ADVANCED COOLING TECHNOLOGIES

The Thermal Management Experts | www.1-ACT.com

THERMAL CONSIDERATIONS FOR MEDICAL APPLICATIONS

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ADDITIONAL INFORMATION

Devin Pellicone

Devin is the Lead Engineer of Product Development at Advanced Cooling Technologies. He has over 10 years of experience designing and building both passive and active two-phase cooling systems. Devin has been leading the development of ACT's pumped two-phase products, pumped-passive HVAC energy recovery products, and advanced two-phase solutions. He holds several patents and has authored numerous journal and conference publications.

Full bios are located in the handouts tab

For more Information Visit our Website:
https://www.1-act.com/

SELECTION TOOL

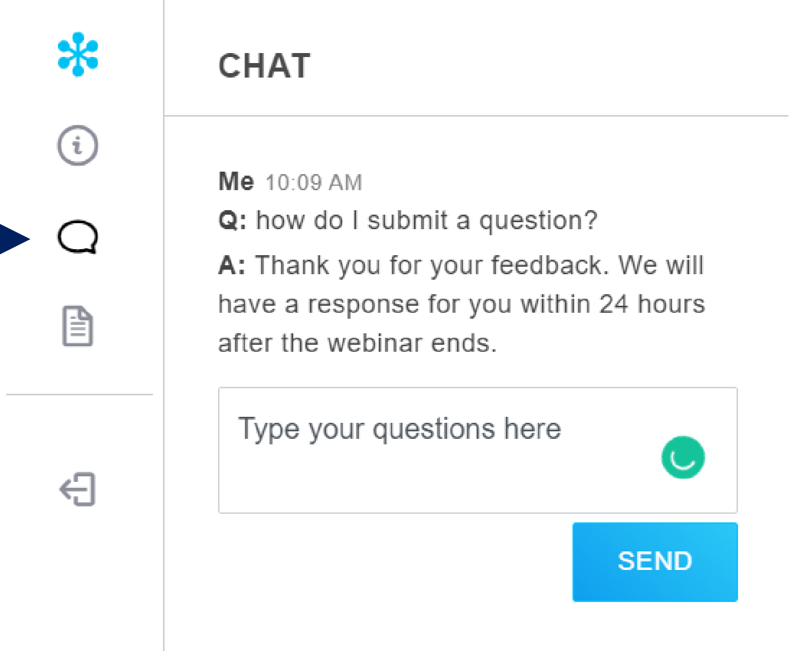
BROCHURES

EBOOK

AGENDA

- ACT overview
- Medical Device Application Considerations
  - Spot cooling
    - Heat Pipes
    - Vapor Chambers
    - HiK™ Plates
    - Thermoelectric Modules
  - Remote Cooling
    - Heat Pipes
    - Loop Thermosyphon
    - Liquid Cooling
    - Pumped Two-Phase
  - Transient vs. Steady State Considerations
    - Phase Change Material

Enter your Questions:



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PROVIDING CUSTOM THERMAL MANAGEMENT SOLUTIONS

Founded in 2003

- Over 240 Employed
- 150,000ft^2

Core Values

- Innovation
- Team Work
- Customer Care

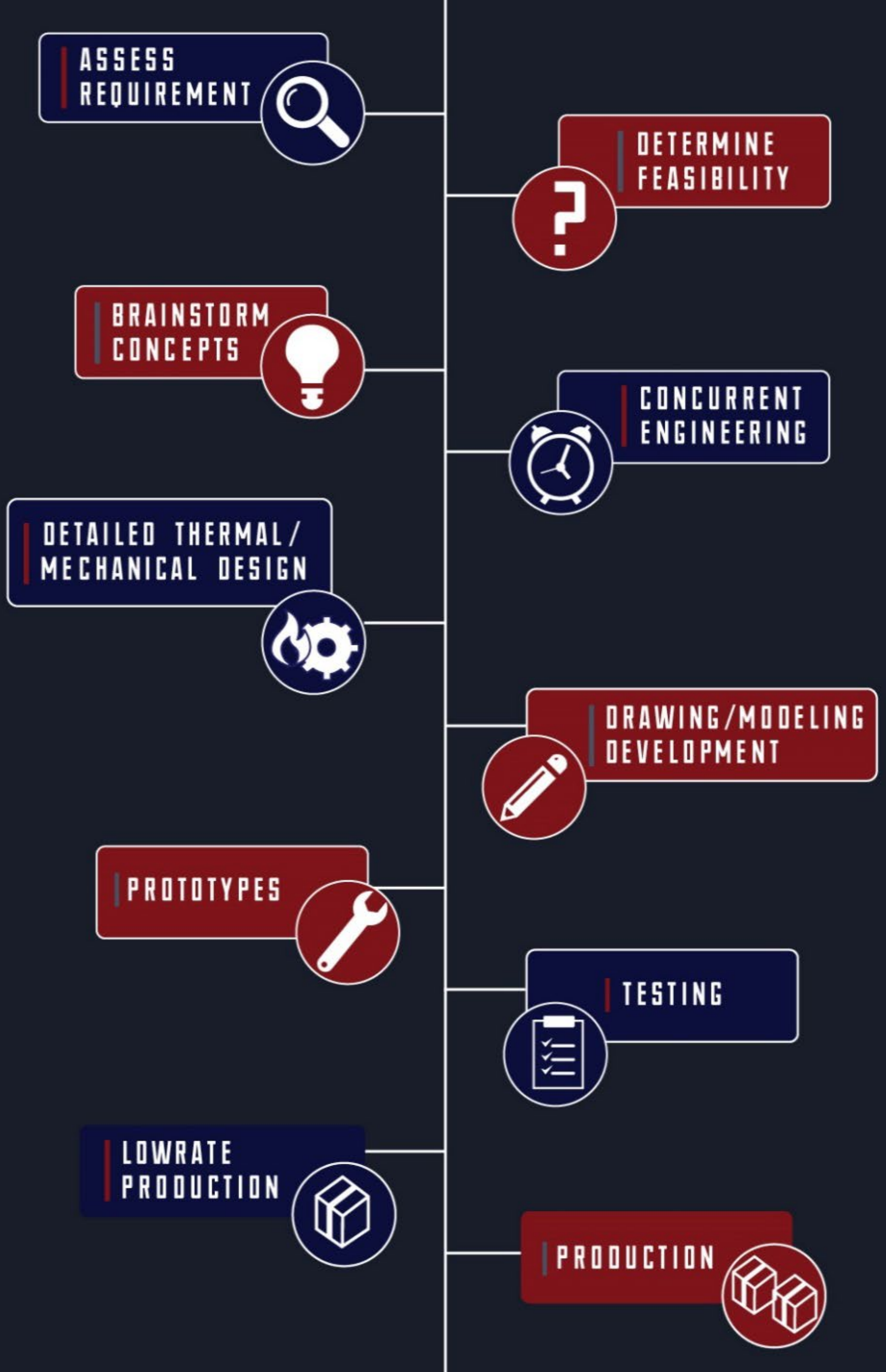
Awards

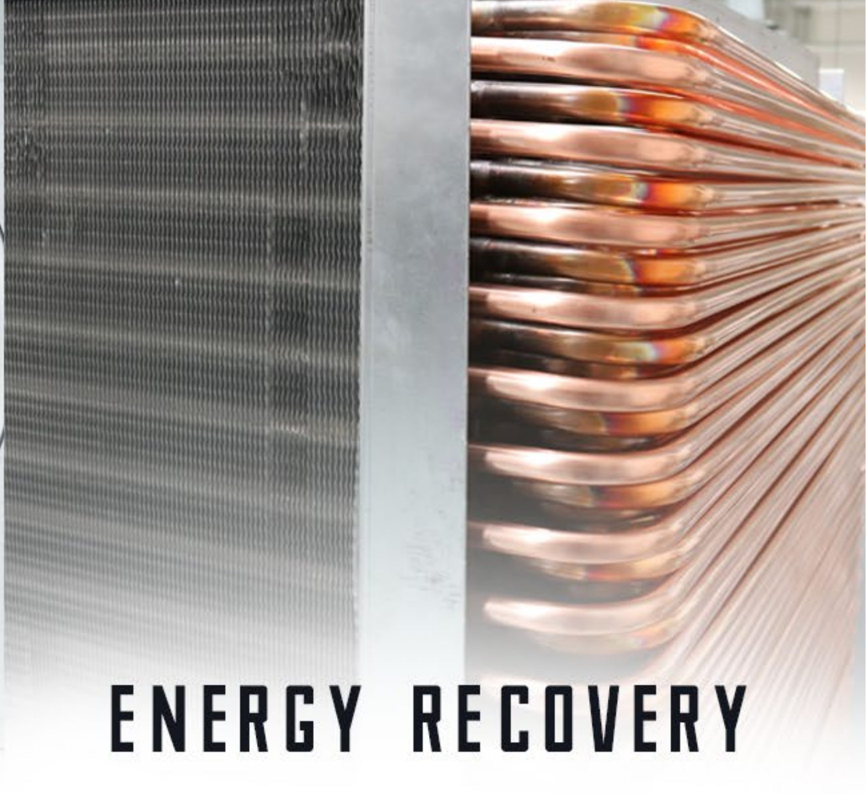
- Mil/Aero 2020 Technology Innovators award
- AHR 2021 Product of the year award in Green Building category
- 2020 Central Penn Business Journal names ACT as #12 fastest growing company in central PA
- 2018 Supplier Excellence Award from L3 Technologies
- Tibbetts Award for SBIR Commercialization
- 2011 Outstanding Supplier Award, Aerospace Prime Contractor

ACT

COLLABORATION & PARTNERSHIP

No matter where you are in your project, ACT can help.





OPERATIONAL SAVINGS – PRECISION COOLING – SIMPLE TO COMPLEX DESIGNS – SYSTEM LEVEL

GE Healthcare

SIEMENS

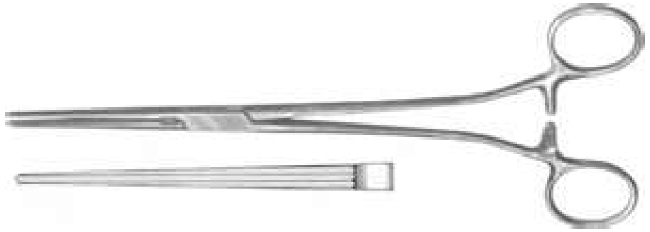
EATON

SAMSUNG

ACT

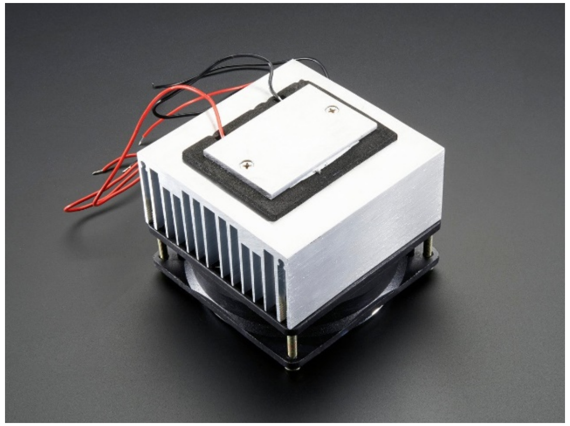
THERMAL MANAGEMENT CHALLENGES IN MEDICAL DEVICES

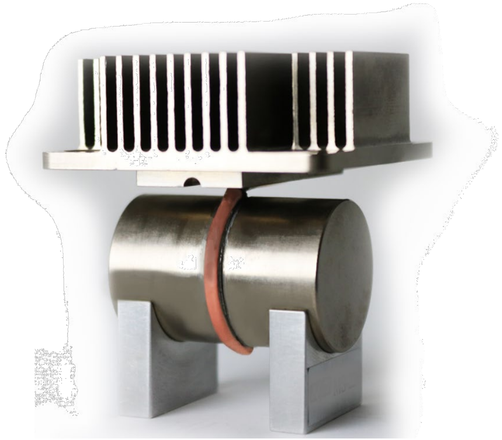
- Packaging Challenges:
  - Spot cooling vs. remote cooling
- Temperature Stability Challenges:
  - Touch safe temperatures for contact devices
  - Precise temperature control
  - Isothermality
- Operating Temperature Requirements
  - Sub-ambient vs. above ambient cooling solutions
- Duty cycle challenges:
  - Steady-state vs. transient solutions



SPOT COOLING

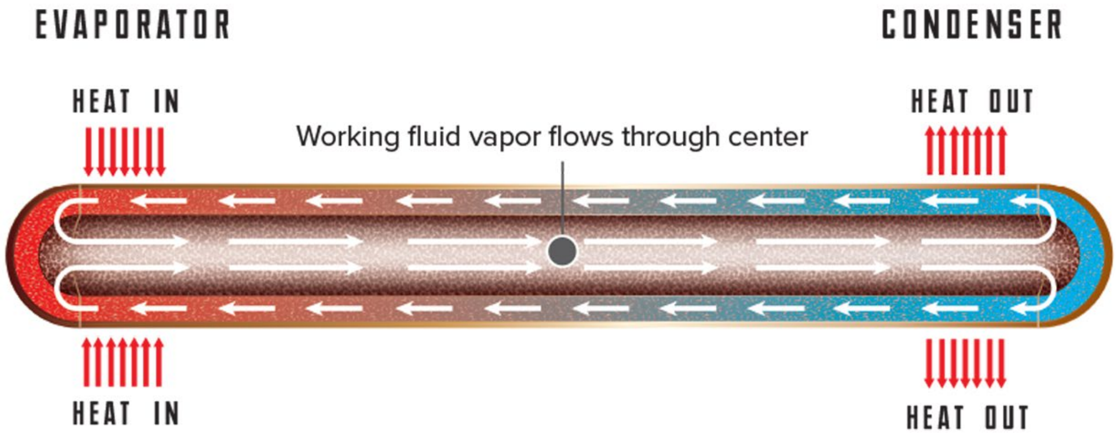
- Spot cooling refers to direct cooling a heat generating component within close proximity of the heat source
  - e.g. CPU heat sink
- Higher component power densities are leading to a reduction in spot cooler usage
- Sometimes heat spreading is required to reduce the load on the heat sink
  - Heat Pipes and Vapor Chambers can be used to effectively spread heat to larger areas for cooling
- Thermoelectric coolers can provide local sub-ambient cooling
  - Can handle only low to moderate heat loads (10's of Watts)

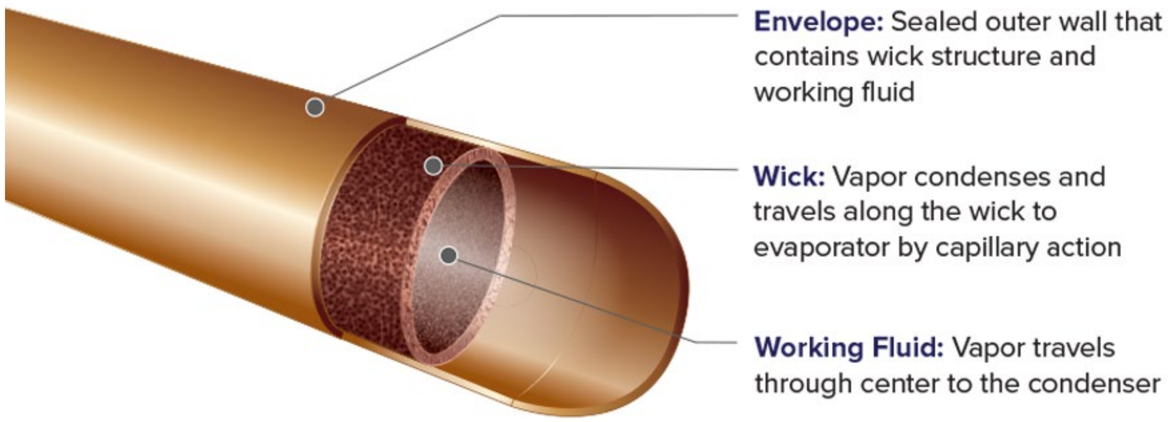




HEAT PIPES

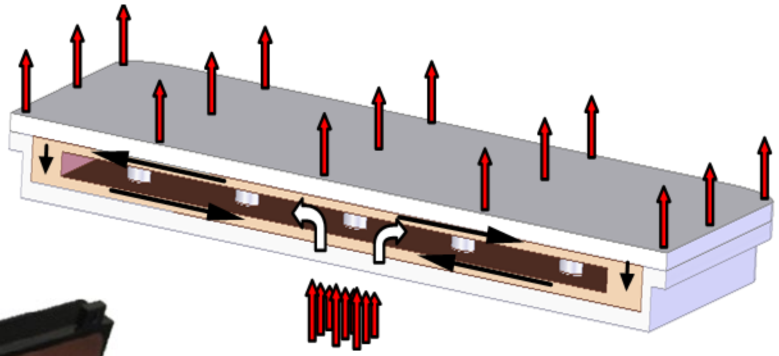
- Passive two-phase heat transfer device operating in a closed system
- Working fluid vaporizes utilizing the latent heat of vaporization
- Vapor flows to cooler end due to the slight pressure difference
- Vapor condenses and returns to evaporator by gravity or capillary force
- Typically a 2-5°C ΔT across the length of the pipe

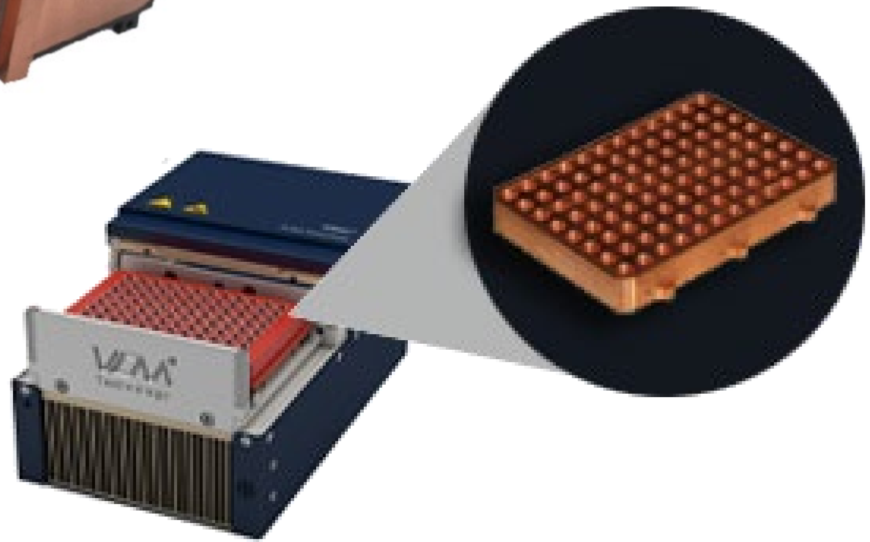




VAPOR CHAMBERS

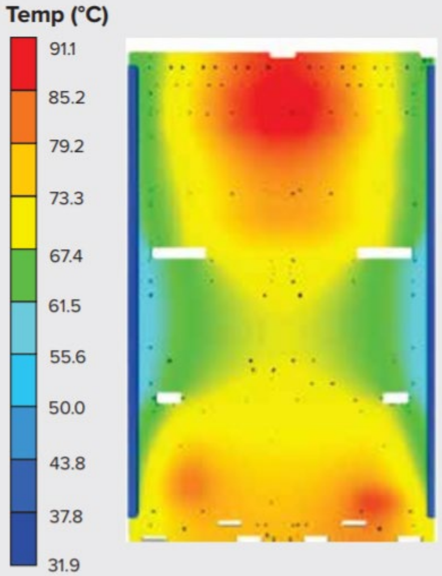
- Planar passive two-phase heat transfer device
- Used for high performance heat spreading and dissipation
- Thickness from 0.12” (3mm)
- Isothermal sink area (+/- 0.2°C)
- Heat Fluxes up to 700W/cm^2
- Custom geometries possible



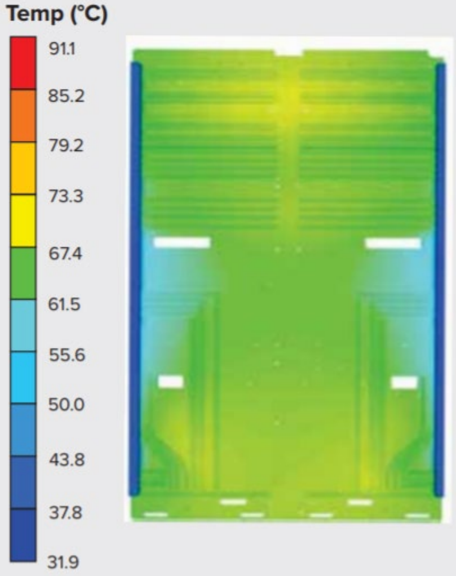


HIK™ PLATES

- Heat pipes embedded into solid plates
  - Typically Aluminum
- K=500-1,200 W/m-k
- Isothermal (+/- 2.0°c)
- Cost effective
- Plate thickness from 0.072” (1.8mm)
- Structural strength ≈ Aluminum
- Weight ≈ Aluminum

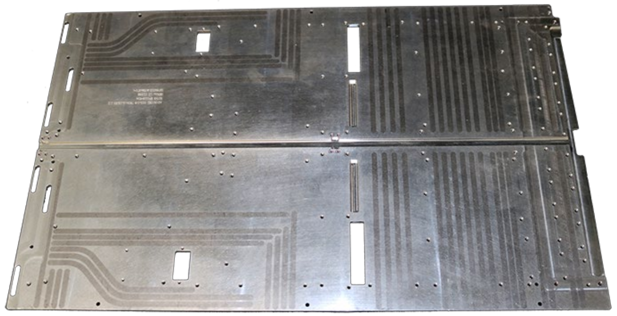


(a) Temperature Profile of an edge cooled aluminum plate with various high powered electronic components



(b) Temperature Profile of a HiK™ Plate that has the same components as Figure A above.

The conventional aluminum plate's highest temperature of 90.3° C was reduced to 69.1° C when the HiK™ aluminum plate was substituted.

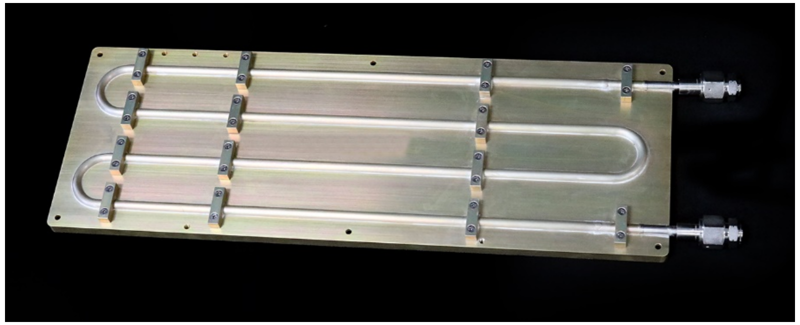


SPOT COOLING SUMMARY

Operating Scenario	Product/Technology	What it does	Applications
Steady State Spot Cooling	Heat Pipes	• 1-D heat spreading • <2°C temperature difference from end to end	• CPUs • LEDs • Surgical devices
	Vapor Chamber	• 2-D heat spreading • High heat flux capability (>500 W/cm^2) • Custom designed	• PCR machines • Laser modules/diodes
	HiK™ Plates	• 2-D heat spreading within bounds of the heat pipes • Lower cost than vapor chamber • Custom designed	• CPUs • LEDs • MRI Machines • Diagnostic equipment • Laser modules/diodes
	Thermoelectric Cooler (TEC)	• Sub-ambient, solid state cooling • No moving parts • <50W capacity • Can be combined with Heat pipes, Vapor Chambers, or HiK™ Plates	• Laser modules/diodes • Temperature sensitive diagnostic equipment

REMOTE COOLING

- Remote cooling is a common form of thermal management in systems with tight packaging constraints
  - Relies on an intermediate heat transport loop to move heat from point A to point B
- There are several cooling technologies for moving heat within an assembly
  - Heat Pipes
  - Loop Thermosyphon
  - Liquid Cooling
  - Pumped Two-Phase (P2P)
- Each technology has an appropriate range of applications in which it is most suitable

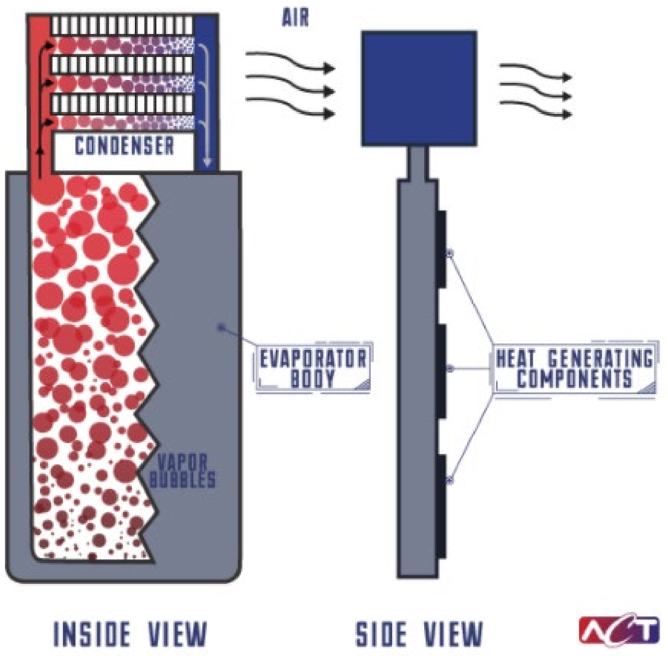


HEAT PIPES

- Best for lower power applications with relatively short heat transport distance requirements
- Operation against gravity
- Heat fluxes up to 40 W/cm^2
- Typically utilize air as the ultimate heat sink
- Common Envelope Materials:
  - Copper
  - Aluminum
  - Stainless steel
- Common Working Fluids:
  - Water
  - Methanol

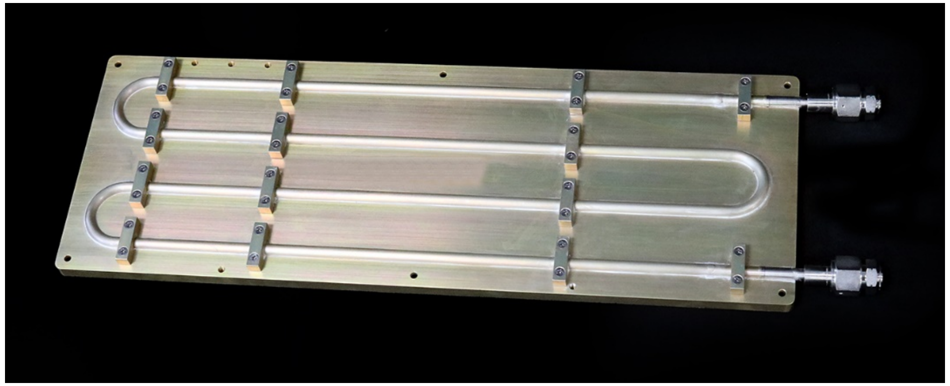
LOOP THERMOSYPHON TECHNOLOGY

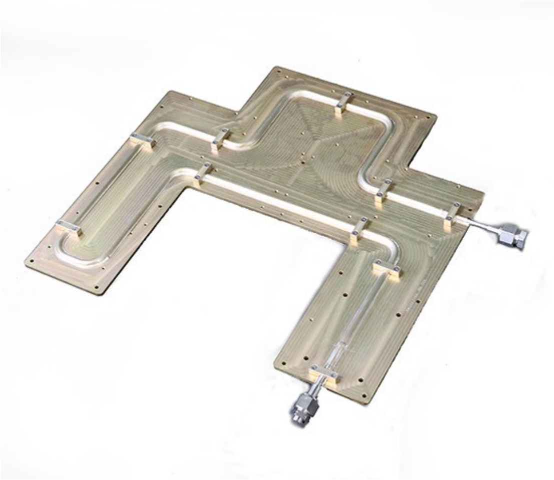
- Higher thermal transport capability than heat pipes
  - 10's of kW are possible
- Longer transport lengths
- Rely on gravity
  - Condenser must be vertically above the evaporator
- Dielectric properties
- Can support sub-ambient cooling with the addition of a chiller
- Common Envelope Materials:
  - Copper
  - Aluminum
- Common Working Fluids:
  - Refrigerants (e.g. r134a)



LIQUID COLD PLATES

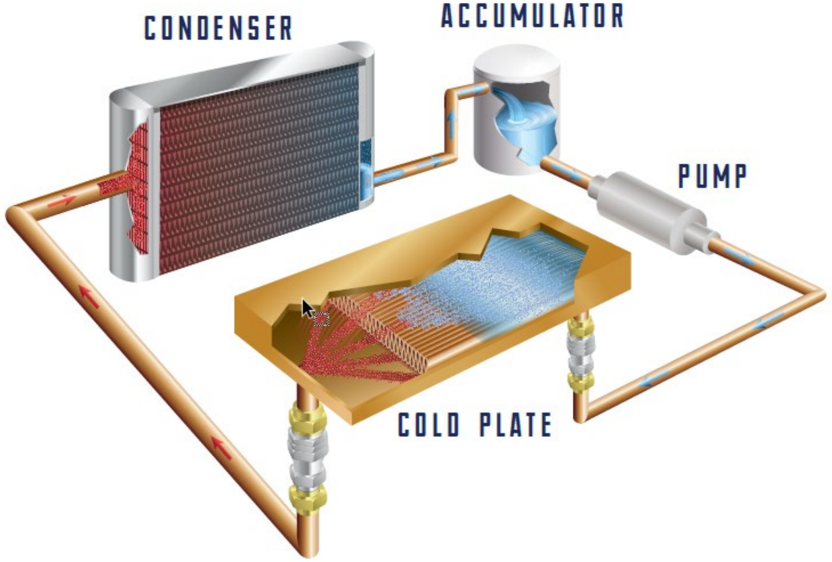
- Highest power capability
  - 10's of kW of thermal load
- Flexibility in installation options
  - Fluid lines can be flexible
- Longest transport lengths
- Requires support equipment to provide liquid to the cold plate
  - E.g. pumps, reservoir, heat exchanger
- Can support sub-ambient cooling with the addition of a chiller
- Common Envelope Materials:
  - Copper
  - Aluminum
  - Stainless Steel
- Common Working Fluids:
  - Ethylene Glycol/Water solutions
  - Propylene Glycol/Water solutions
  - Deionized Water

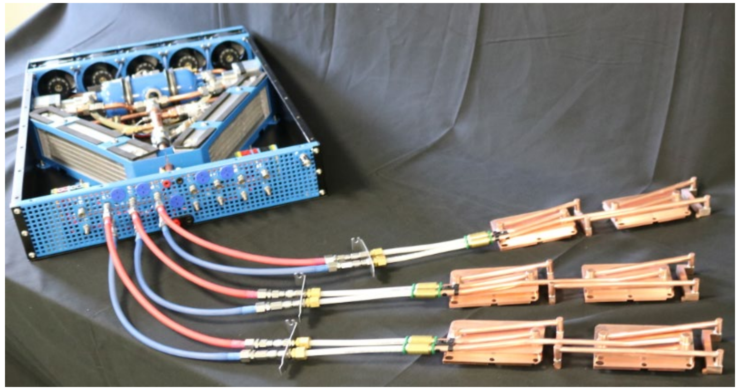




PUMPED TWO-PHASE – P2P

- Highest power capability
  - 10's to 100's of kW of thermal load
- Two-phase heat transfer provides best temperature control, isothermality, and energy efficiency
- Dielectric properties
- Highest heat flux capability
- Flexibility in installation options
  - Fluid lines can be flexible
- Requires support equipment to provide liquid to the cold plate
  - E.g. pumps, reservoir, condenser
- Can support sub-ambient cooling with the addition of a chiller
- Common Envelope Materials:
  - Copper
  - Aluminum
- Common Working Fluids:
  - Refrigerants (e.g. r134a)





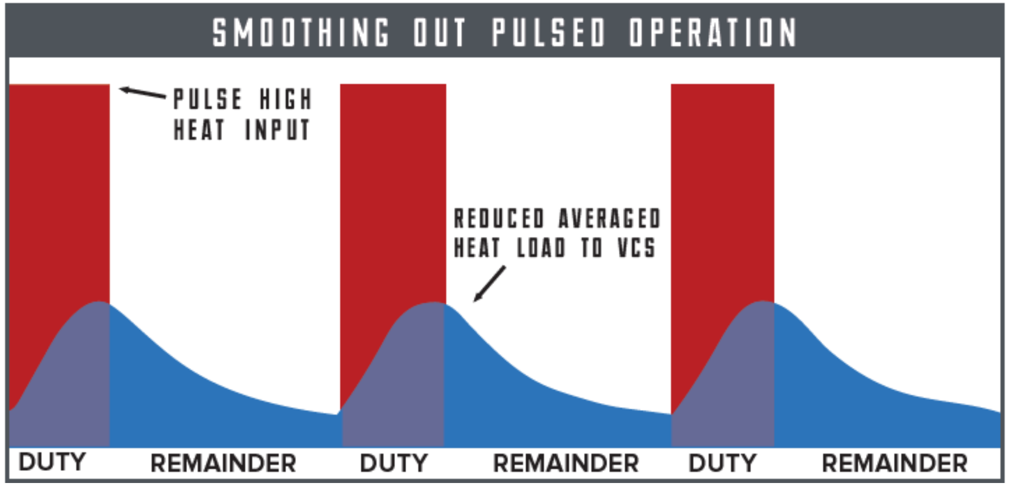
REMOTE COOLING SUMMARY

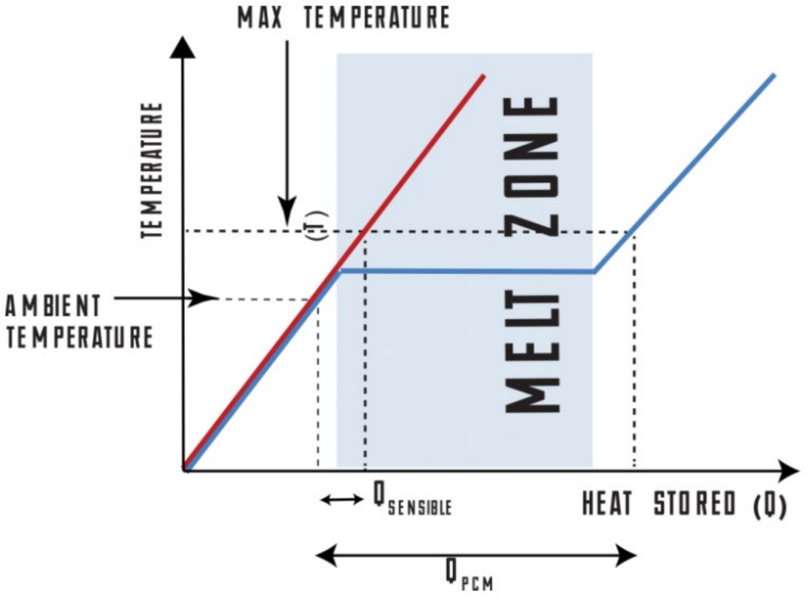
Operating Scenario	Product/Technology	What it does	Applications
Steady State Remote Cooling	Heat Pipes	• Short thermal transport distances (<1 meter) • <40W/cm2 • Can operate against gravity	• CPUs • Laser modules/diodes • MRI Machines • Diagnostic equipment
	Loop Thermosyphon[1]	• Longer transport distances (<10 meters) • Must be gravity-aided • High power capability (10's of kW) • Dielectric fluids	• Power Electronics • Laser modules/diodes • MRI Machines • Diagnostic equipment
	Liquid Cooling [1]	• Longest transport distances (10's of meters) • Higher power capability (10's of kW) • Operate in any orientation • Requires balance of plant components	• Power Electronics • Laser modules/diodes • MRI Machines • Diagnostic equipment
	Pumped Two-Phase[1]	• Longest transport distances (10's of meters) • Highest power capability (10's to 100's of kW) • Operate in any orientation • Requires balance of plant components • Dielectric fluids	• Power Electronics • Laser modules/diodes • MRI Machines • Diagnostic equipment

[1] Can support sub-ambient cooling with the addition of a chiller

TRANSIENT VS. STEADY STATE

- Transient heat generation should have a transient cooling system
- Phase Change Materials (PCMs) can be used as thermal batteries/capacitors to dampen out peak loads
  - Store energy during high load operation and dissipate it over longer idle periods
- Most PCMs melt along a constant temperature absorbing energy without increasing component temperature





PHASE CHANGE MATERIAL

- PCM is used in short duration or pulsed operation
  - Reliable / passive
  - Weight and Volume Benefits
- Solid to liquid phase change allows the high latent heat of the PCM to absorb and store energy
- Common envelope materials:
  - Copper
  - Aluminum
  - Stainless Steel
- Common PCMs
  - Paraffin waxes
  - Vegetable-based materials
  - Sugar alcohols

Property or Characteristic	Paraffin Wax	Non-Paraffin Organics	Hydrated Salts	Metallics
Heat of Fusion	High	High	High	Med.
Thermal Conductivity	Very Low	Low	High	Very High
Melt Temperature (°C)	-20 to 100+	5 to 120+	0 to 100+	150 to 800+
Latent Heat (kJ/kg)	200 to 280	90 to 250	60 to 300	25 to 100
Corrosive	Non-Corrosive	Mildly Corrosive	Corrosive	Varies
Economics	$$	$$$ to $$$$	$	$$ to $$$
Thermal Cycling	Stable	Elevated Temperature Can Cause Decomposition	Unstable over Repeated Cycles	Stable
Weight	Medium	Medium	Light	Heavy

TAKE AWAY

- There is no ‘one size fits all’ cooling solution for medical devices
- Designers should consider the following when selecting an appropriate cooling solution:
  - Packaging considerations
    - Local vs. remote cooling
  - Power requirements
  - Steady state vs. transient performance
  - Operating orientation
  - Above ambient vs. sub-ambient
- Consider thermal management early on in the development cycle to enable the most efficient solutions


Idea
Technology
INNOVATION
Invention
Research
Creativity
Improvement

QUESTIONS?