



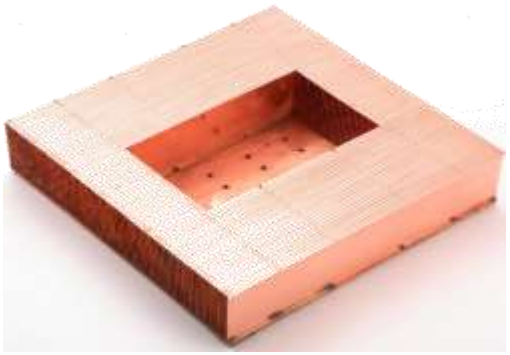



BOYD
TRUSTED INNOVATION

Enhanced Two Phase Thermal Solutions

Heat Pipe Assemblies
Special High Performance Heat Sinks

Overview



Loop heat pipe

Vapour chambers

Thermatower

Low temp heat pipes

Loop thermosyphon

Special wick processes

High temp heat pipes

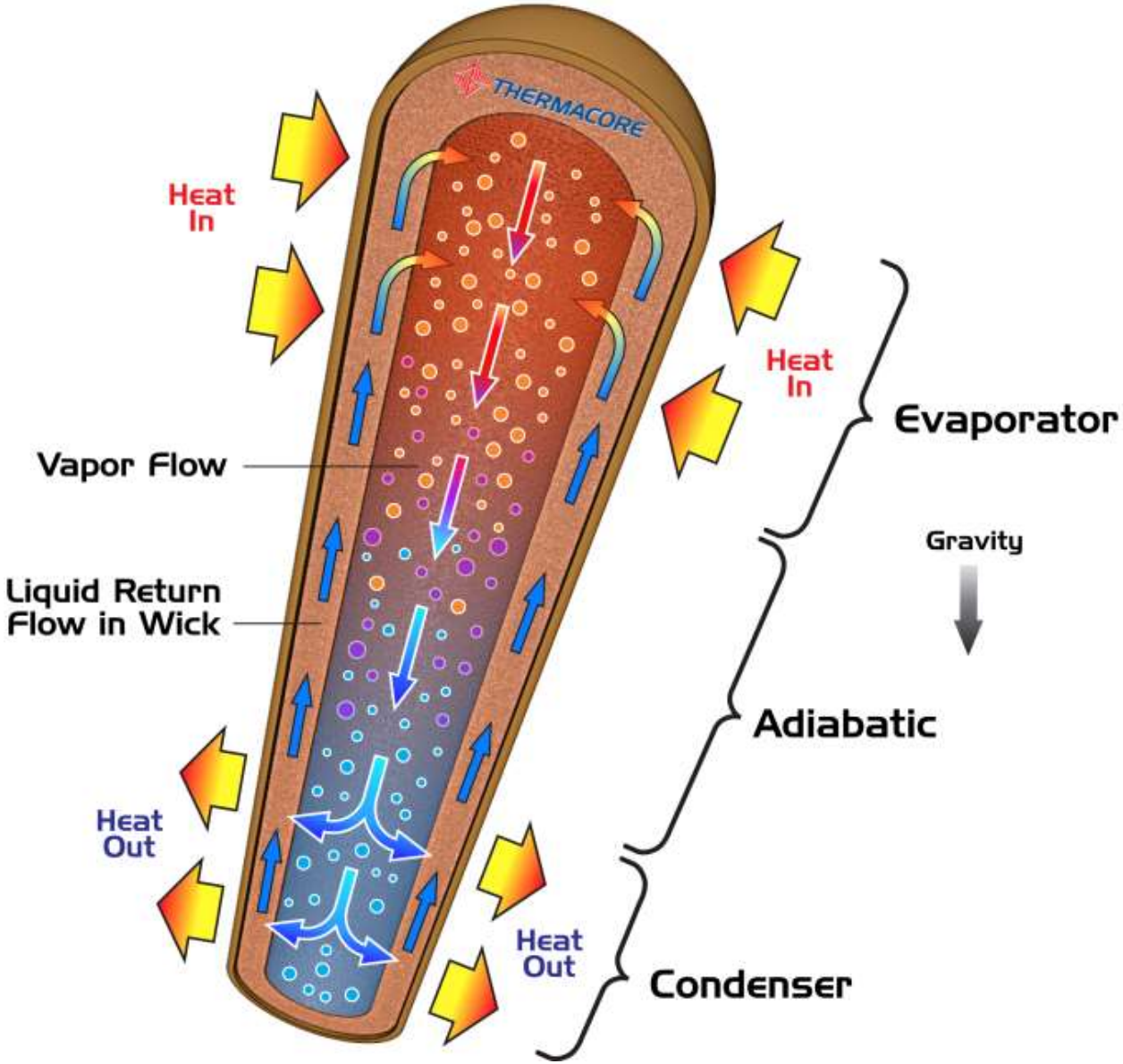
Long series heat pipes (2m)

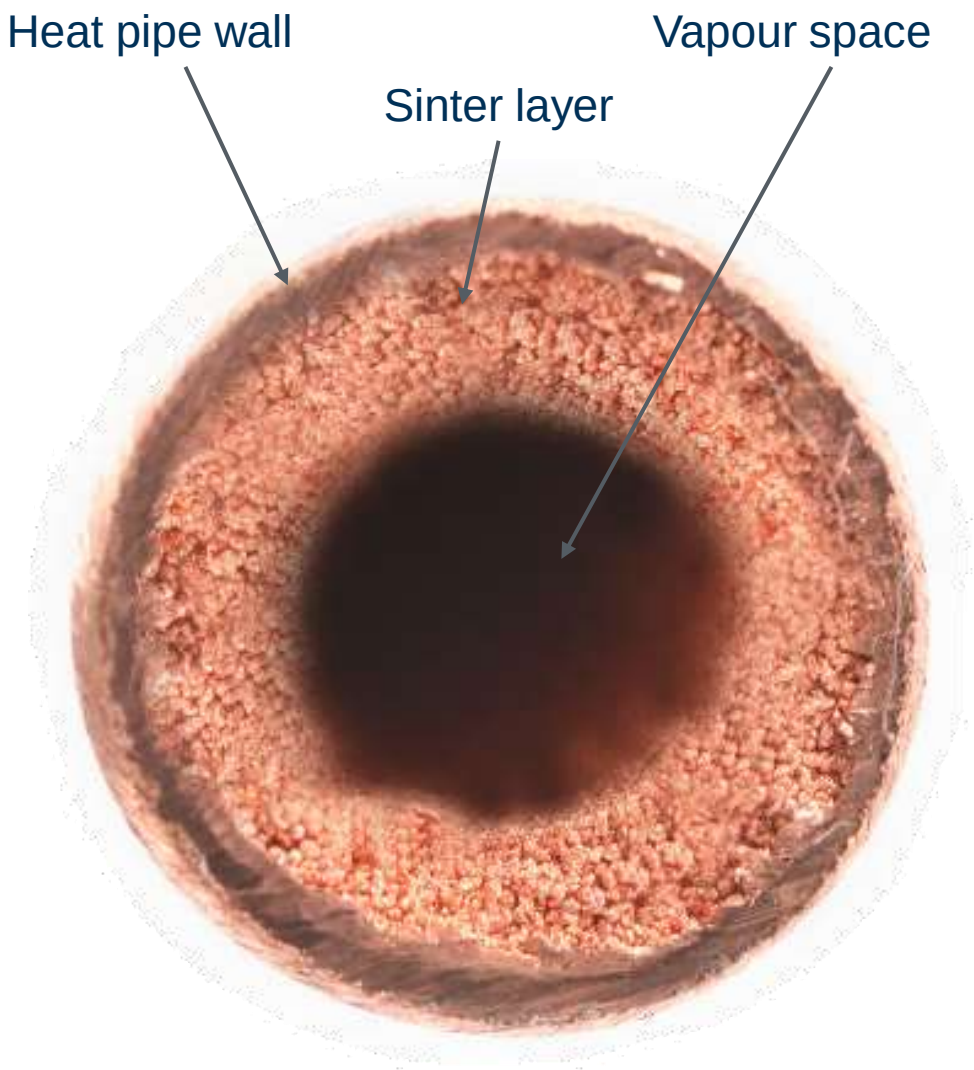
Large diameter heat pipes (Ø43mm)

High integrity space heat pipes

Two Phase products

How Heat Pipes Work – The Basics

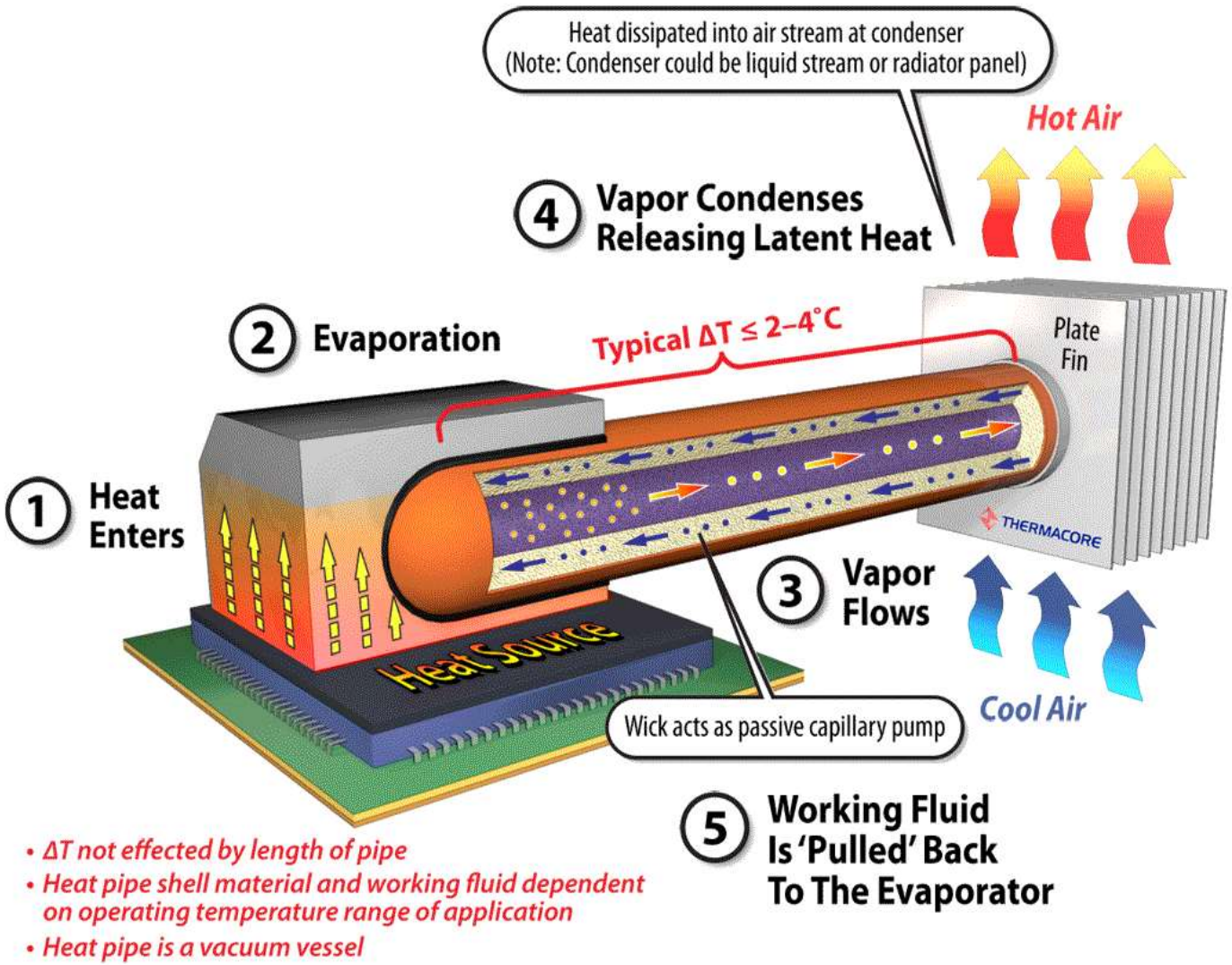




How Heat Pipes Work – The Basics

"A heat pipe is a heat transfer mechanism that can transport large quantities of heat with a very small difference in temperature between the hotter and colder interfaces."

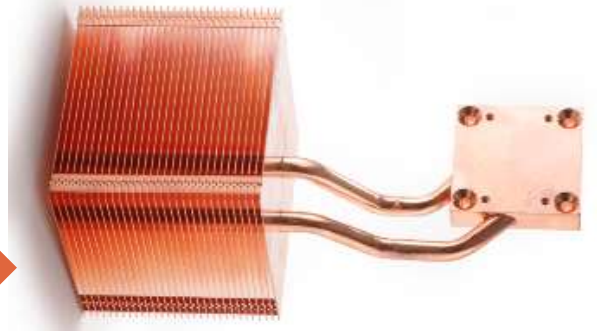
"Inside a heat pipe, at the hot interface a fluid turns to vapour and the gas naturally flows and condenses on the cold interface. The liquid falls or is moved by capillary action back to the hot interface to evaporate again and repeat the cycle."
(http://en.wikipedia.org/wiki/Heat_pipe)



Operating Temperatures

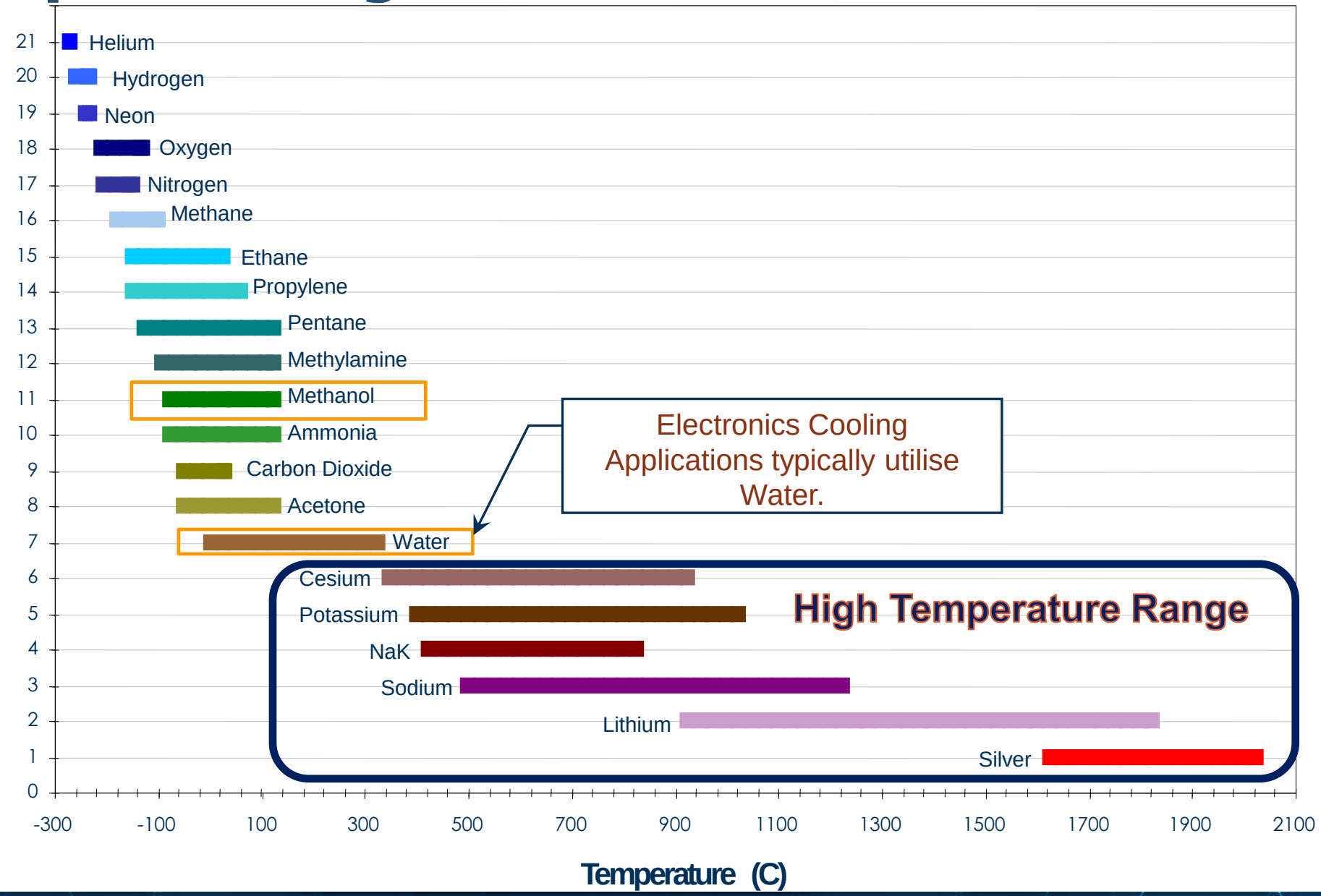
- **Cryogenic Temperatures (-265˚C to 0˚C)**
  - **Example Applications**
    - Satellite and Medical
  - **Thermal Technologies:**
    - Heat Pipes and Loop Heat Pipes

- **Mid Range Temperature (0˚C to 300˚C)**
  - **Example Applications**
    - Satellite, Numerous Military Applications, Automotive, Chemical Reactors, Computers, Telecommunications
  - **Thermal Technologies**
    - Heat Pipes, Flexible Heat Pipes, Loop Heat Pipes, Flexible Laminate Heat Pipes, Pumped Liquid Cooling



- **High Temperature (300˚C to 2000˚C)**
  - **Example Applications:**
    - Isothermal Furnace Liners (IFLs), Turbine Blades, Solar Stirling, Wing/Cowl Leading Edges, Space Nuclear
  - **Thermal Technologies:**
    - Liquid Metal Heat Pipes

Heat Pipe Working Fluids



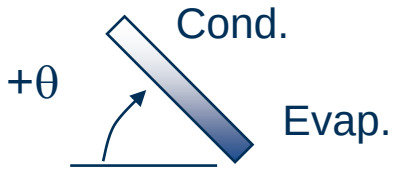
Heat Pipe Wick Structure

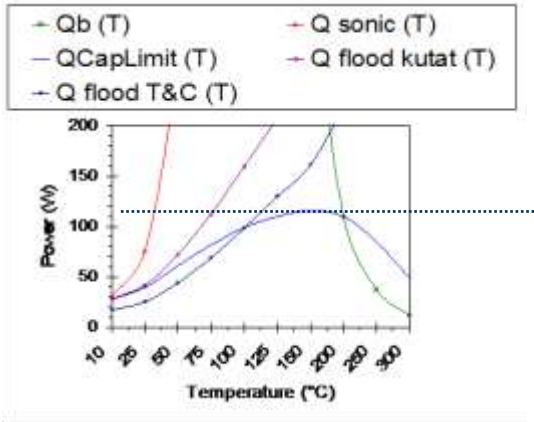
- Groove Wick
- Screen/Woven Wick
- Sintered Powered Wick

Wick Structure	Operational Orientation Relative to Gravity	Power Density / Heat Flux Capabilities	Freeze Tolerance
Wickless (i.e. Thermosyphon)	+90° to +5° "Orientation Sensitive"	Up to 5 W/cm^2 "Very Low Density"	Not Freeze Tolerant
Grooves	+90° to +0° "Orientation Sensitive"	Up to 10 W/cm^2 "Low Density"	Not Freeze Tolerant
Screen/Wire	+90° to -5° "Orientation Sensitive"	Up to 15 W/cm^2 "Medium Density"	Not Freeze Tolerant
Sintered Powder	+90° to -90° "Orientation Insensitive"	> 15 W/cm^2 (350 W/cm^2 achievable) "High Density"	Can be Designed for Freeze Tolerance

Heat Pipe Orientation

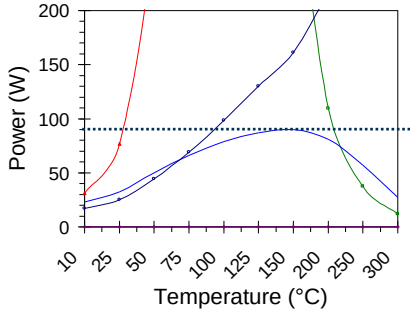
Gravity Aided





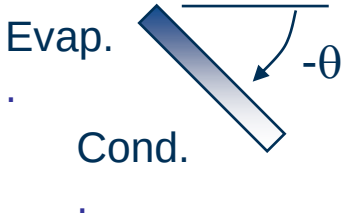
115 Watts

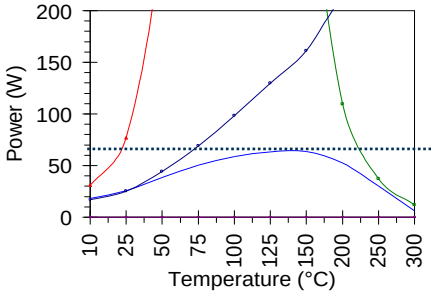
Horizontal



90 Watts

Against Gravity

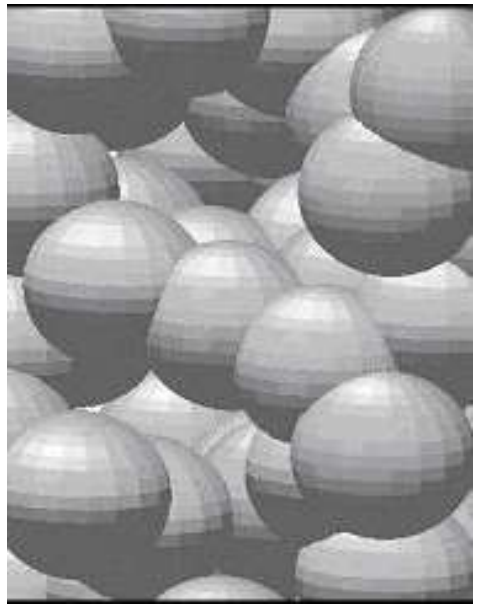




65 Watts

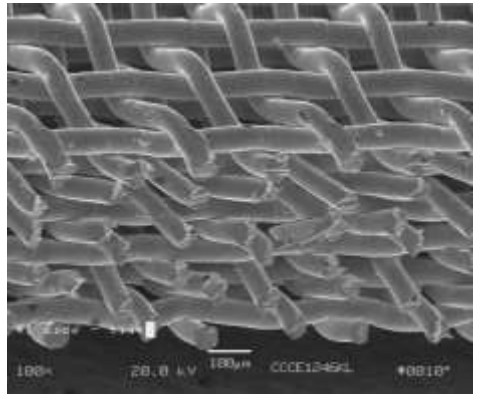
Sintered Wick Structure

- Most common heat pipe used in Electronics Cooling
- Wick structure is sintered metal powder
- Good capillary limit, high return of liquid to evaporator
- Annealed container allows easy bending and flattening
- Allows easy embedding into heat sink bases and assemblies
- Can be mass produced in Asia for cost reduction
- Might not be the lowest dT solution available



Screen Mesh Wick Structure

- No distinctive market, one of the oldest types
- High power handling capabilities due to large vapour space
- Great structural strength due to hard container material
- Bending of heat pipes is hard to accomplish and needs to be considered in the design process
- More than one mesh grade is available and can be tailored to application requirements

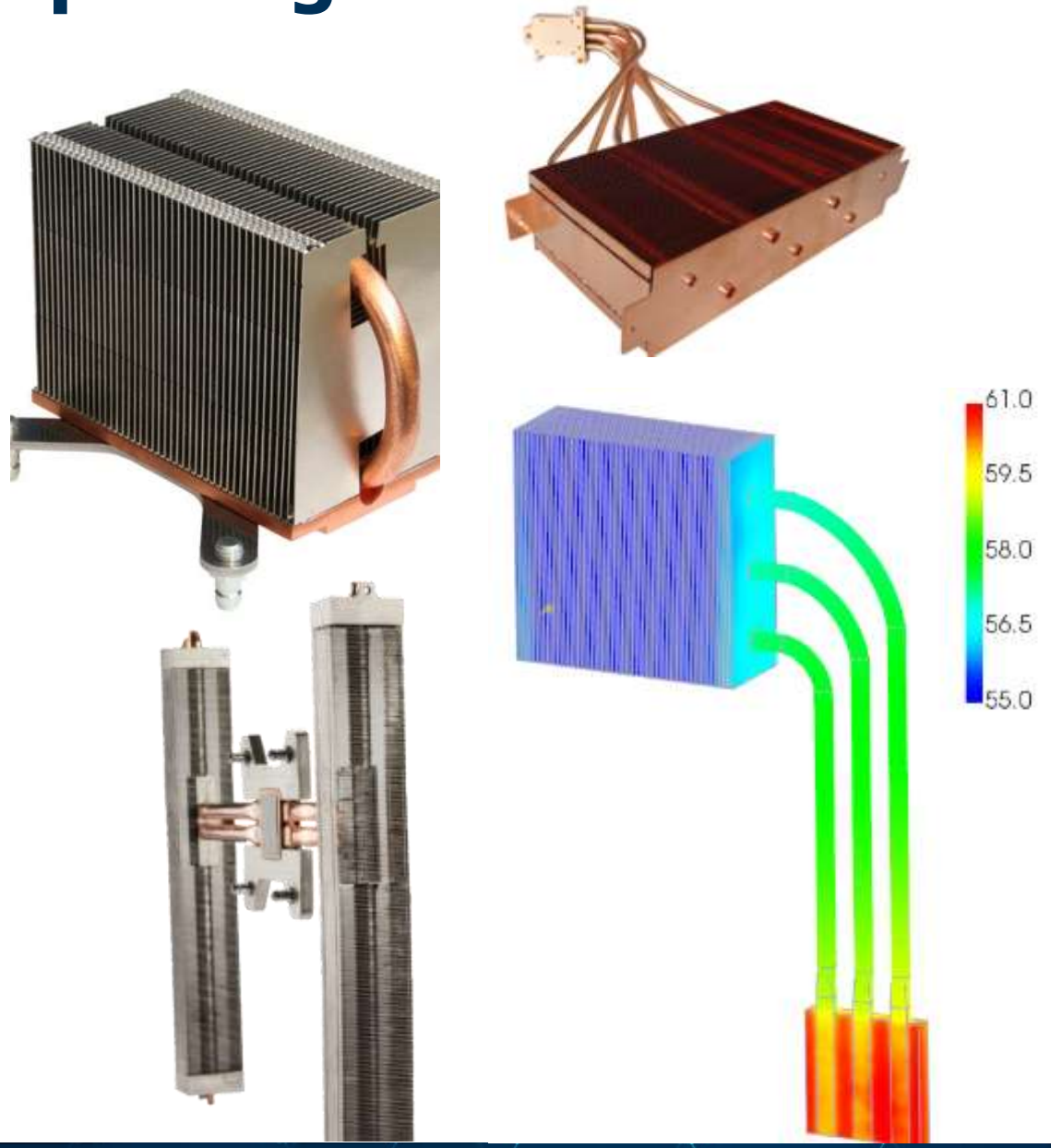


Grooved Wick Structure

- Liquid Return relies on the groove geometry or gravity to return to the evaporator
- Mostly used in space applications for satellite panels
- Aluminium grooved heat pipes can be extruded into nearly any shape. Ammonia used as working fluid.
- Ammonia suitable for temperature range in Space
- Heat Pipe can become integral part of larger panels.

Heat Pipe Assemblies for Transporting Heat

- Transport heat to area where it can be dissipated more effectively
  - To a remote fin stack or thermal solution
  - To another part of the heat sink not within the base for improved fin efficiency



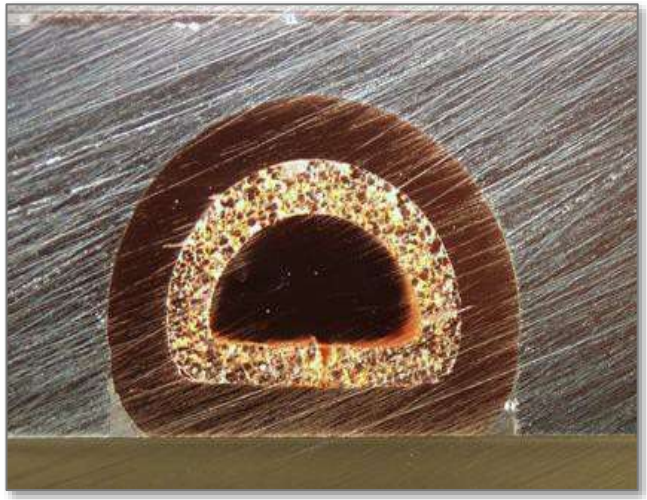
Embedded Heat Pipes for Heat Spreading

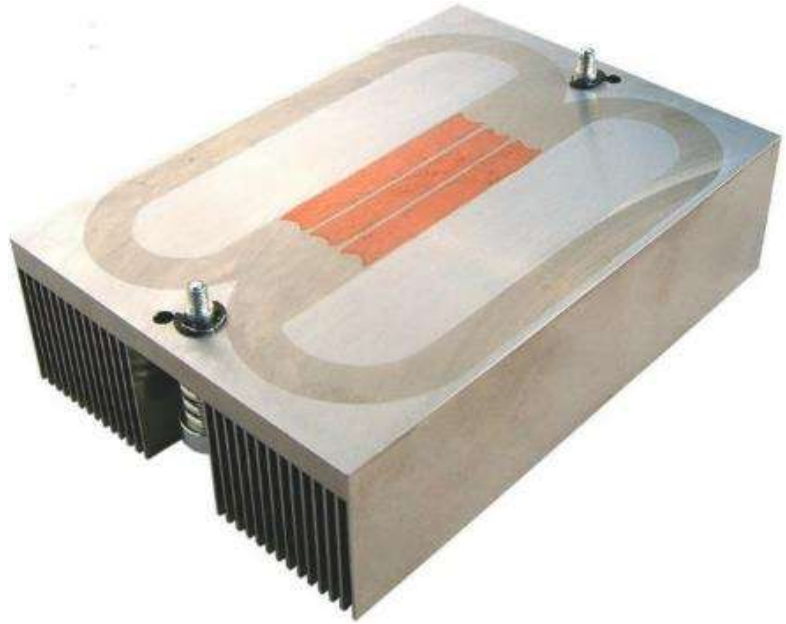
DISPERSE HEAT LOADS MORE EVENLY ACROSS A SURFACE FOR MORE UNIFORM, OPTIMIZED COOLING

ENABLE SMALLER, LIGHTER WEIGHT SOLUTIONS

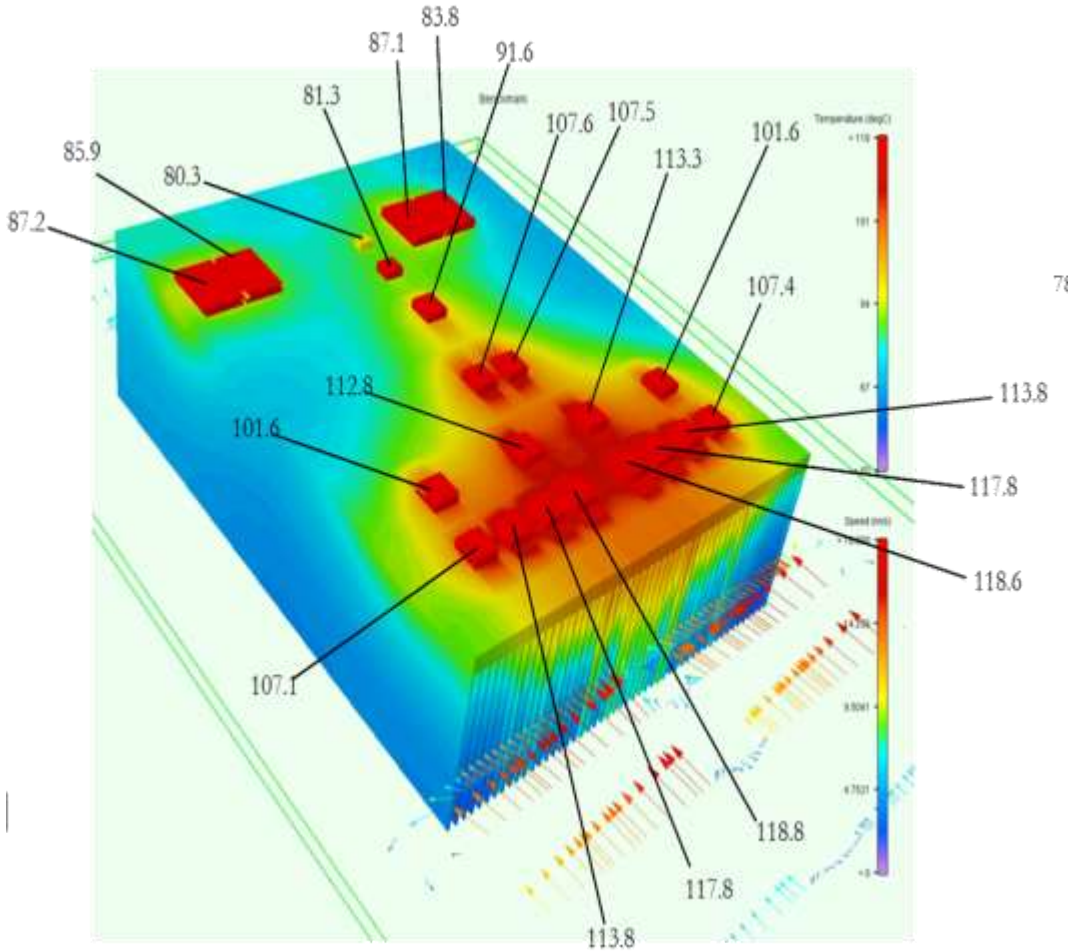
HI-CONTACT® PROCESS FOR BETTER HEAT TRANSFER

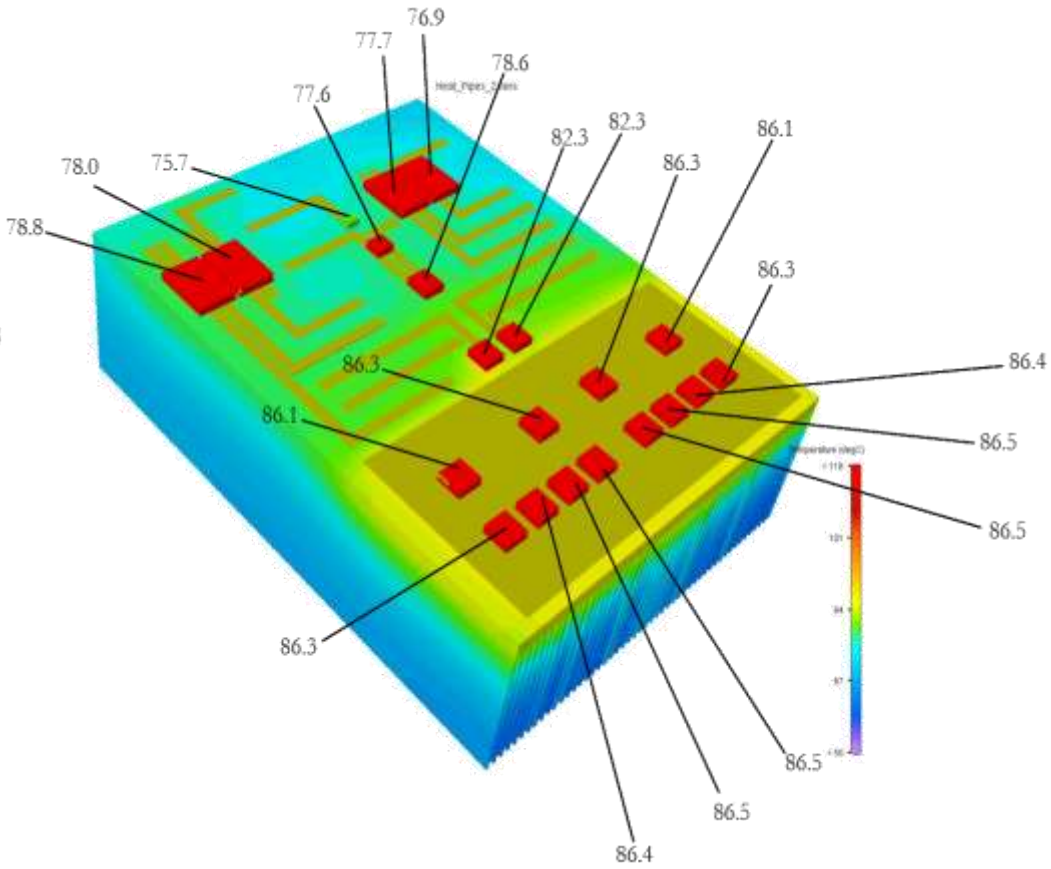
BEST OPTION FOR HIGHER PERFORMANCE COOLING WITH NO ACTIVE COMPONENTS





Base Spreading Resistance





T_{max} reduced from 118.8 ˚C to 86.5˚C

2-Phase Thermal Solutions - Overview

Specification

- Normally manufactured from copper, but aluminium, stainless steel and other material can be used
- Used when power densities are typically <25 w/cm^2
- In plane thermal conductivity > 20,000W/mK
- Varying diameters from 3mm up to 30mm
- Operating and storage temperature range of -0°C to +300°C
- Boyd are the only company to manufacture heat pipes qualified for space

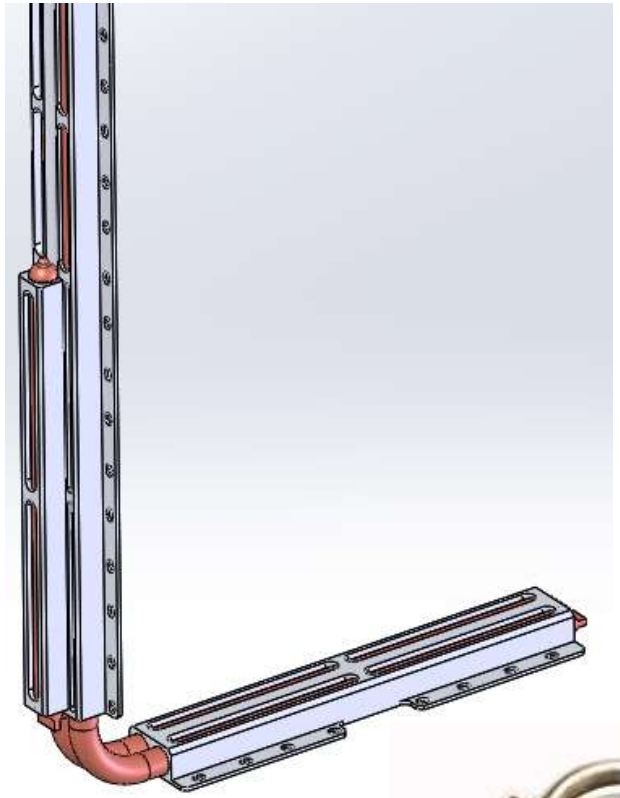
Features & Benefits

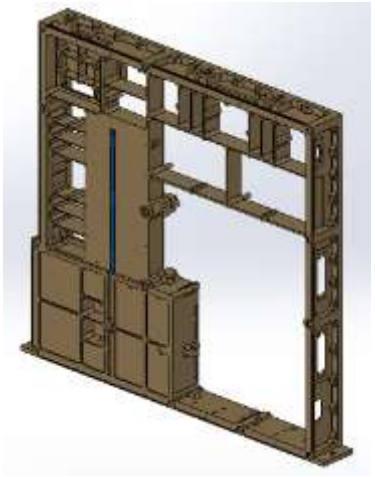
- A very flexible technology for integration in many applications
- Can be incorporated in a product as a drop-in replacement for equivalent all aluminium or copper heat spreaders
- A relatively low-cost technology
- Can be integrated into fin structures and solid heat spreaders
- High thermal conductivity
- Can be affected by gravitational forces

Pricing

- Heat pipes pricing alone dependent upon diameter and length
- Pricing for integration into heat sinks and heat spreaders is dependent upon geometry and complexity

Heatpipe Applications





- **Two Phase Cooling Solutions**

- Communication Satellites
- Solid State Power Amplifiers (SSPA)
- Single piece thermal design for evaporator and condenser
- Multiple Source Collection
- Operating Temperature: -20°C to +110°C
- Embedded Heat-Pipes

- **Technology**

  - Embedded Heatpipes Assemblies

Heatpipe Applications

- **Two Phase Cooling Solutions**

- Naval Radar
- Video Distribution Server
- Telecom Base Station
- Blade Server
- High Power Electronics

- **Technology**

  - Embedded Heatpipes Assemblies

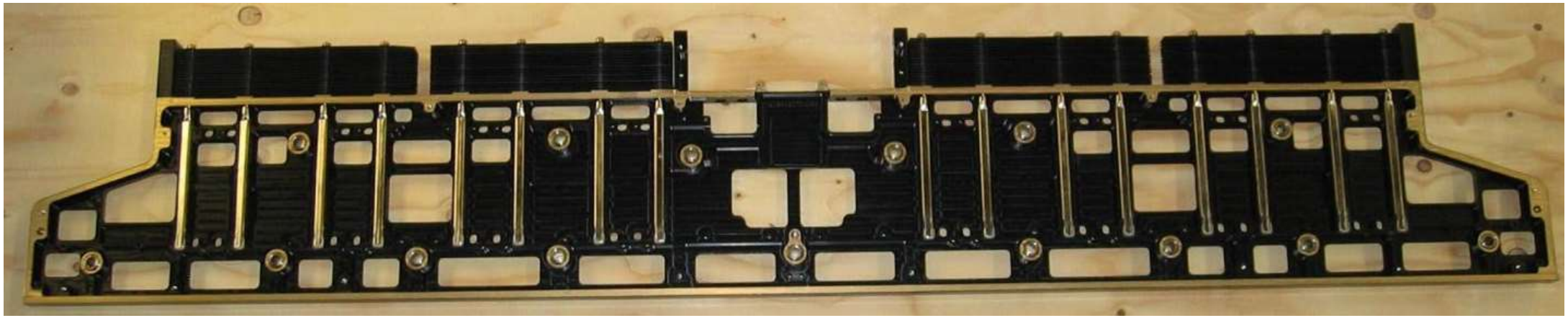
Aerospace Applications

- **Two Phase Air-Cooled Cooling Solutions**

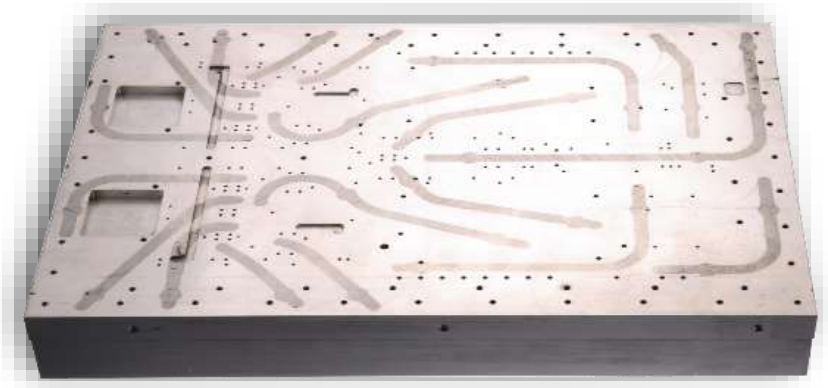
- Airbourne Radar
- ATR Chassis

- **Technology**

  - Embedded Heatpipes Assemblies



Special High Performance Heat Sinks



- **Two Phase Cooling Solutions**

- Telecommunications
- Radar Assemblies
- Traction
- Data Centres

- **Technology**

  - Embedded Heatpipe Assemblies

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