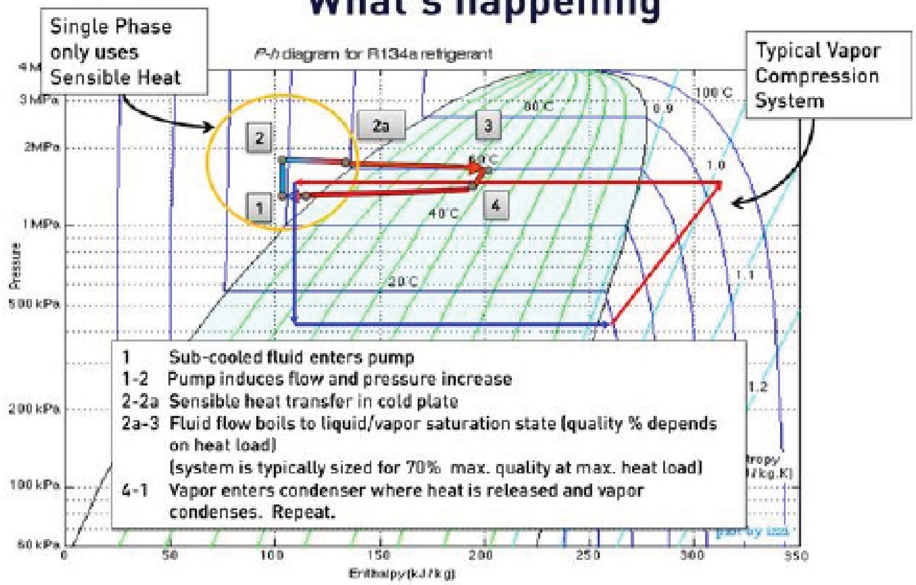
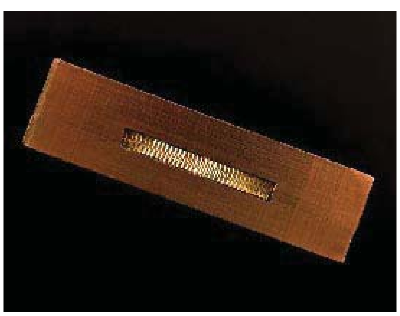
What's happening



The enthalpy chart illustrates how the system works and how we achieve our performance gains. The lines are exaggerated for clarity and here we are comparing our pumped 2-phase system against a classic vapor compression system. In our system the fluid enters the pump at point #1, there is a small pressure rise and from point 2-2a the fluid pick us sensible heat. This triangle, 1-2-2a-1 is the only region single phase water loops operate in.



As we enter the vapor dome (2a) the fluid starts to boil. We set the exit quality at a certain % depending on the application, we want to make sure we leave enough headroom for overload conditions. At point 3-4 the vapor enters the condenser, the heat is rejected and the liquid flows back to the pump to repeat the cycle. As more or less heat is put into the system the cooling loop self optimizes by either boiling more or less, reaction time is almost instantaneous so there is very little thermal cycling at the die. This reason alone makes this an ideal solution for electric vehicles as the power module cycles from off to full load.

The system is Isothermal and this is an important concept because it is the bane of most thermal designs. Since we are not absorbing sensible heat the cold plate remains roughly the same temperature across it's face. Multiple cold plates remain roughly the same (+/- 0.5c) from module to module.

The Pump
The heart of the system is a specially designed Parker pump with a continuous duty life in excess of 50,000hrs. The pump shown will dissipate about 2.5kW.

Parker

ENGINEERING YOUR SUCCESS.

Important Concepts

Dielectric Fluid - A dielectric is a non-conducting substance, i.e. an insulator

Enthalpy of vaporization - Is the energy required to transform a given quantity of a substance into a gas

Enthalpy of condensation - The heat which must be released to the surroundings to compensate for the drop in entropy when a gas condenses to a liquid

Isothermal - An isothermal process is a change in which the temperature of the system stays constant

Theta - One of the counter intuitive aspects of a two-phase system is how the thermal resistance goes down as source area goes up.

A way to think about this quantitatively is to neglect spreading resistance for the moment. In this case Theta (degC/W), the thermal resistance, is directly proportional to 1/UA where U is the heat transfer coefficient and A is the area available for heat transfer. As either A goes up or U goes up then Theta decreases. In the case of two-phase heat transfer in a cold plate where the hydraulic diameter is fixed and exit vapor quality is fixed then U, the heat transfer coefficient is constant (integrated over the source area). As the source size increases then the area for heat transfer goes up (fin area below the source). If A doubles then Theta is halved and so on, very low thermal resistances can be measured for large source areas. This is exactly what we observed when we went from microprocessor cold plates to IGBT cold plates. We started at 0.025 C/W for 20mm X 20 mm source and measured as low as 0.007 C/W for a multiple source cold plate with an IGBT mounted on it. Both had the same fin pitch, fin thickness etc.

Two-phase thermal resistance is always better than single phase thermal resistance at equivalent conditions (theoretically and experimentally)

Contact Information:

Parker Hannifin Corporation
Precision Cooling
10801 Rose Ave
New Haven, IN 46774

+1.260.255.5108
+1.866.851.0660
precision.cooling@parker.com

www.powerelectronicscooling.com