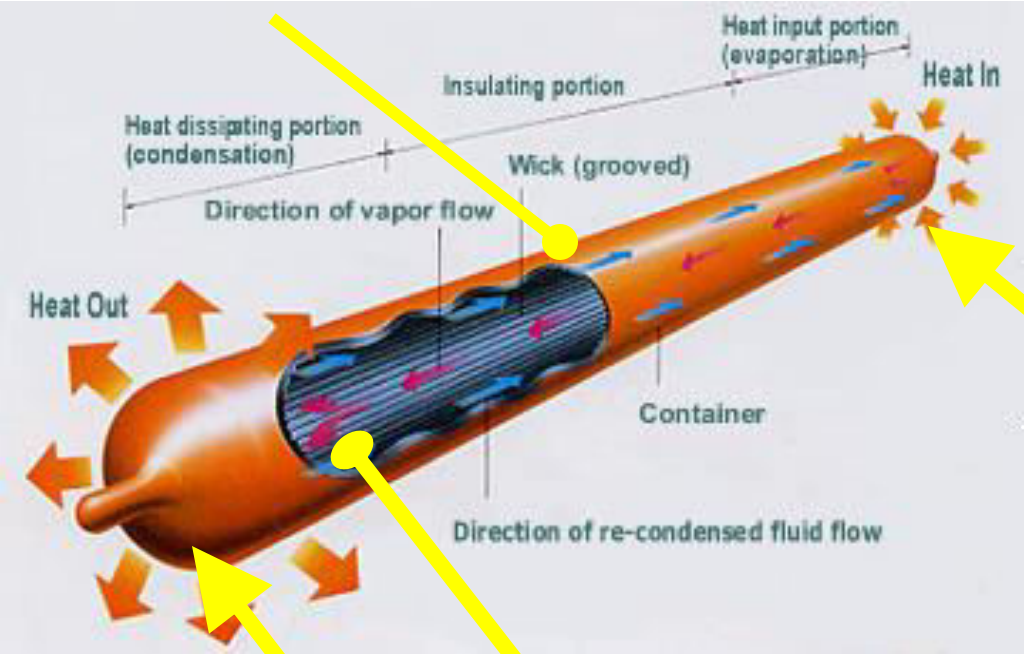
Fundamentals of Heat Pipes

Energy Conservation & Waste Heat Recovery

IIT Kharagpur – NPTEL 2017

Basic Components of Heat Pipe

Adiabatic section



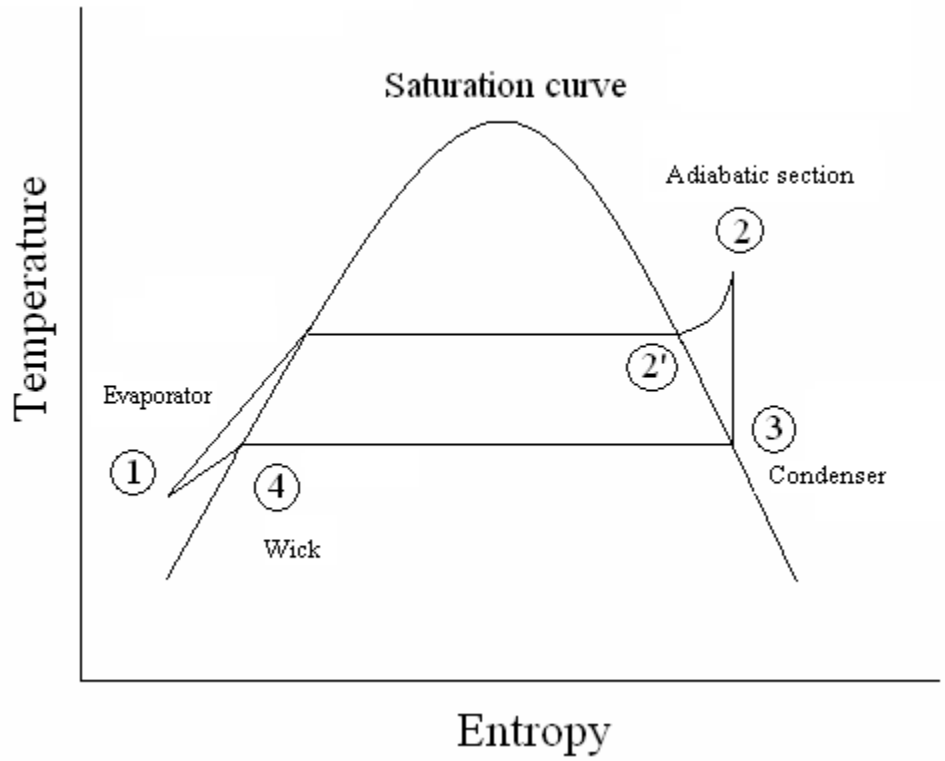
evaporator

wick

condenser

http://www.lightstreamphotonics.com/images/tech_orangecontainer_small.png

Ideal Thermodynamic Cycle

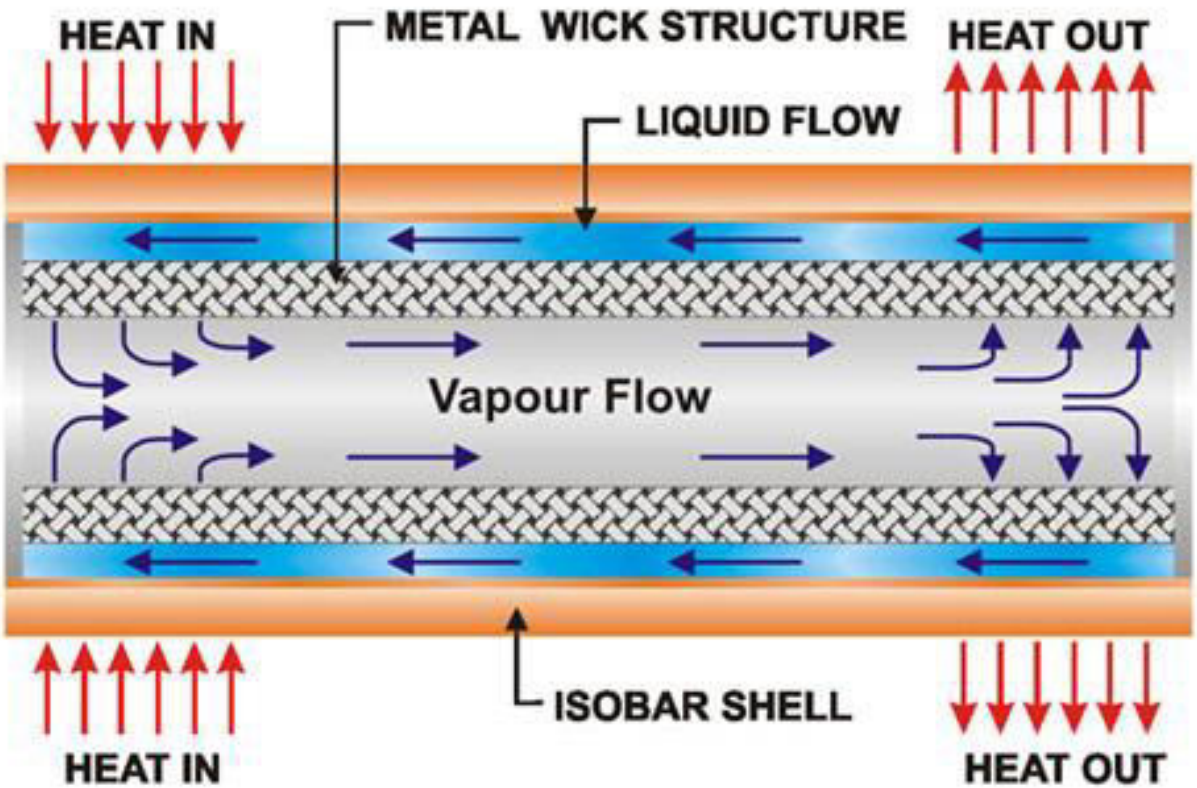


(Faghiri, 1995)

- 1-2 Heat applied to evaporator through external sources vaporizes working fluid to a saturated(2') or superheated (2) vapor.
- 2-3 Vapor pressure drives vapor through adiabatic section to condenser.
- 3-4 Vapor condenses, releasing heat to a heat sink.
- 4-1 Capillary pressure created by menisci in wick pumps condensed fluid into evaporator section.

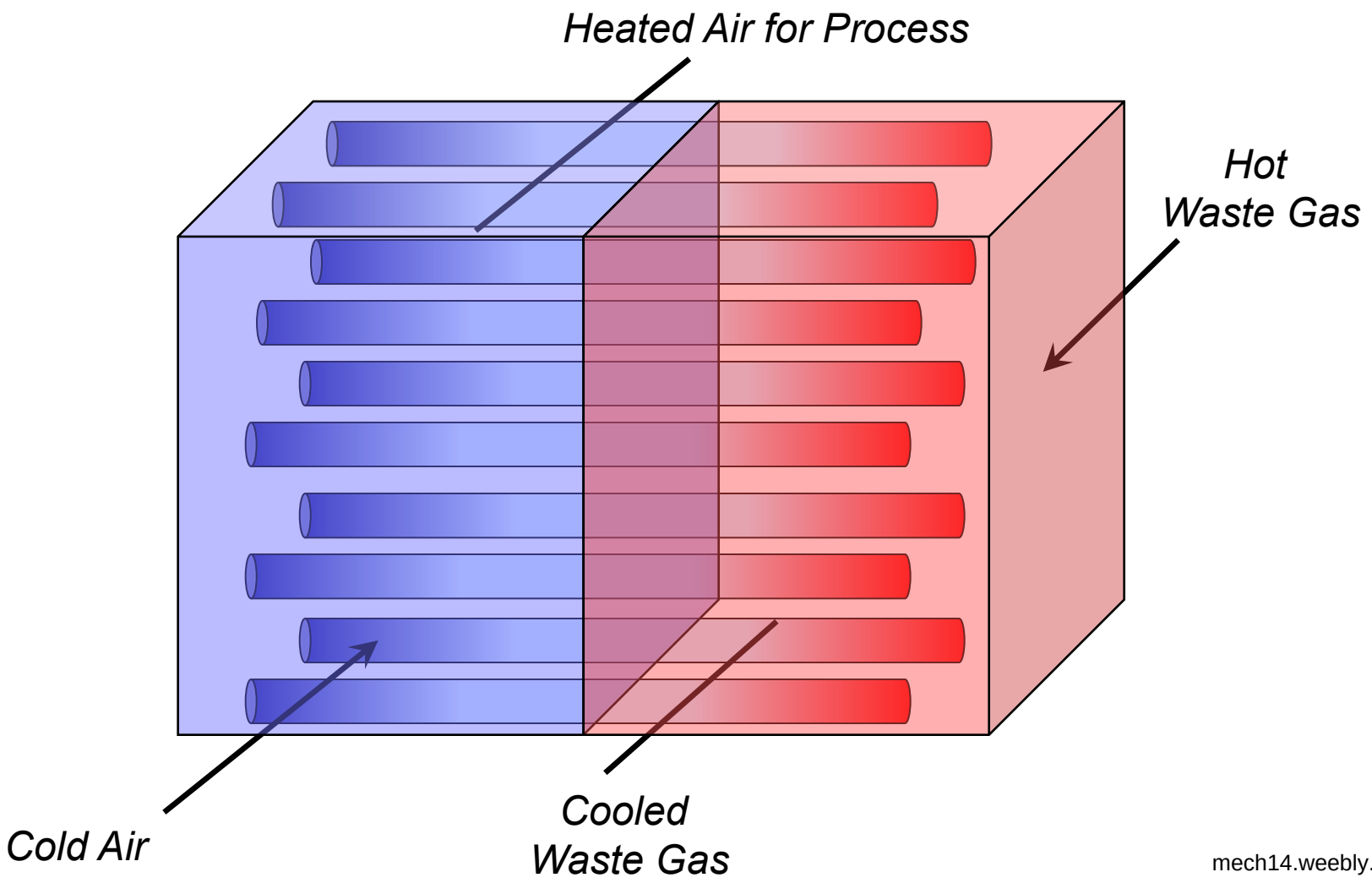
Advantages of Heat Pipes

- Very high thermal conductivity
  - *Effective axial k ~10,000 W/m-K*
  - *https://www.youtube.com/watch?v=2vk5B6Gga10*
- Light, Reliable and cheap
- Means of transporting heat from Point A (inconvenient location) to Point B (convenient" location) with minimum thermal resistance

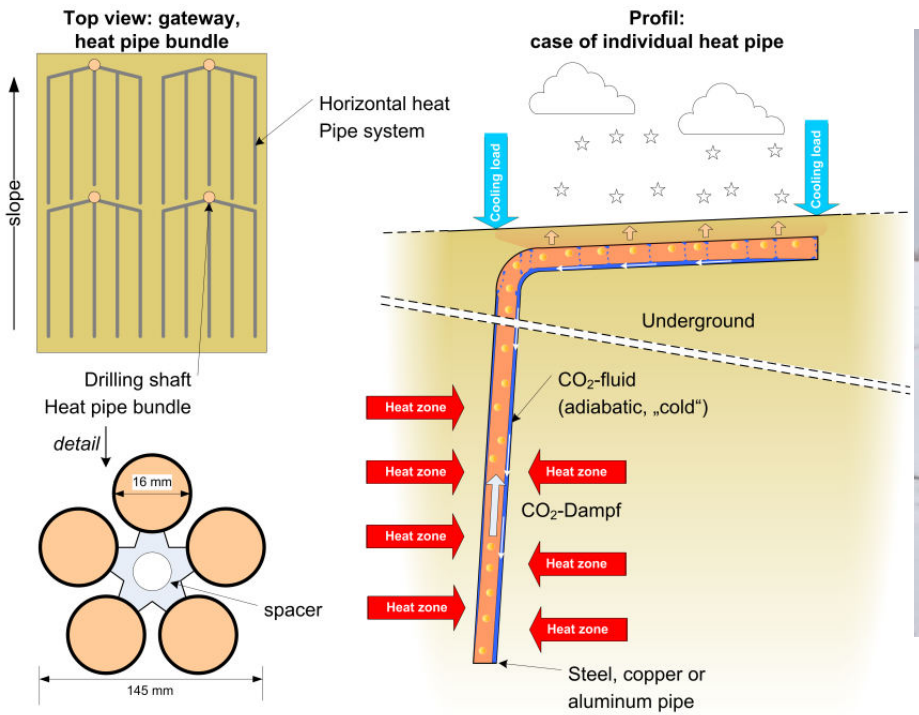


http://www.acrolab.com/products/isobars-heat-pipes.php

Application – Gas to Gas Heat Recovery



Application: De-icing



Zorn R, Steger H, and Kölbel T., 2015, "**De-Icing and Snow Melting System with Innovative Heat Pipe Technology**", *Proceedings World Geothermal Congress 2015*

Heat Pipe - applications

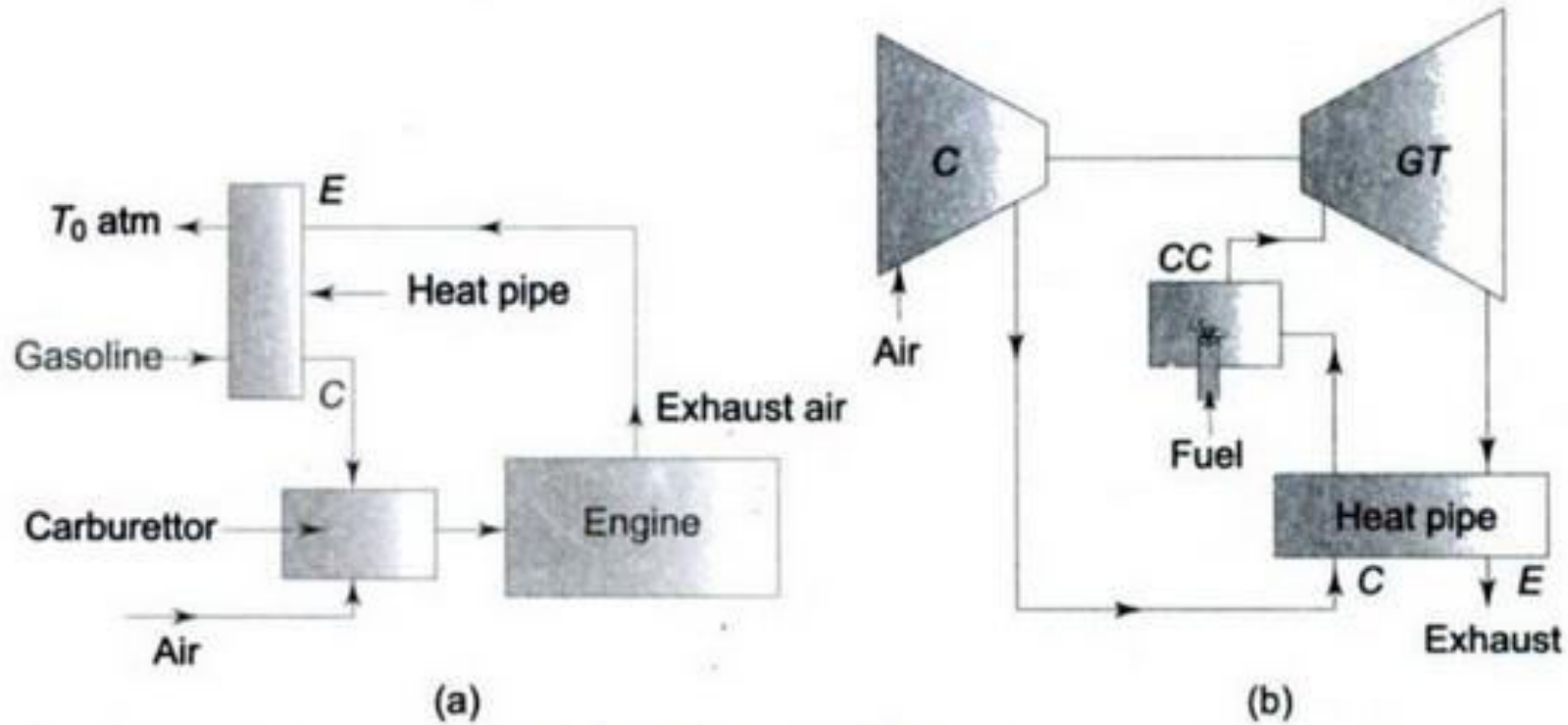
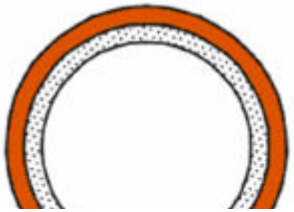
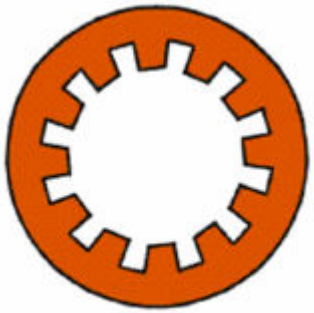


Fig. 8.45 Applications of heat pipe in (a) I.C. engine and (b) gas turbine plant

P K. Nag – Heat and Mass Transfer

Wick Structures

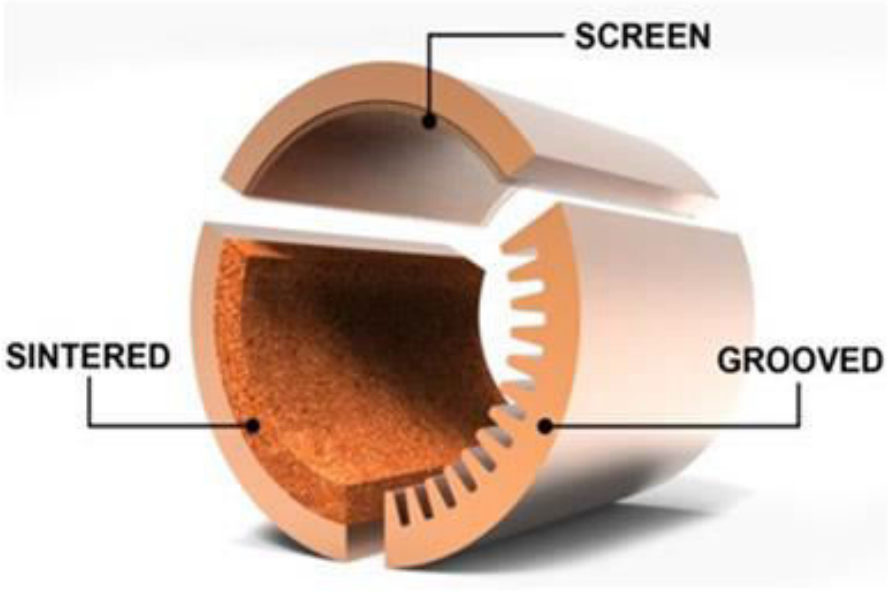




A

C. Axial Grooves

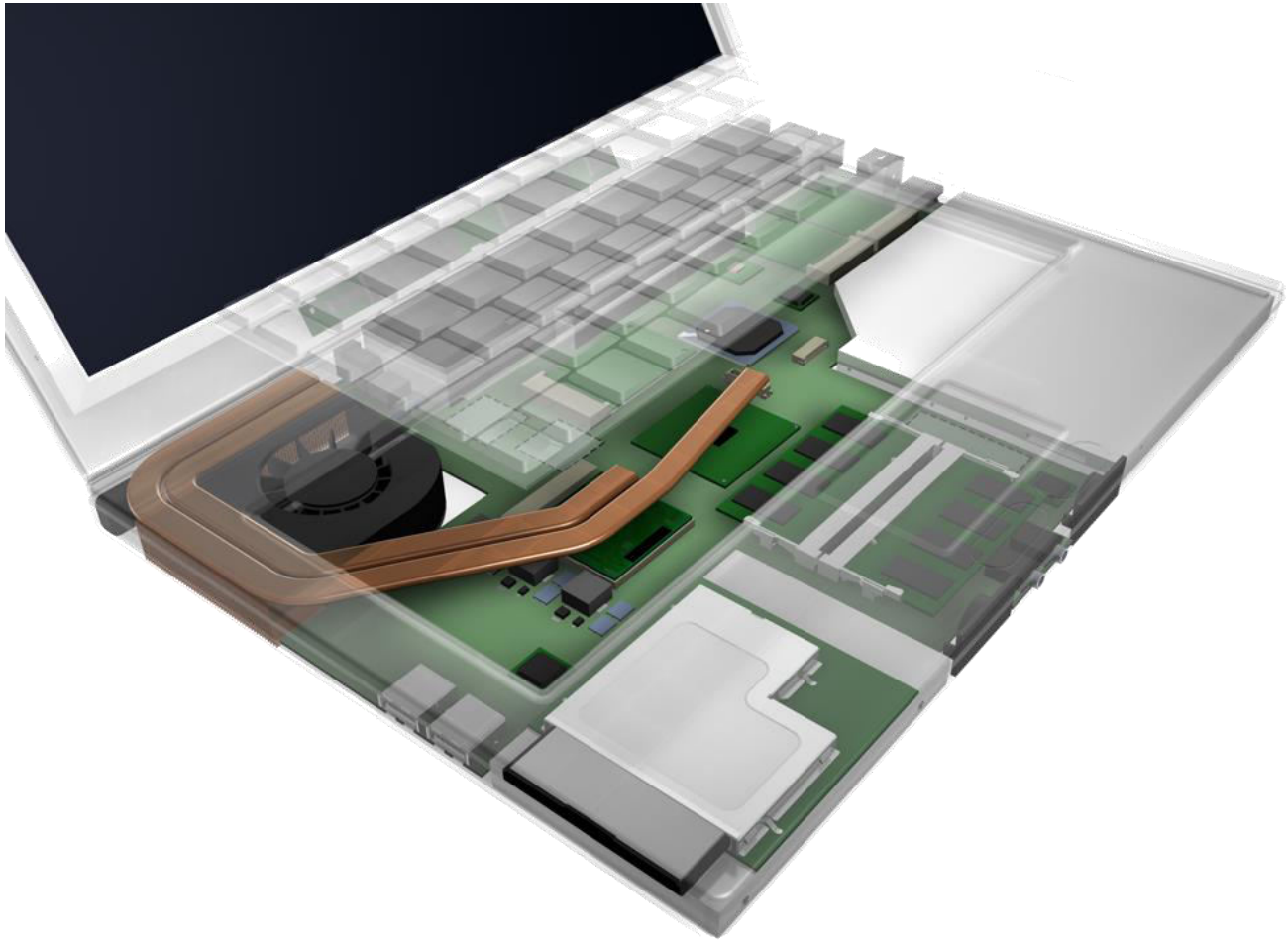
dia/index.php/Capillary_Wick_Designs_and_Structures_in_Heat_Pipes



http://celsiainc.com/heat-pipe/

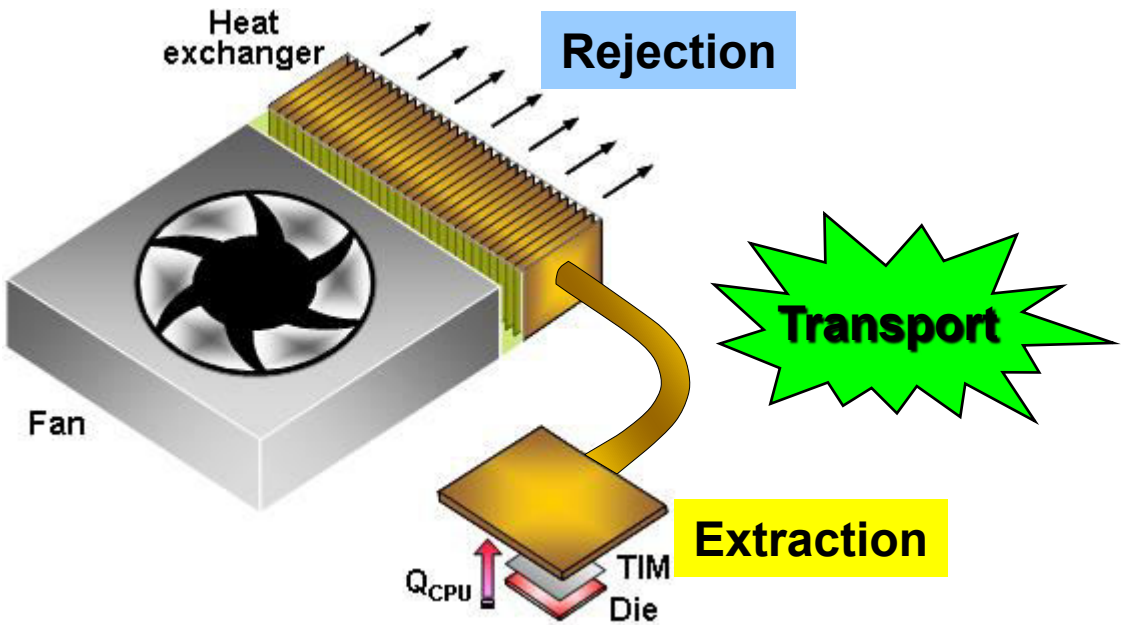
mech14.weebly.com

Laptop Thermal Design



Bhattacharya et al. (2009)

CPU Solution in Laptops – Heat Pipe



mech14.weebly.com
Mongia, Bhattacharya and Pokharna (2008)

Main Heat Transfer Limitations

- *Capillary limit-* occurs when the capillary pressure is too low to provide enough liquid to the evaporator from the condenser. Leads to dryout in the evaporator. Dryout prevents the thermodynamic cycle from continuing and the heat pipe no longer functions properly.

- *Boiling Limit-* occurs when the radial heat flux into the heat pipe causes the liquid in the wick to boil and evaporate causing dryout.

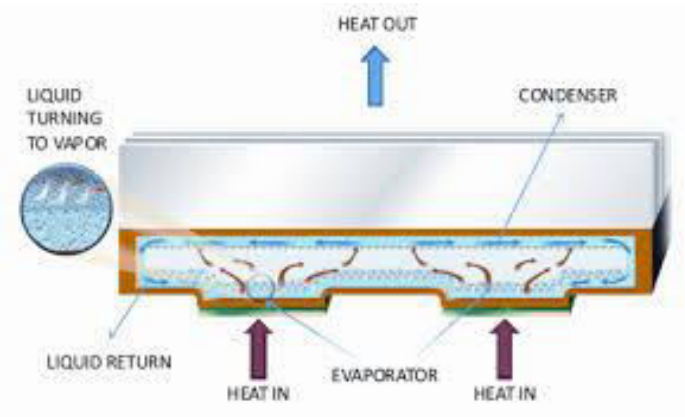
(Faghiri, 1995)

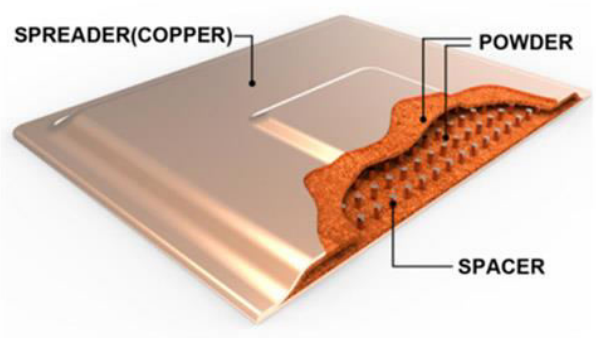
Heat Transfer Limitations

- *Entrainment Limit-* at high vapor velocities, droplets of liquid in the wick are torn from the wick and sent into the vapor. Results in dryout.

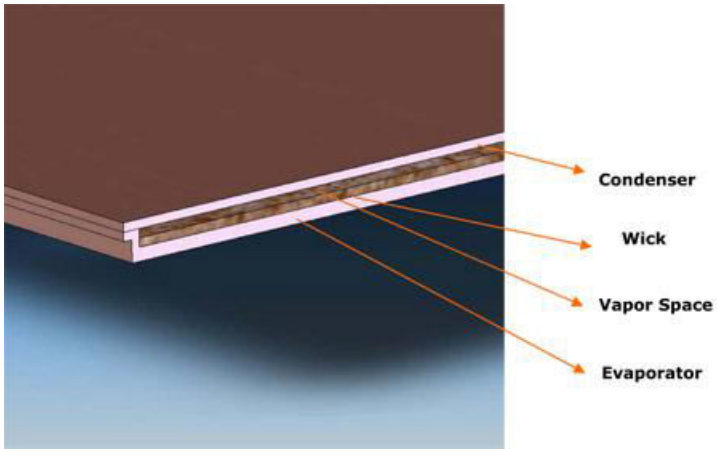
- *Sonic limit-* occurs when the vapor velocity reaches sonic speed at the evaporator and any increase in pressure difference will not speed up the flow; like choked flow in converging-diverging nozzle. Usually occurs during startup of heat pipe.

Vapor Chambers





http://celsiainc.com/



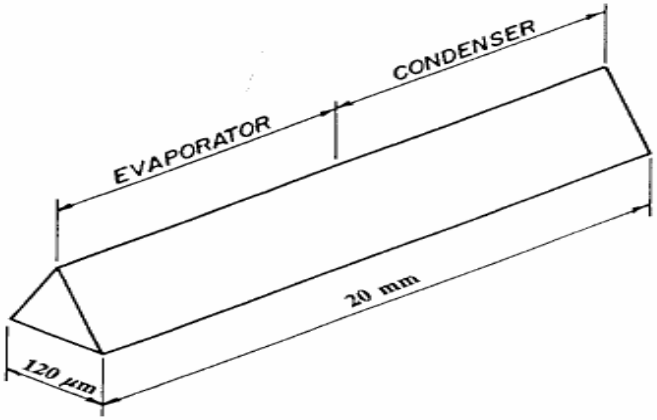
- Flattened profile (2-D)
- Same working principle

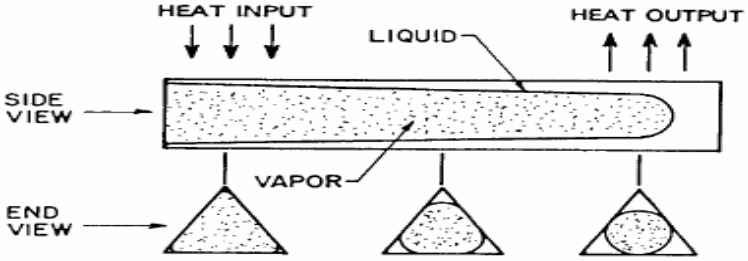
mech14.weebly.com

http://www.thermacore.com

Micro Heat Pipes

- *Micro heat pipes*- small heat pipes that are noncircular and use angled corners as liquid arteries. Characterized by the equation: $r_c / r_h \geq 1$ where r_c is the capillary radius, and r_h is the hydraulic radius of the flow channel. Employed in cooling semiconductors (improve thermal control), laser diodes, photovoltaic cells, medical devices.



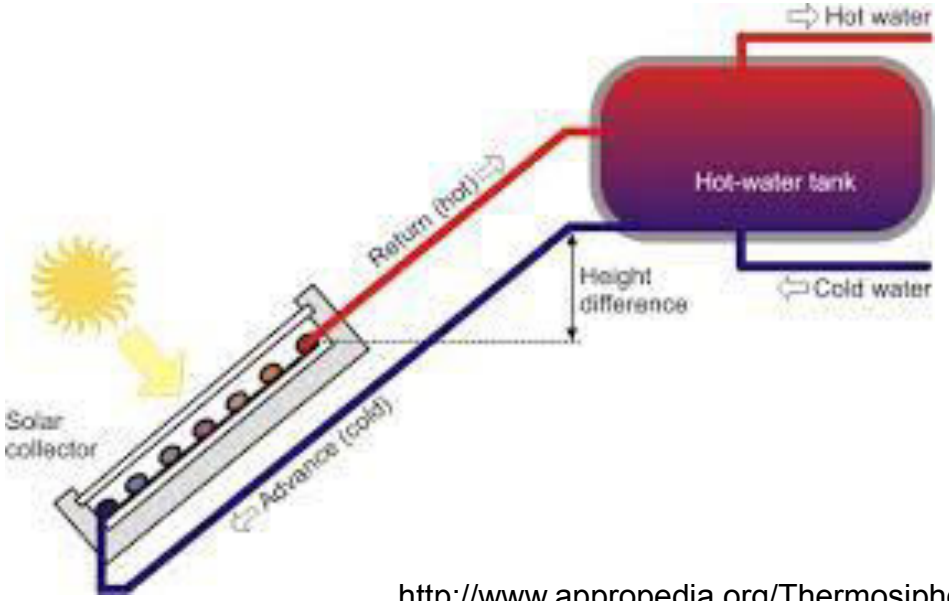


Micro–heat pipe operation.

(Peterson,1994)

Thermosiphon

- **Thermosiphon** (alt. **thermosyphon**) is a physical effect and refers to a method of passive heat exchange based on natural convection, which circulates a fluid without the necessity of a mechanical pump (*Wikipaedia*)



http://www.appropedia.org/Thermosiphon

Thank You