Experimental evaluation of cooling performance for liquid immersion with bubble assisted natural convection

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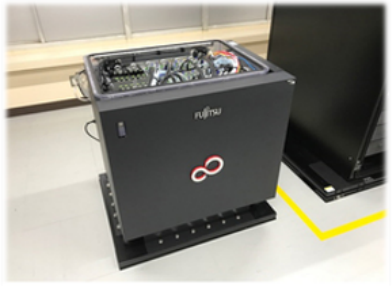
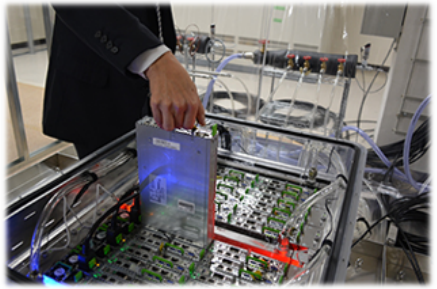
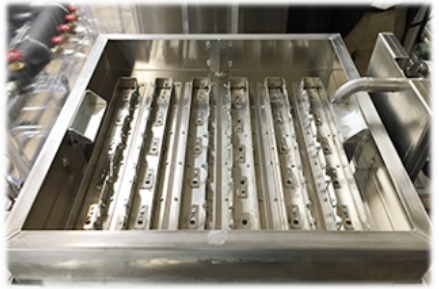
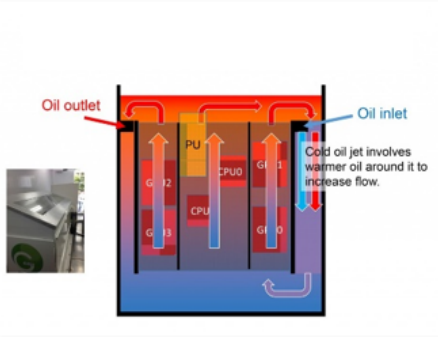
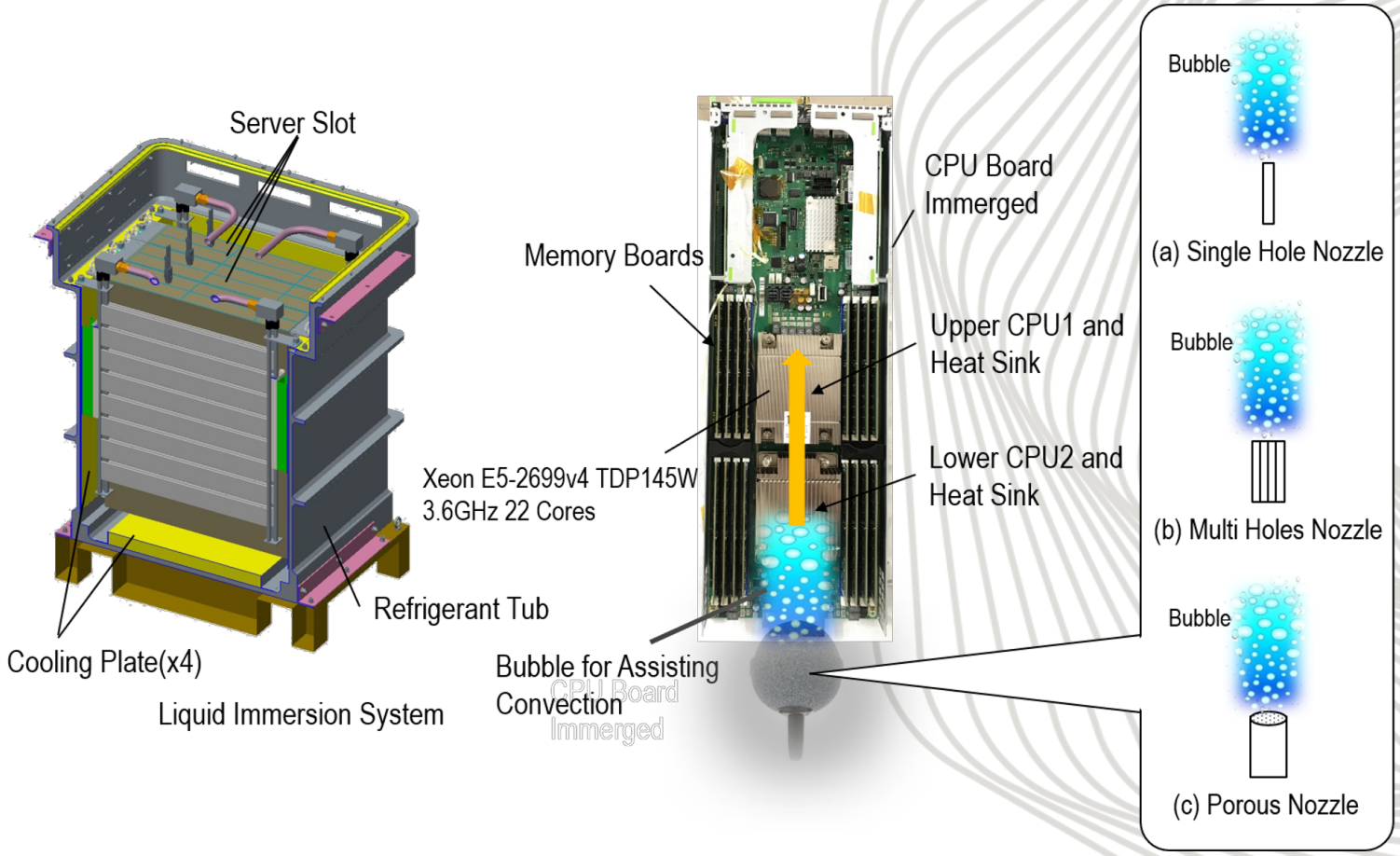
Immersion cooling

Type	Single Phase			2 Phases
	Forced Convection	Natural Convection	Refrigerant Dripping	Boiling
Structure	 Forced convection of refrigerant by pump inside liquid tank	 Natural convection with the power of the CPU's heat as the driving force by merely immersing in refrigerant	 Refrigerant drip onto the CPU	 Boiling (vaporization) of refrigerant on the CPU surface and circulation of liquefaction on the surface of the cooling plate
Refrigerant	High Boiling Temp.(Fluorinert FC43/FC3283, Silicone Oil Si6/Si35)			Low Boiling Temp.(Novec)
Feature	Pump for refrigerant convection essential	Pump for refrigerant convection unnecessary	Small pump required for lifting refrigerant	Phase change due to boiling phenomenon

Immersion cooling performance

	Forced Convection	Natural Convection	Bubble-assisted Convection
PUE	Middle	Low	Low
Cooling Capacity	High	Middle	High

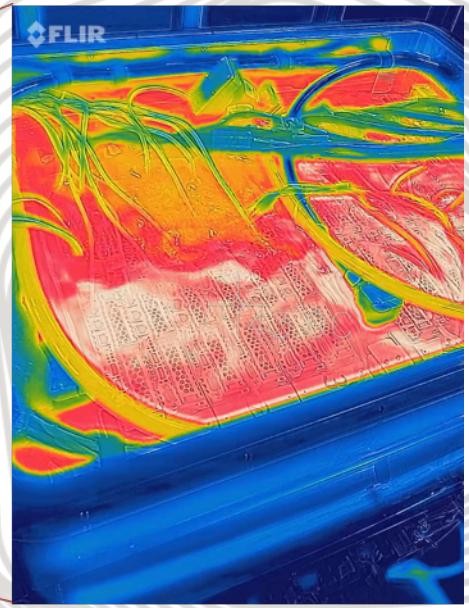
Bubble assisted immersion cooling



Bubble assisted immersion cooling

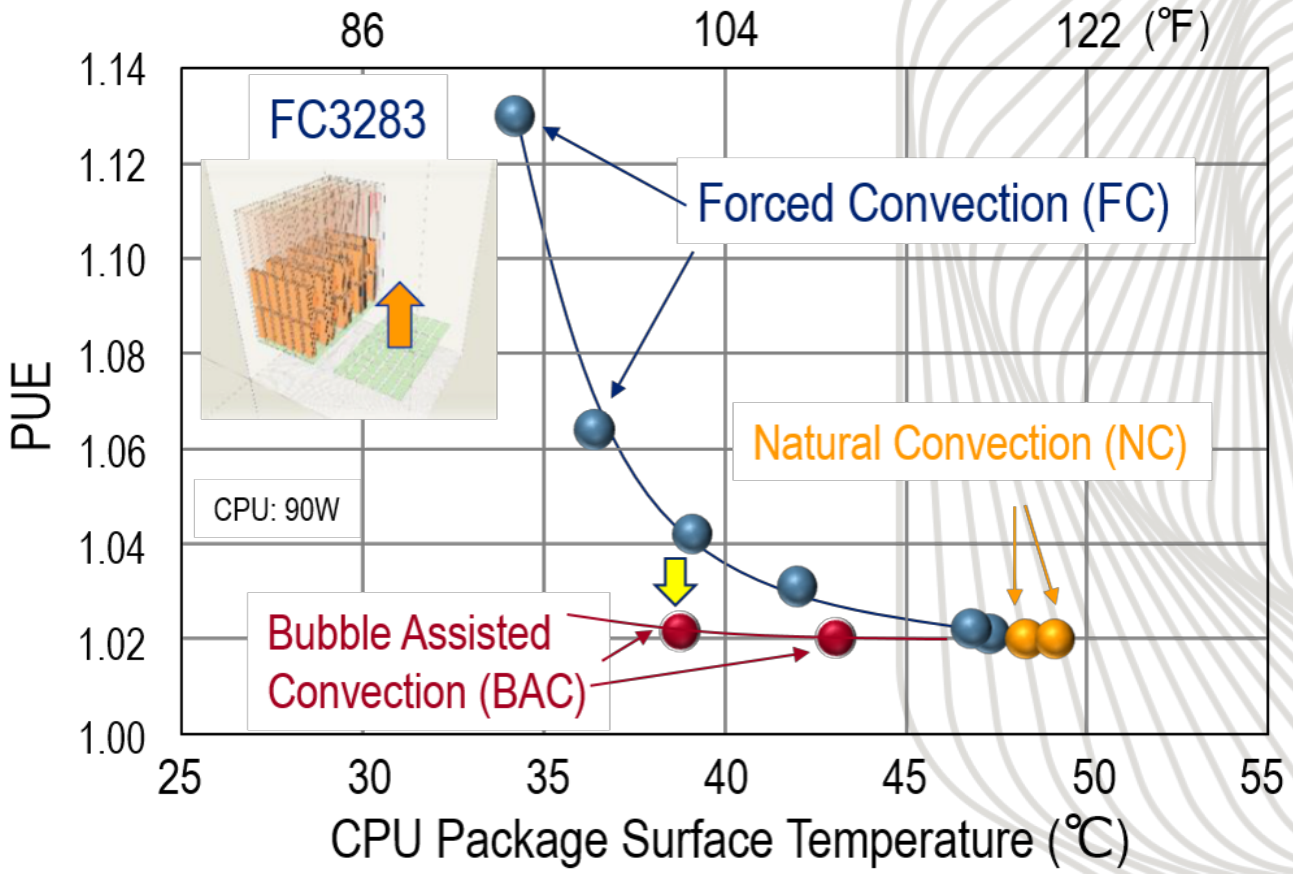
With Low Bubble Flow Rate(1 L/min)

With High Bubble Flow Rate(5 L/min)

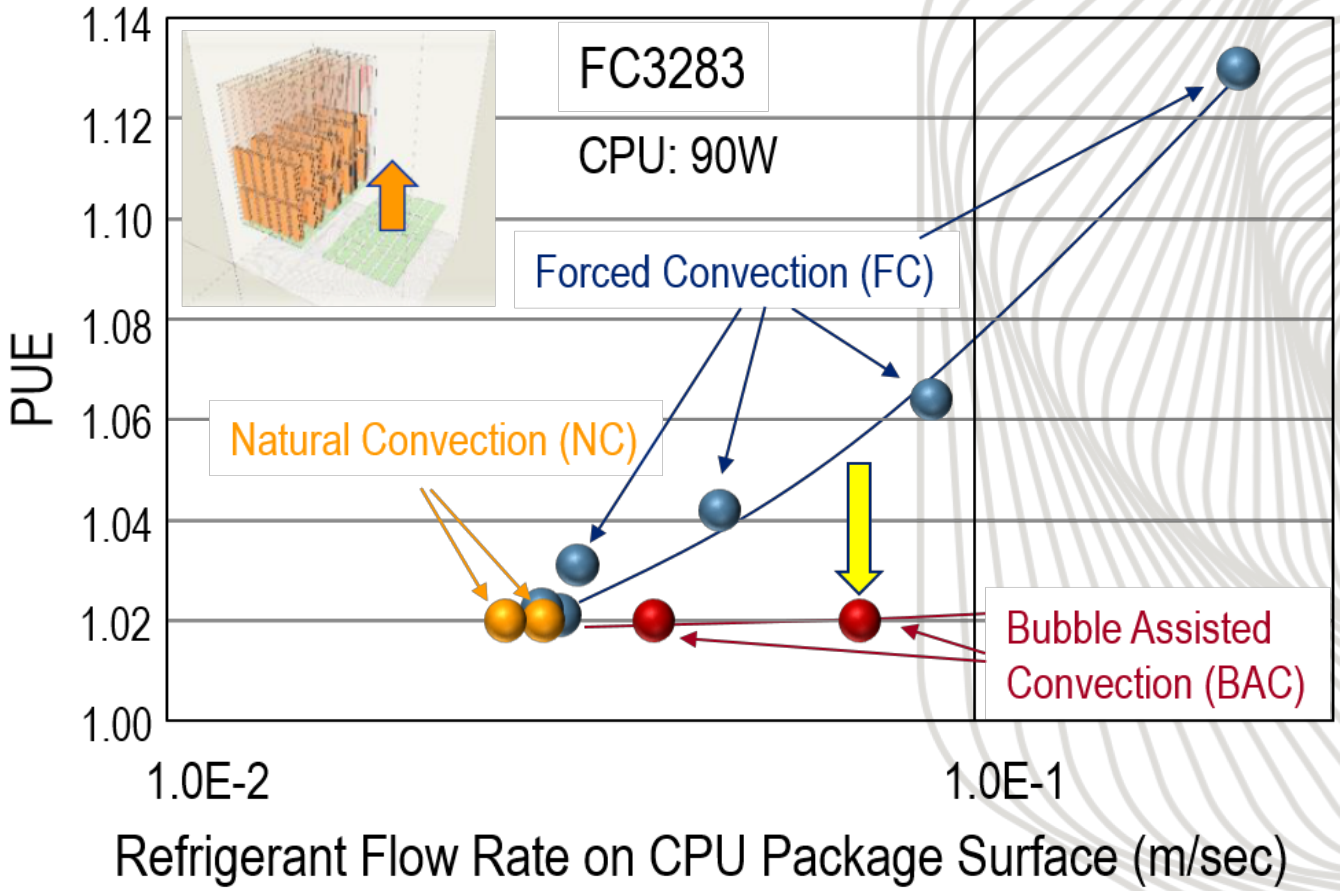


Bubble

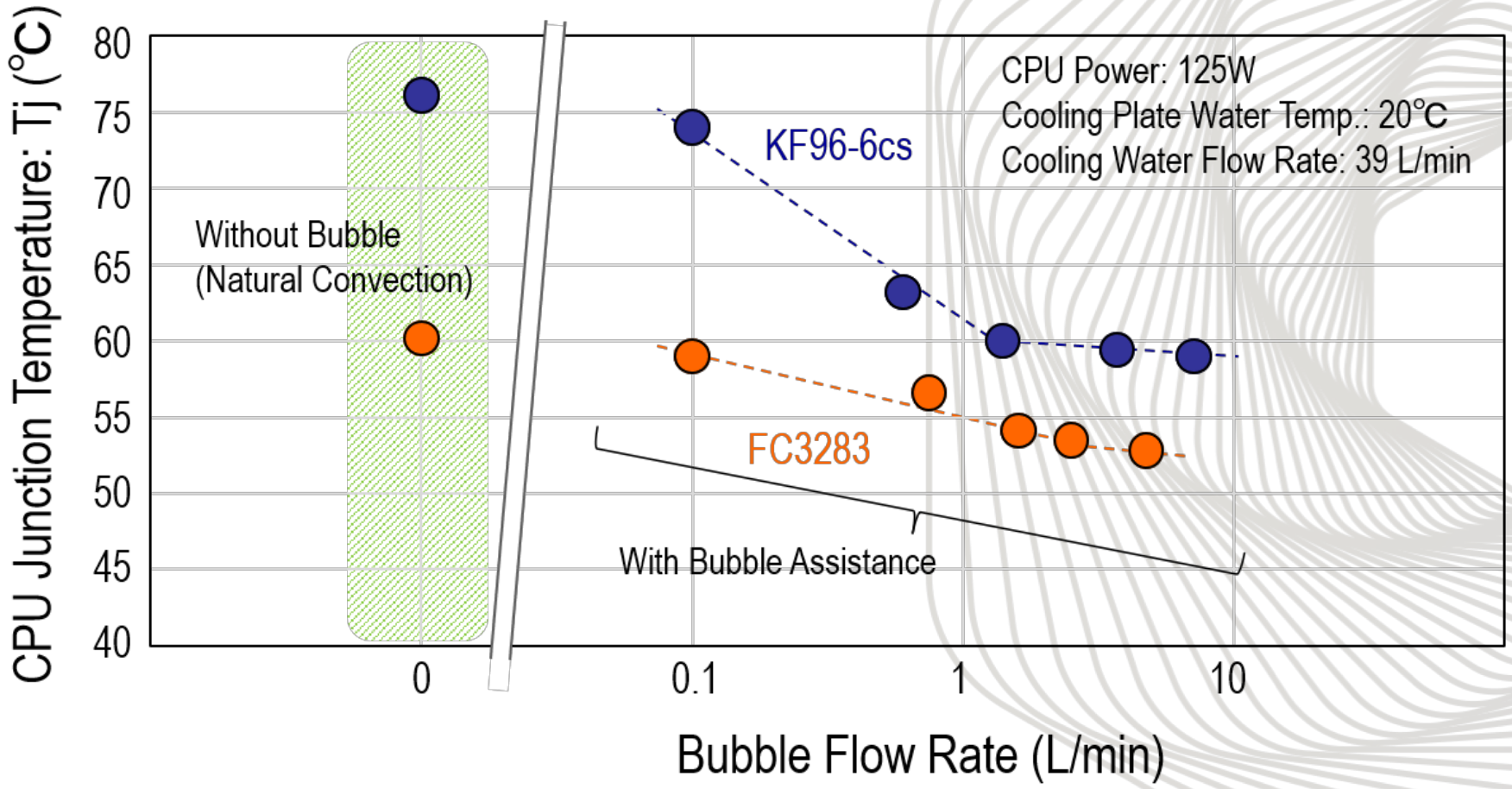
Cooling performance



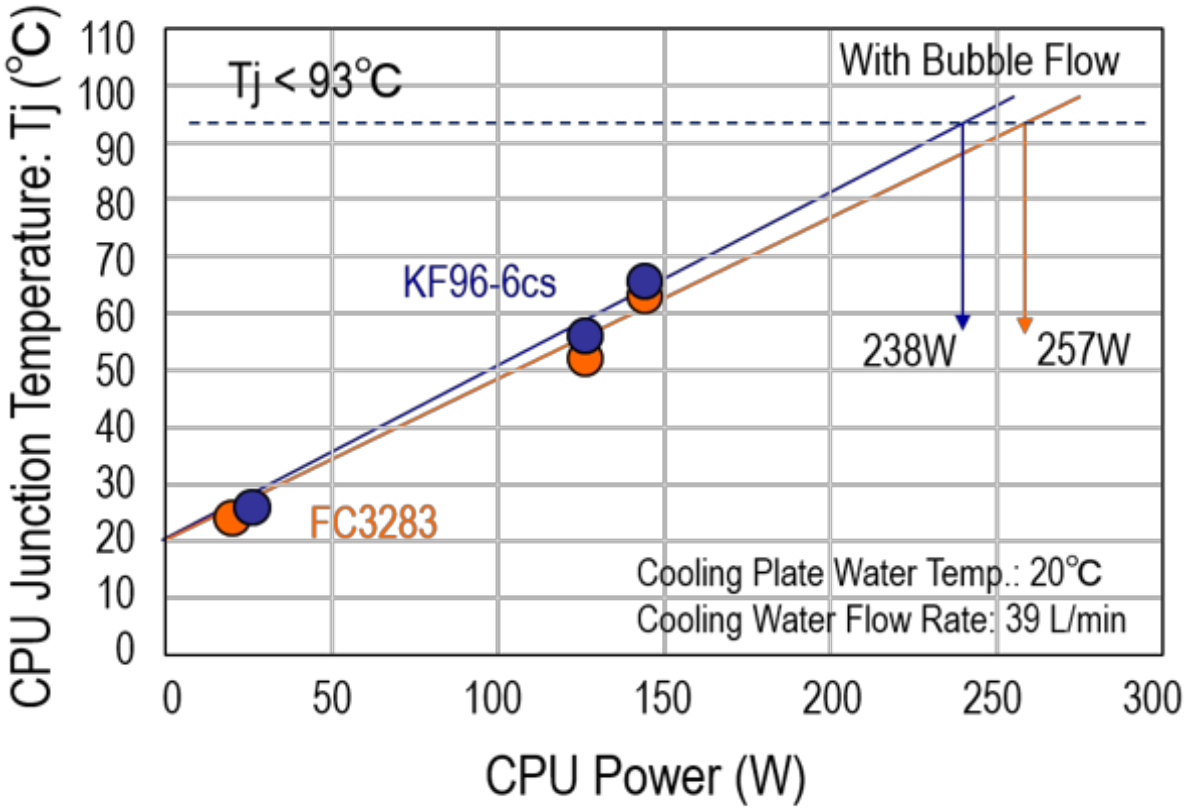
Cooling performance

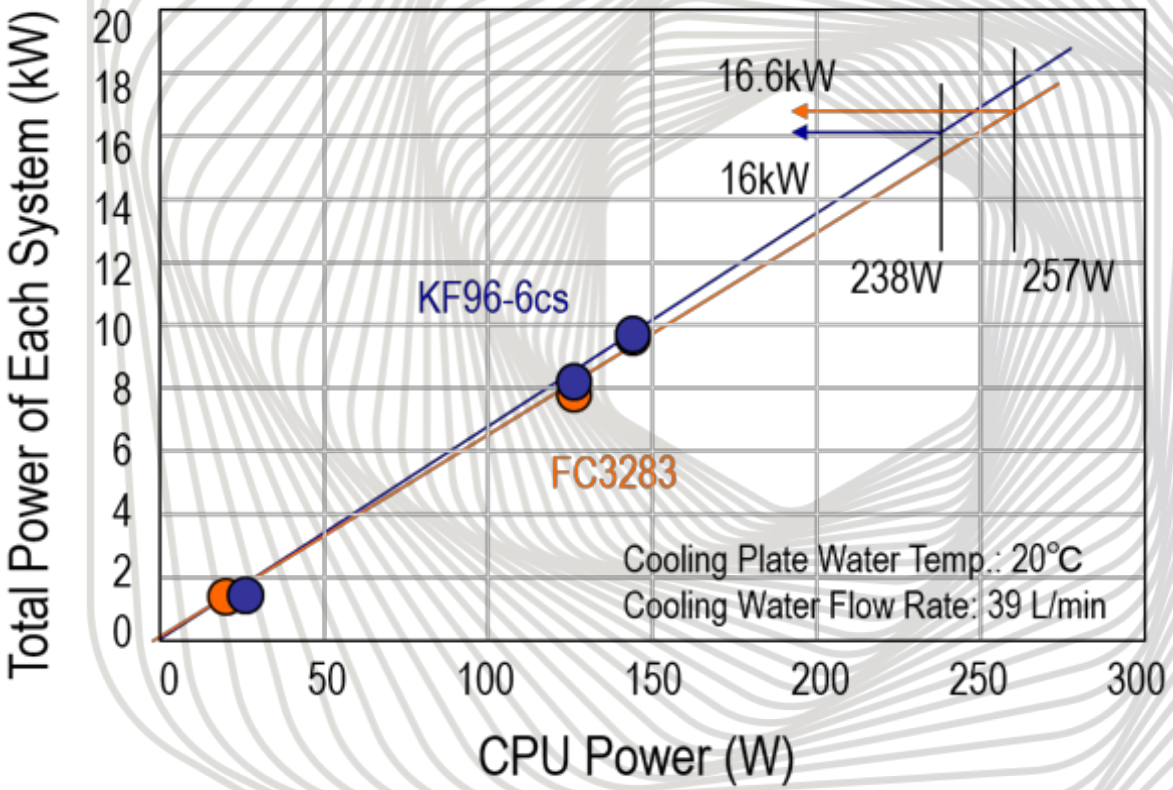


Cooling performance

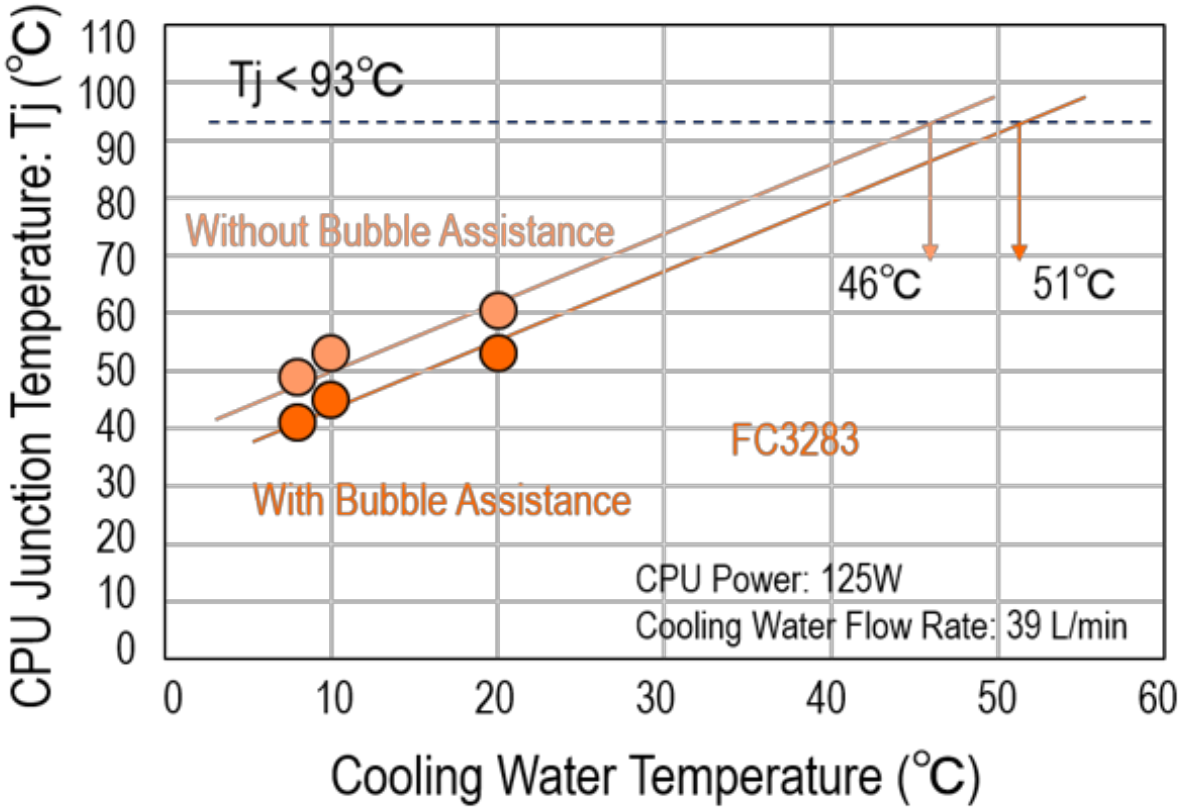


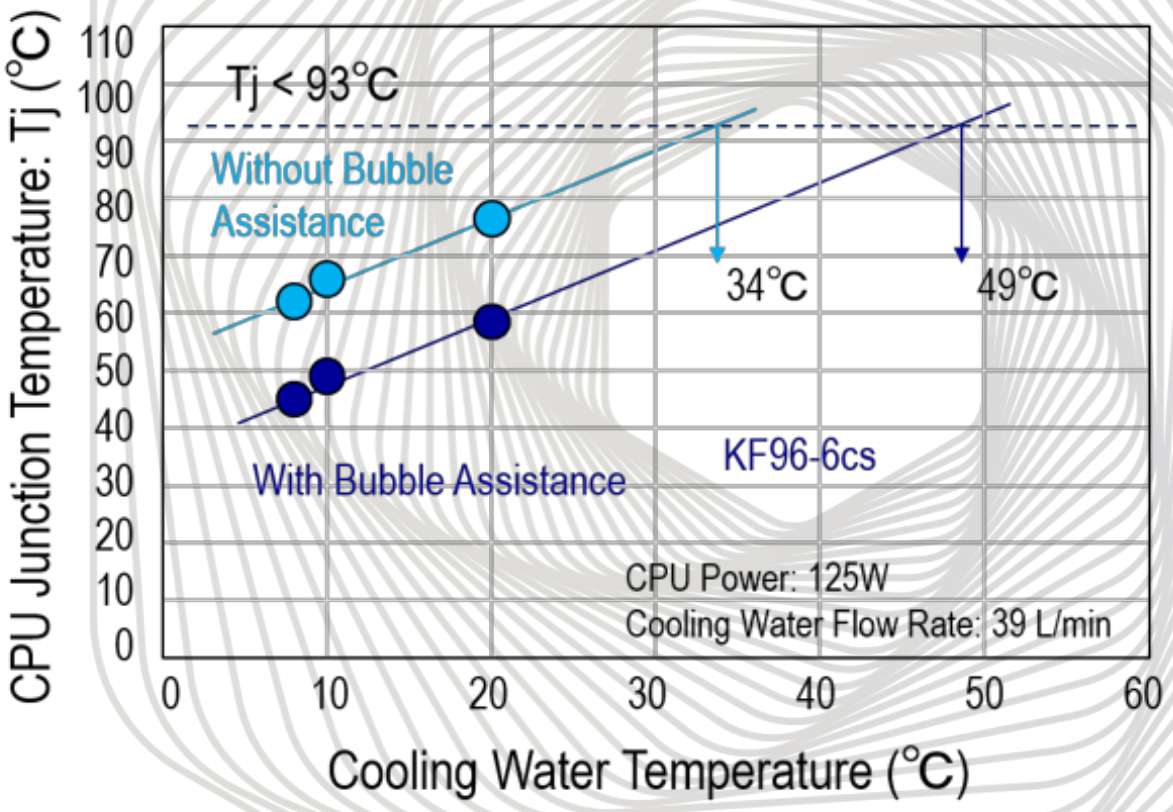
Cooling performance



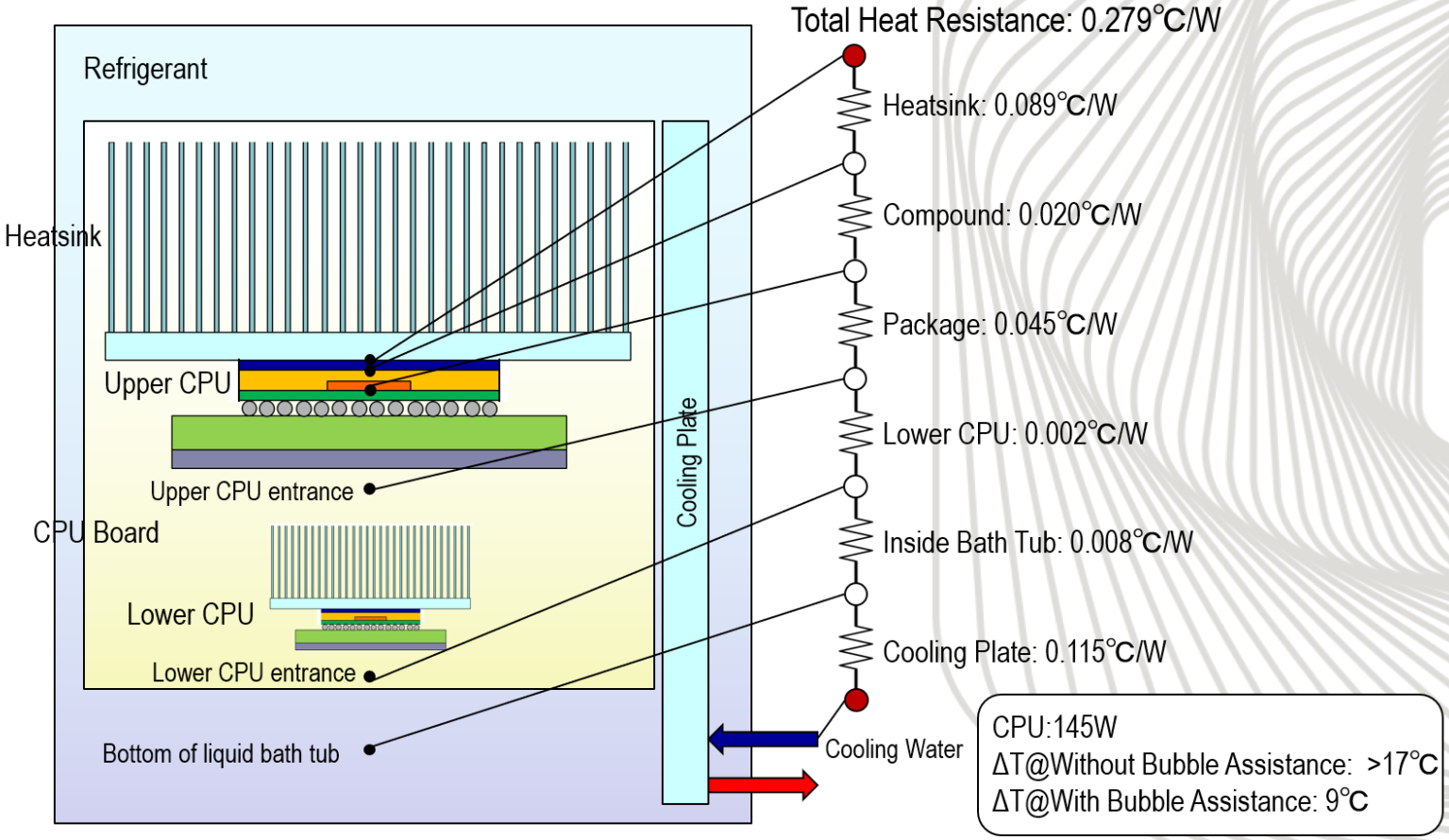


Cooling performance





Heat resistance



PUE

	Server	Water Cooling	Bubble Generation
Contribution	1	0.02-0.03	0.005-0.015

Summary

1. Bubble assisted natural convection enabled both ***low PUE(1.02-1.04)*** in simple natural convection and ***high cooling limit performance*** in forced convection.
2. Through the use of bubble assisted natural convection, higher viscosity refrigerants can also be a sufficient replacement of fluorocarbon refrigerants, which leads to ensuring their ***cost advantage*** and more importantly ***sustainability***.