to flow and require more energy to move than equal amounts of lighter fluids. Viscosity and associated performance under temperature extremes is also to be considered.

Table 2 – Coolants: Comparison of select specific gravities and other properties

Fluid	SG	Thermal conductivity W/mK	Viscosity cP	Boiling °F	Freezing °F	Cost
1,1,1,2-Tetrafluoroethane (R-134A)	0.52	0.082	0.20	-15°	-154°	$$$
Mineral oil	0.92	0.106	6.64	-392°	-15°	$$
Water	1.00	0.580	1.00	212°	32°	$
Propylene glycol, 50% solution	1.04	0.357	5.20	223°	-49°	$$
2,3,3,3-Tetrafluoropropene R1234yf)	1.10	0.064	0.16	-22°	-238°	$$$
Ethylene glycol, 50% solution	1.13	0.402	2.51	224°	-35°	$$
Hydrofluoroether (HFE)	1.61	0.075	0.45	93°	-189°	$$$$
Fluorinert FC-72	1.68	0.057	0.64	133°	-130°	$$$$
Perfluoropolyether (PFPE)	1.70	0.090	0.45	392° -500°	23°	$$$$

Pressure drop (ΔP) and performance

Pressure drop in liquid cooling systems is related to friction between the fluid and tubing, valves, and connectors. This varies with phase change systems and compresssible fluids, which will require a modified approach.

Fluid heat transfer energy (Q)

The capacity for heat transfer is directly proportional to the mass flow rate of the coolant. Increasing the flow rate will come with the added costs of pumps, power and higher system pressure ratings approach.

Quick disconnect (QD) features affecting flow

Shutoff configurations, valve designs and orifice size are critical in maintaining high *Cv* for more efficient cooling even through smaller connectors. Non-latched blindmate QDs with axial tolerance help ensure flow performance.

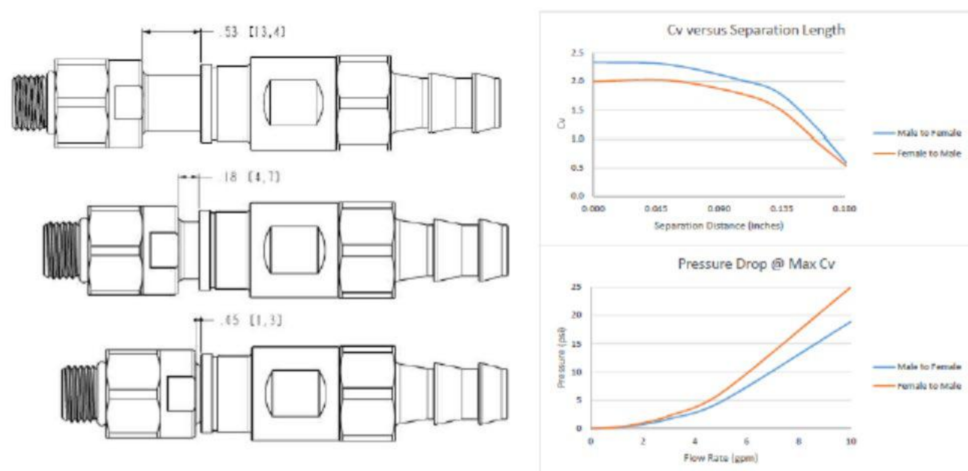


Figure 3 - Blind Mate Flow Impedance x Connection Length

Conclusion

The many flow variables in liquid cooling present the opportunity to optimize each EV system, innovating and fine tuning for optimal thermal performance.