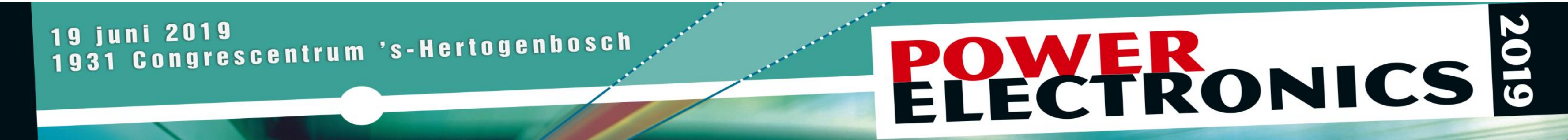
# First aid for thermal challenges with electronics

Ad Musters – Thal Technologies bv 19 June 2019



# Thal Technologies

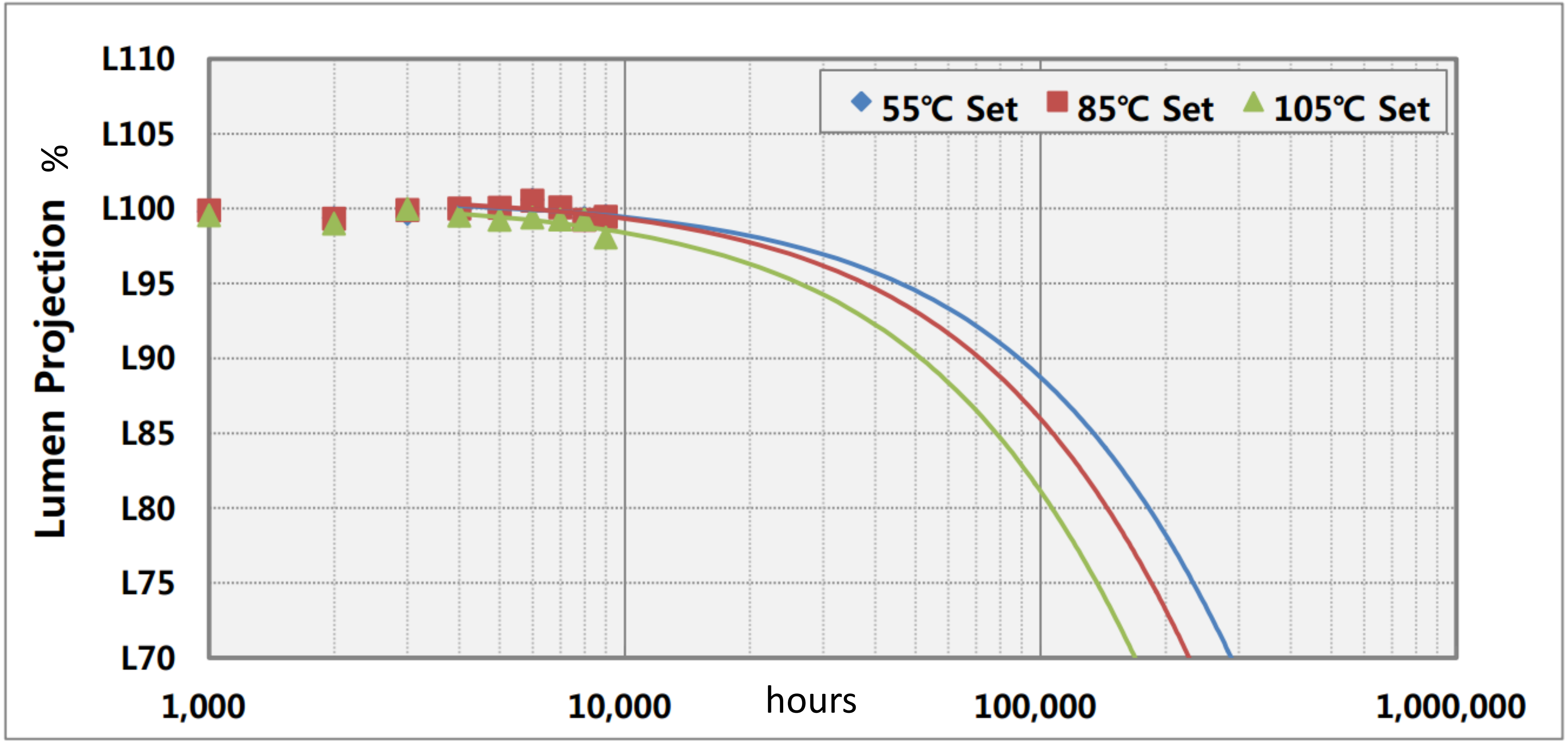
- Founded in 2003
- Office and factory in The Netherlands
- Thermal management materials and converting
- LED modules
- LED Solution provider and knowledge center

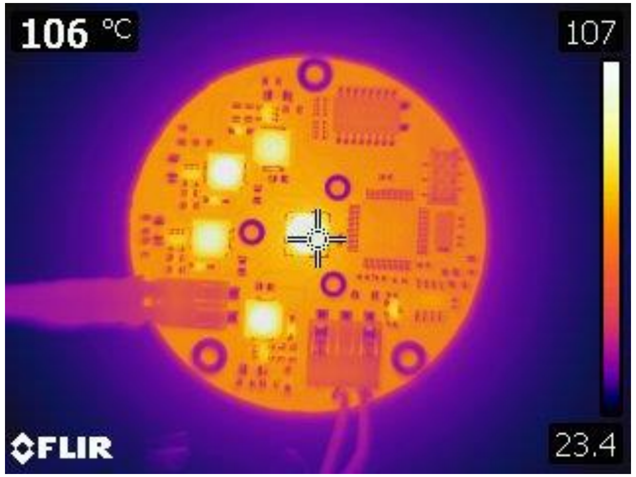
# Introduction

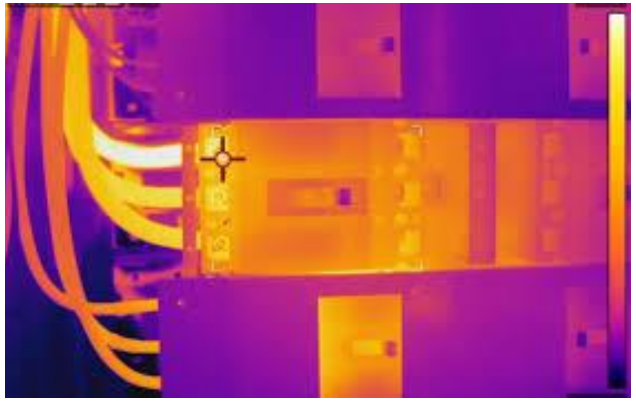
- Why thermal management?
- Thermal management theory
- PCB cooling principles
- Thermal interface materials
- Heatsink selection
- Examples

# Influence of temperature on lifetime

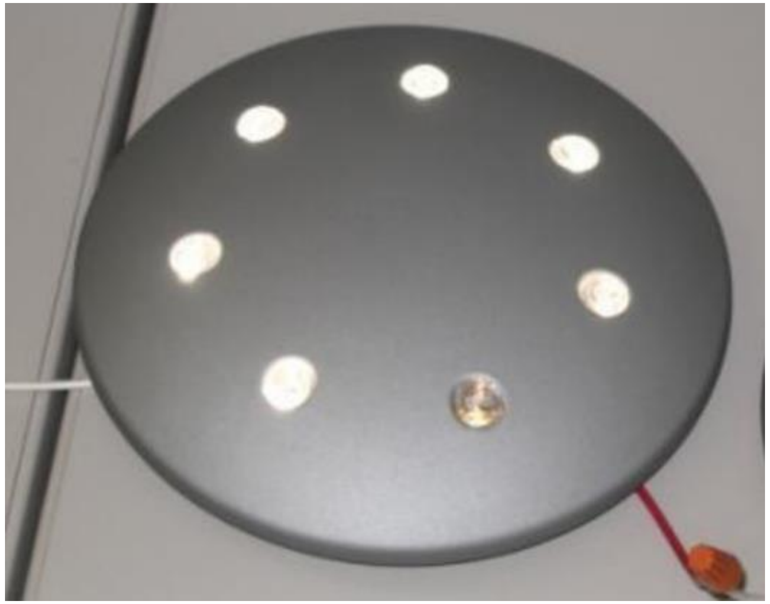
Example of led lifetime

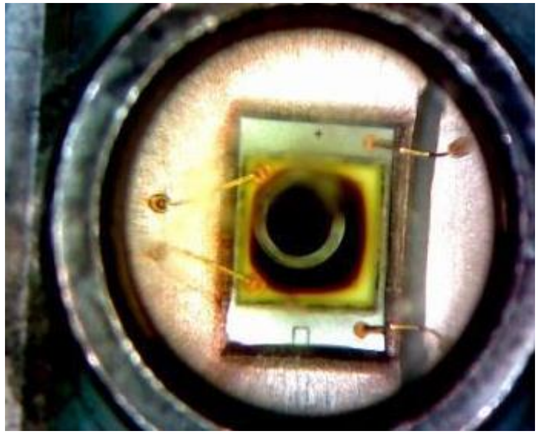


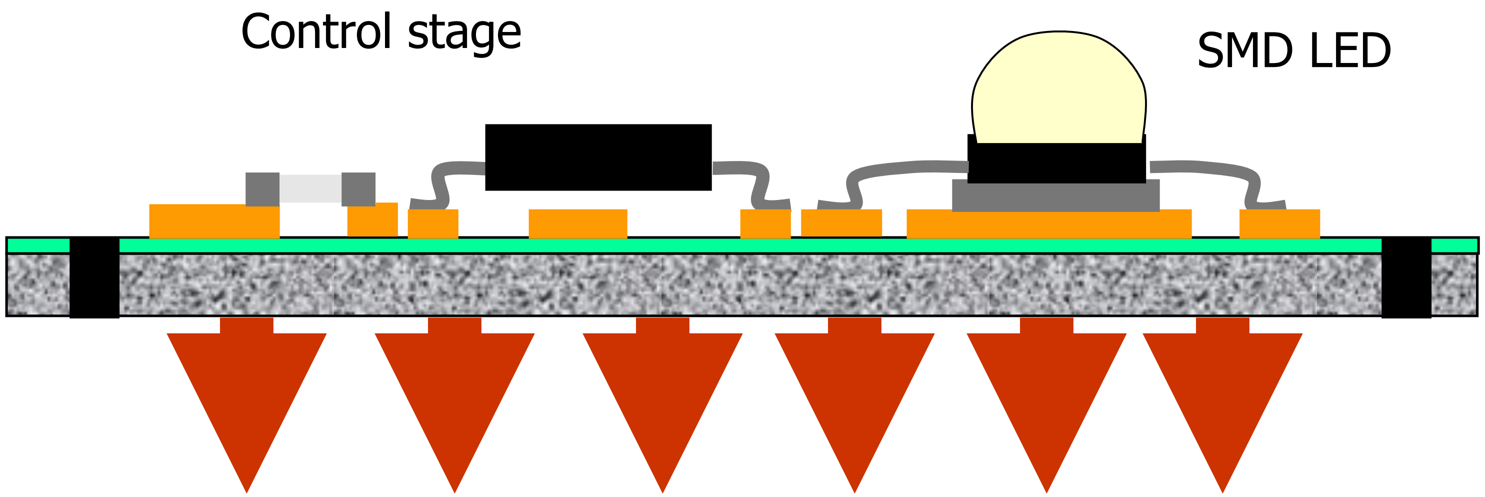



# Not all is as it seems…

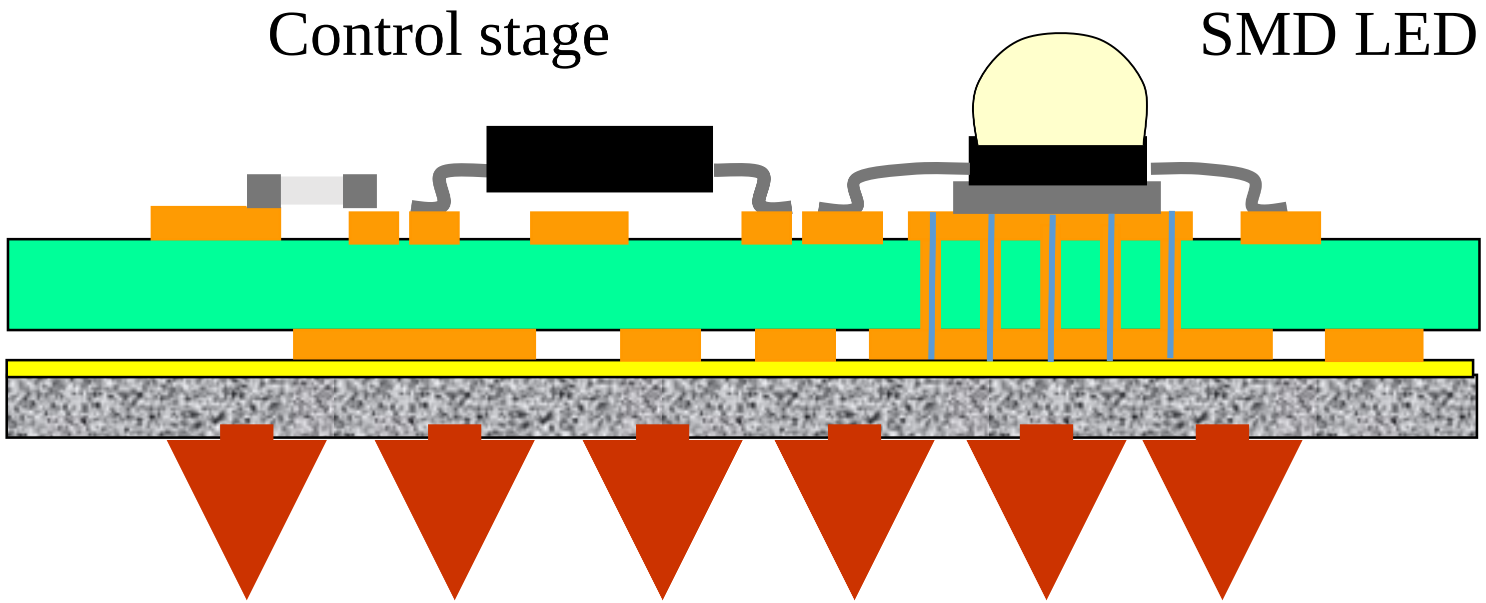




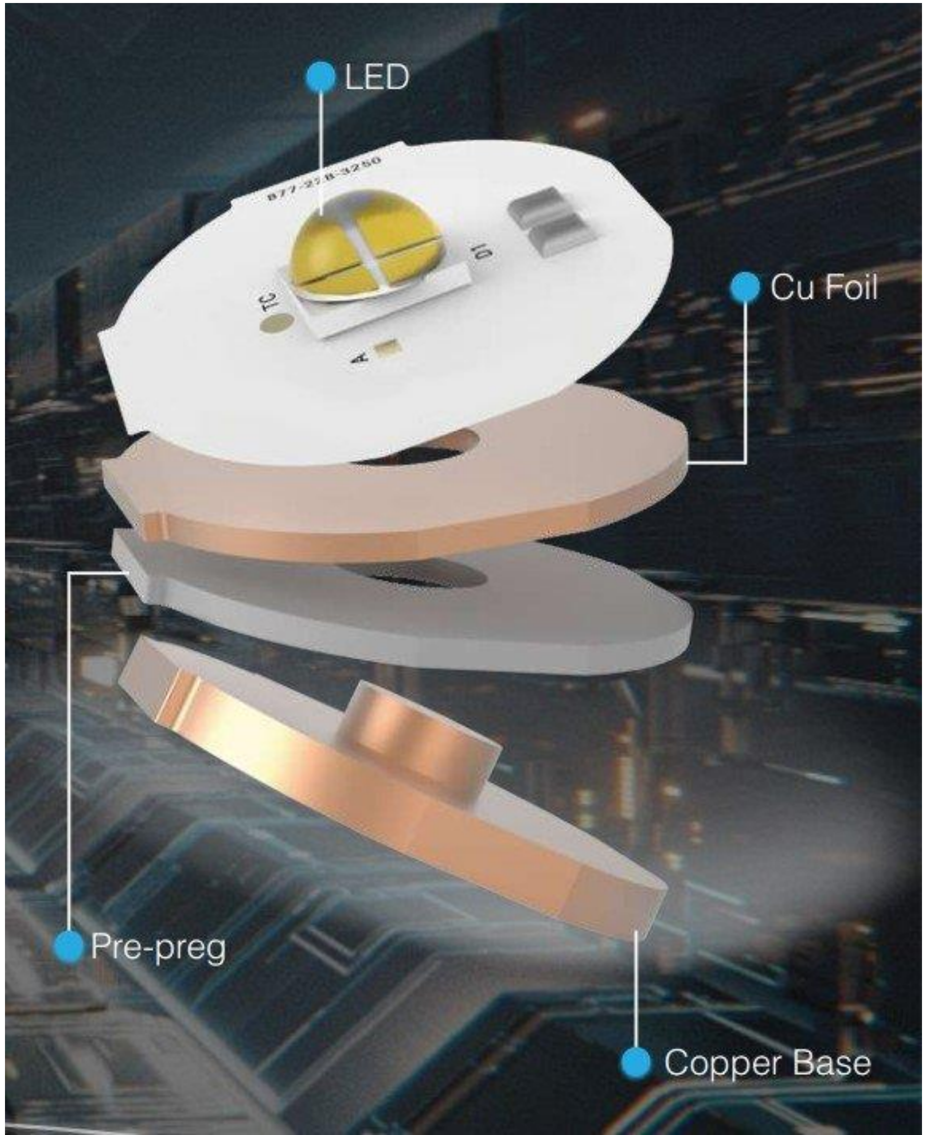
# Cooling via Aluminum base Printed Circuit Board



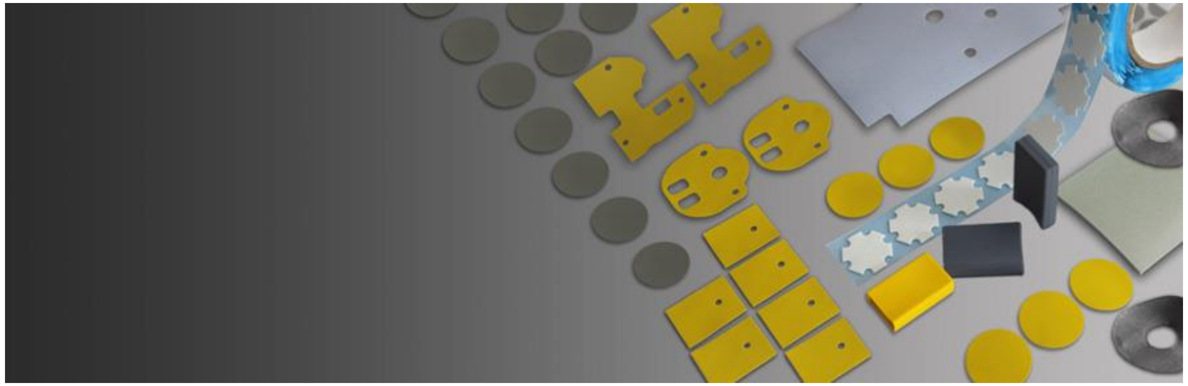
# Cooling through the PCB to a cool base plate



# Pedestal design Metal board



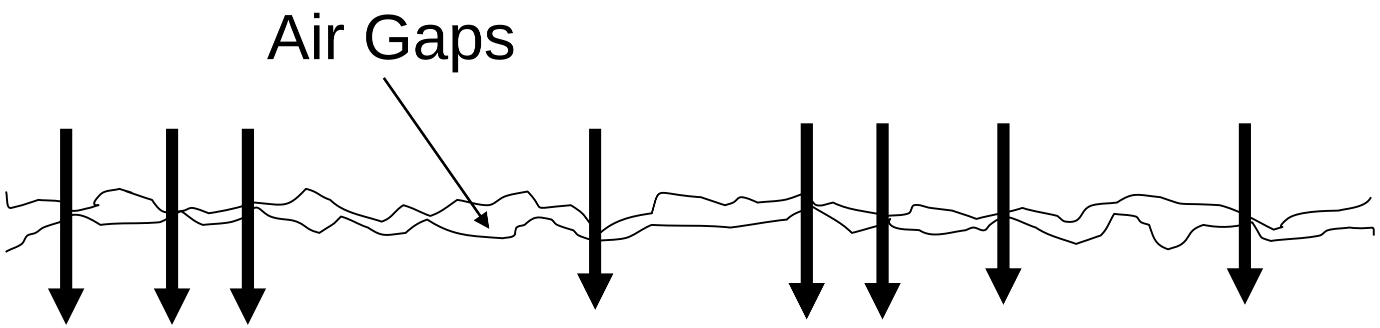
# Thermal interface material



- Purpose: Good contact between PCB and Cooling surface or heatsink.
  - COB → thermal grease or phase change
  - Metal core PCB → graphite foil, thin gap pad or tape
  - FR4 PCB → thin gap pad or tape

# Interfacial Thermal Resistance

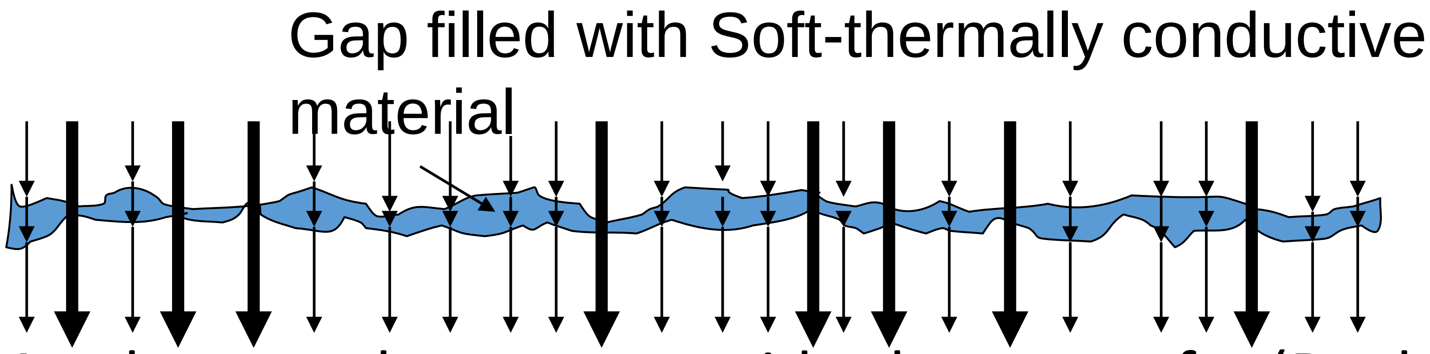
- Every surface to surface interface produces a resistance to heat transfer




- Point to point contact provides the majority of heat transfer (Air is a poor conductor of heat)

# Interfacial Thermal Resistance

- Every surface to surface interface produces a resistance to heat transfer



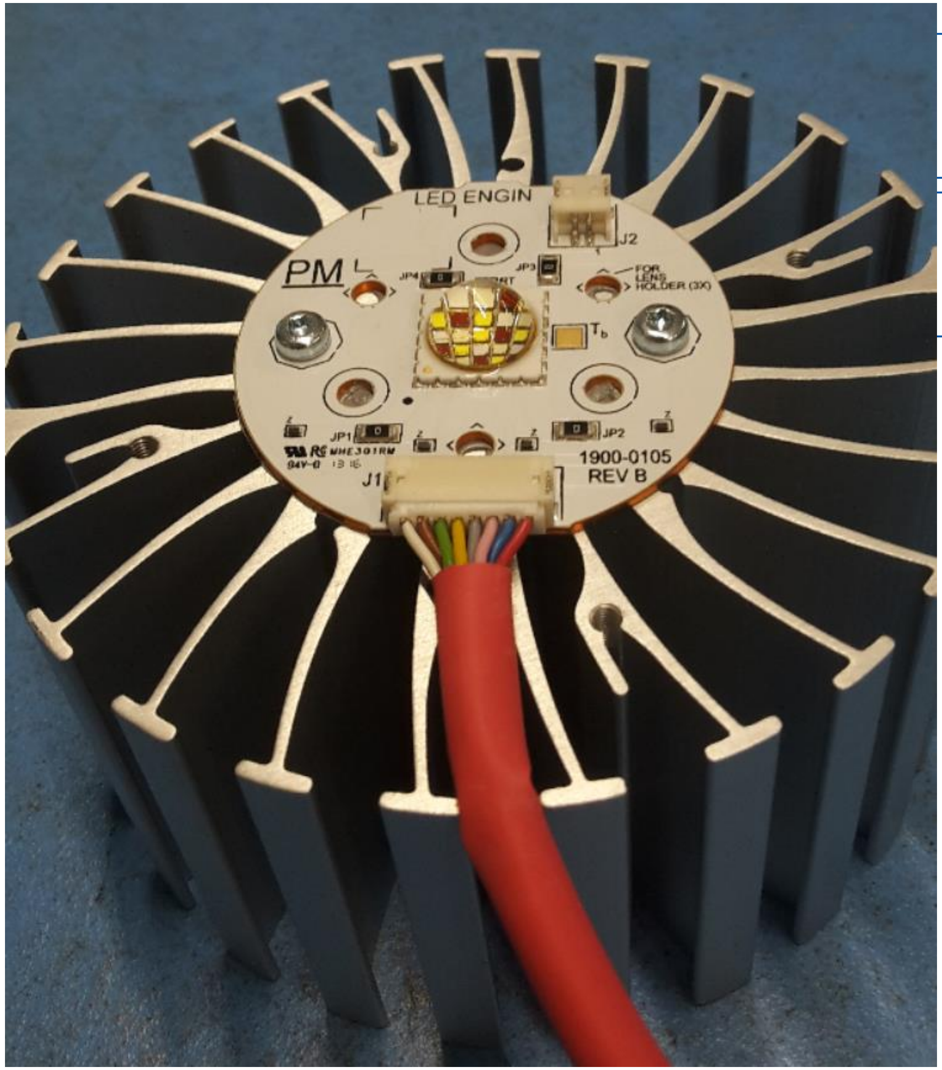

- Metal to metal contact provides heat transfer (Replace Air with a soft -thermally conductive material)

# Heatsinks

Why: Increase cooling surface

- Extrusion or sheet aluminum
- Die cast aluminum
- Active Cooling, fan or jet cooling
- Often the housing is the heatsink

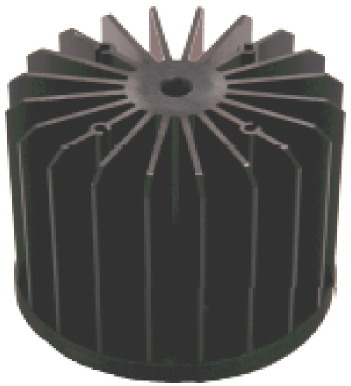
Heatsink with LZP connectorised PCB in downlighter

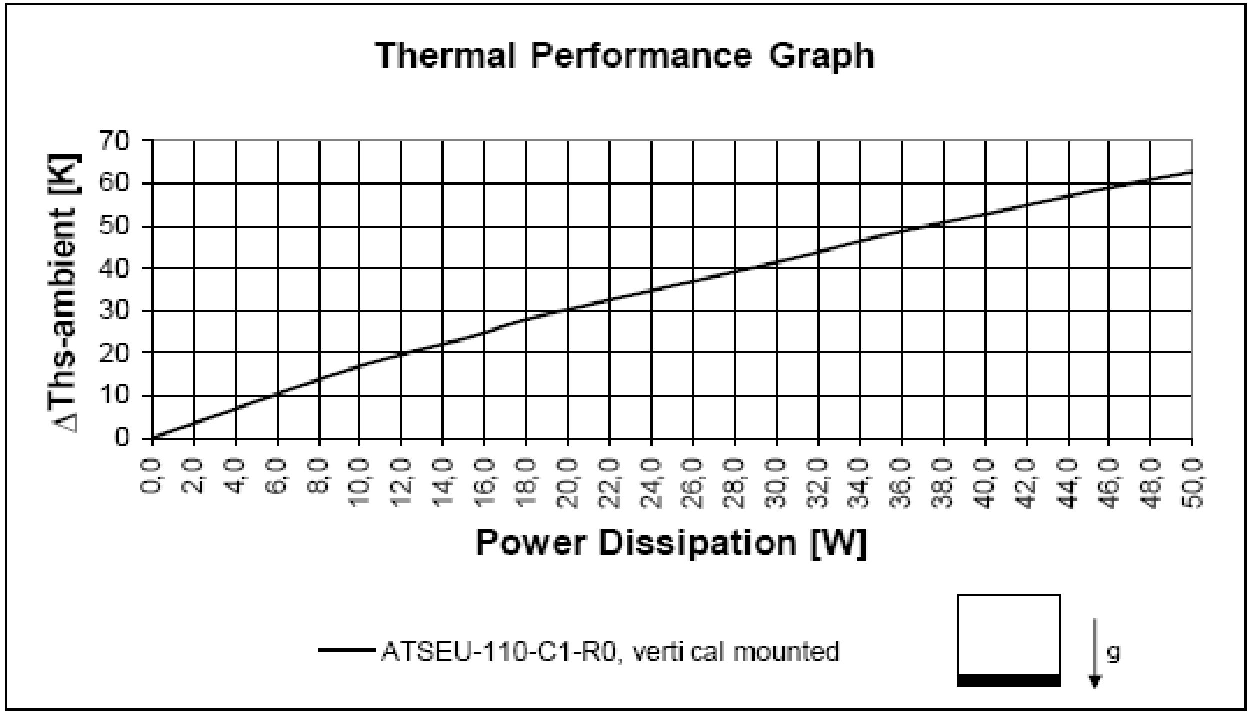


Application: LED lighting
Cooling: Natural Convection

# Heatsink datasheet for Natural convection

| Heat Sink Configuration | Dimensions [mm] |
|---|---|
| Diameter (D) | 100 |
| Length (L) | 95 |
| Base thickness (t) | 10 |
| No. of Fins | 20 |
| Weight (grams) | 700 |
| Note | Baseplate with outer thread M101x1 and mounting holes |

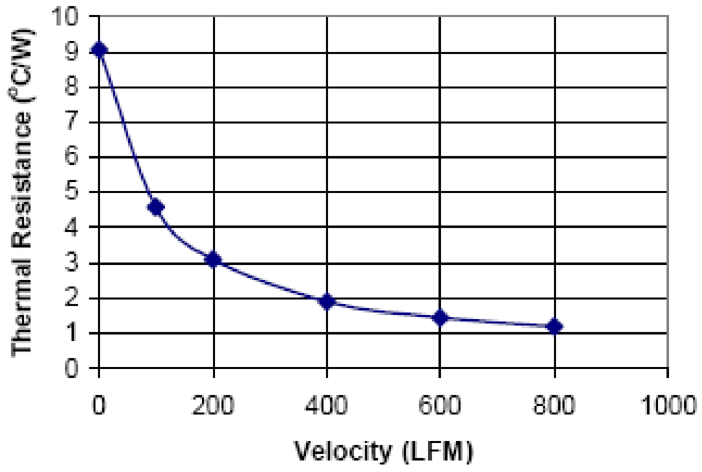


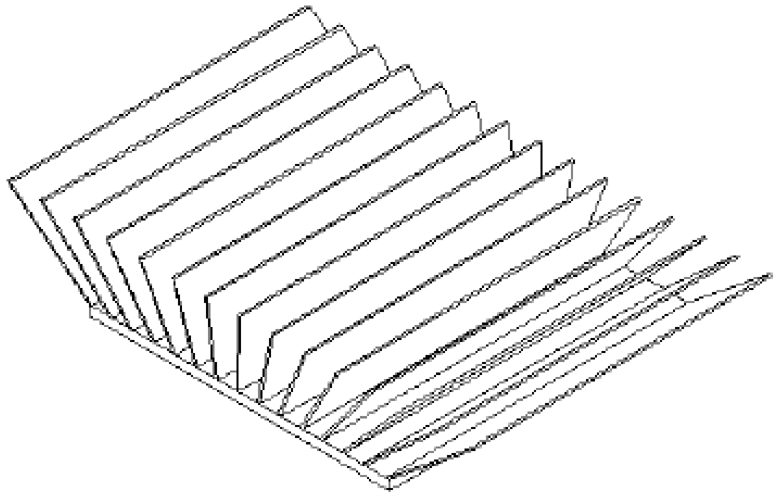


$R_{ca}$ = case-to- ambient thermal resistance (°C/W)
V = velocity (ft/min)

# Heatsink datasheet for fan cooling

| Heat Sink Configuration | Dimension (mm) |
|---|---|
| Height (H) | 10 |
| Width (W) | 40 |
| Length (L) | 40 |
| Base plate thickness (t) | 1.3 |
| Fin Thickness (l) | 0.4 |
| No. of Fins | 15 |
| Weight (grams) | 12 |



# Thermal fundamentals and calculations

## Heat transfer

Temperature rise $\Delta T_1$ from junction to air:

$Q = h_{tot} \times A \times \Delta T_1$

Q = power dissipation

h = heat transfer coefficient

A = surface area

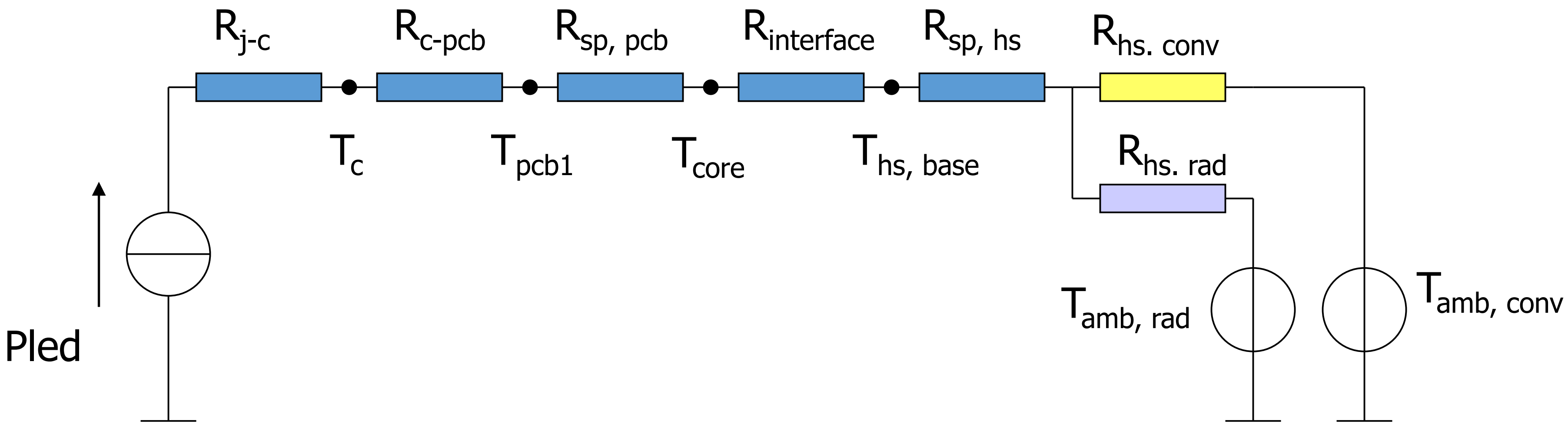
## Three modes of heat transfer:

- $h_{tot} = h_{cond} + h_{conv} + h_{rad}$
  - Conduction
  - Convection
  - Radiation

# Input parameters

- Ambient temperature
- Life time expectations
- Safe surface temperature
- Junction maximum temperature
- Plastics maximum temperature

# Electrical equivalent, simplified



# Datasheet

365nm UV LED Gen 2 Emitter

# LZ1-00UV00

## Electrical Characteristics @ $T_C$ = 25°C

Table 6:

| Parameter | Symbol | Typical | Unit |
|---|---|---|---|
| Forward Voltage (@ $I_F$ = 700mA) | $V_F$ | 3.8 | V |
| Temperature Coefficient of Forward Voltage | $\Delta V_F/\Delta T_J$ | -1.3 | mV/°C |
| Thermal Resistance (Junction to Case) | $R\Theta_{J-C}$ | 4.2 | °C/W |

# Conductive heat transfer

- Conductive path from source to the next layer

$$\frac{q}{A} = -k\frac{dT}{dx}$$

q = Power dissipation [W]

A = Area over which the power is coupled [$m^2$]

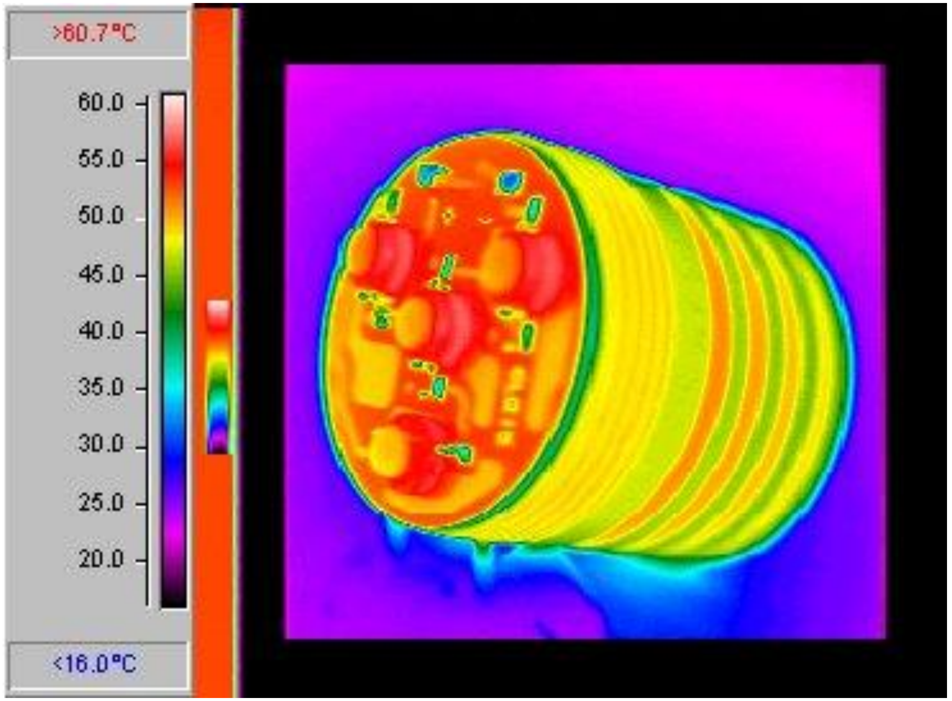
k = Thermal conductivity [W/mK]

dx = thickness of the layer or length of the thermal path. [m]

dT = Temperature difference over the total thermal path [K]

# Thermal conductivity

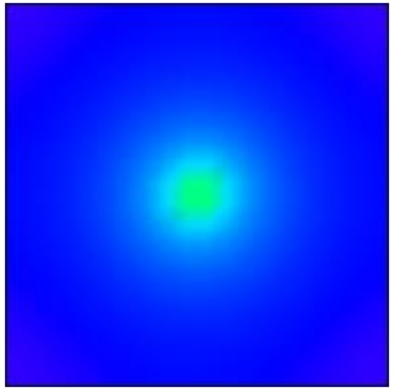
- Ideally the whole system should have the same temperature. This can be reached with the use of highly thermal conductive (k) materials and minimizing the interfacial resistance.



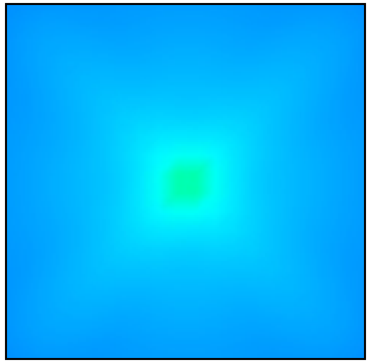
# Material Thermal conductivity

| | |
|---|---|
| Copper | 90..400 W/mK |
| Gold | 290 W/mK |
| Aluminium | 50 .. 235 W/mK |
| Steel (low carbon) | 66 W/mK |
| Boron Nitride | 39 W/mK |
| Solder | 20..50 W/mK |
| Stainless Steel | 20 W/mK |
| Alumina | 27 W/mK |
| Mica | 0.7 W/mK |
| Water | 0.5 W/mK |
| Heat sink compound | 0.5 .. 4 W/mK |
| FR4 | 0.3 W/mK |
| Epoxy | 0.2 .. 0.3 W/mK |
| Mylar | 0.2 W/mK |
| Air | 0.027 W/mK |

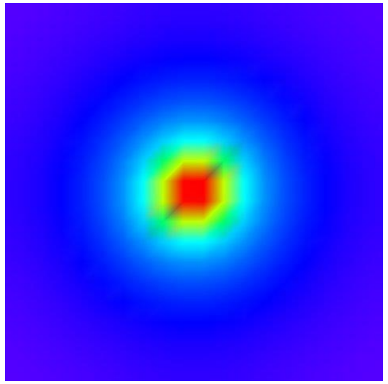
# Simulation example spreading resistance



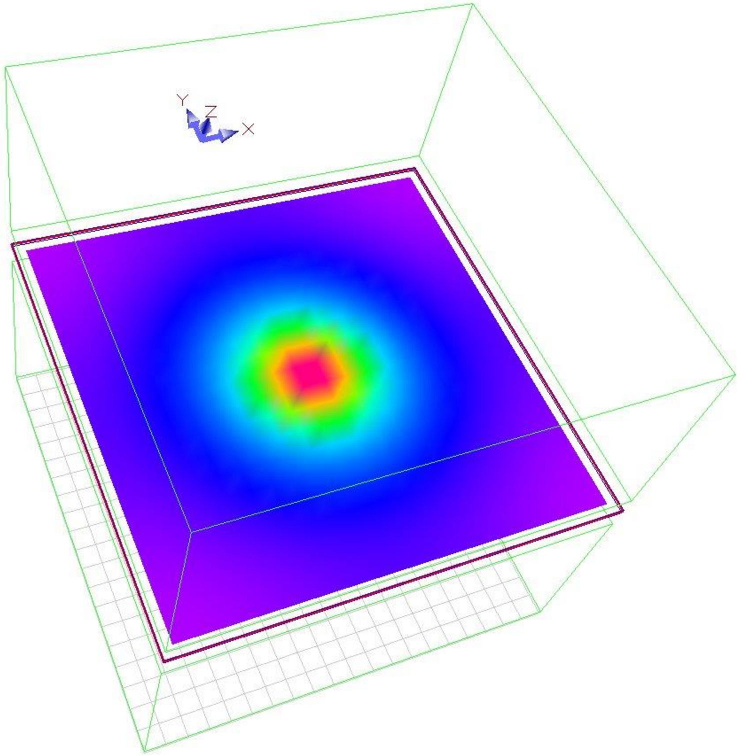
k = 50 W/mK



k = 400 W/mK



k = 5 W/mK



# Convective heat transfer

## Assembly is in Still Air

- Use the following equation for rule of thumb

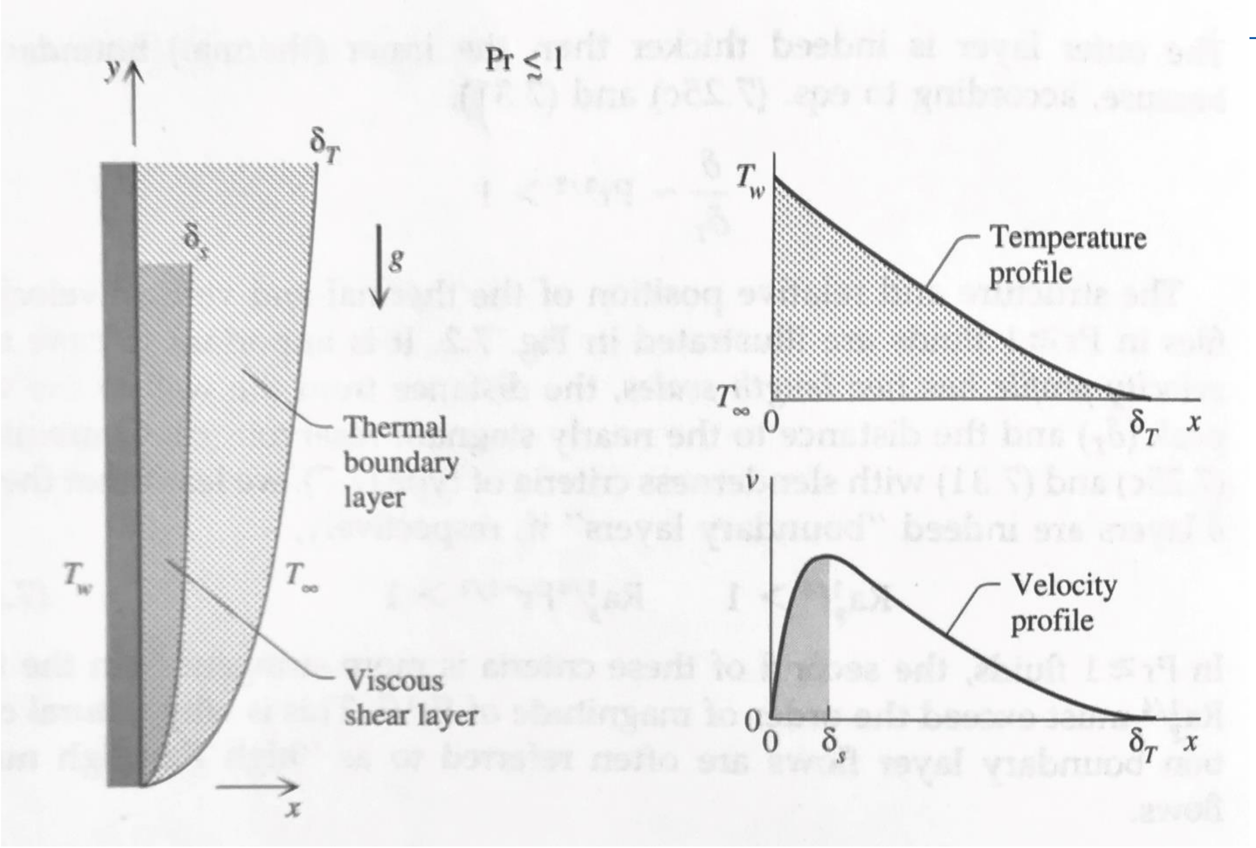
$$q = h\,A\,\Delta T$$

$$h = a\left(\frac{\Delta T}{L}\right)^{1/4}$$

q = dissipated power (W)
A = Area ($m^2$)
T = (Temperature plate – Temperature ambient) (K)
L = plate length (m)
h = convective heat transfer coefficient ($W/m^2K$)
a = coefficient 1.32 for top of plate, 0.59 for bottom, dependent on shape and orientation

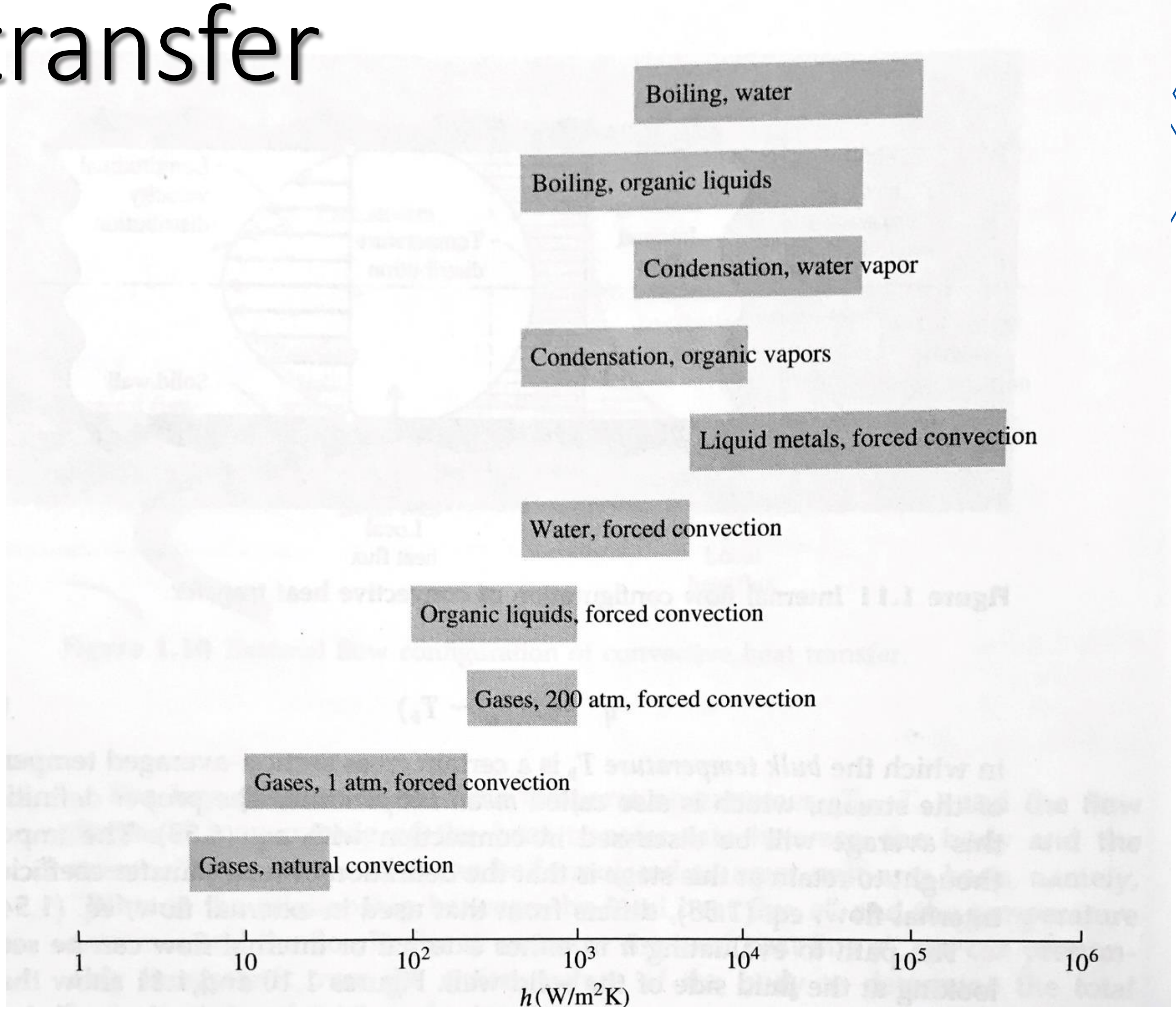
Still air (or natural convection) still requires air flow (e.g. holes in cover), otherwise air is just a good insulator

# Buoyancy Heat transfer with air on vertical wall




Source: Heat Transfer, Adrian Bejan

# Heat transfer




Source: Heat Transfer, Adrian Bejan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# Radiation

- Radiation can remove heat from the heatsink but also pick up e.g. solar irradiation and cause a heat rise of the system.
- Radiation contribution is strongly dependent on the surface treatment and temperature difference.

# Radiation

$$Q_{12} = h_{rad} \times A \times \Delta T$$

$$Q_{12} = \varepsilon F_{12} A \sigma (T_1^4 - T_2^4)$$

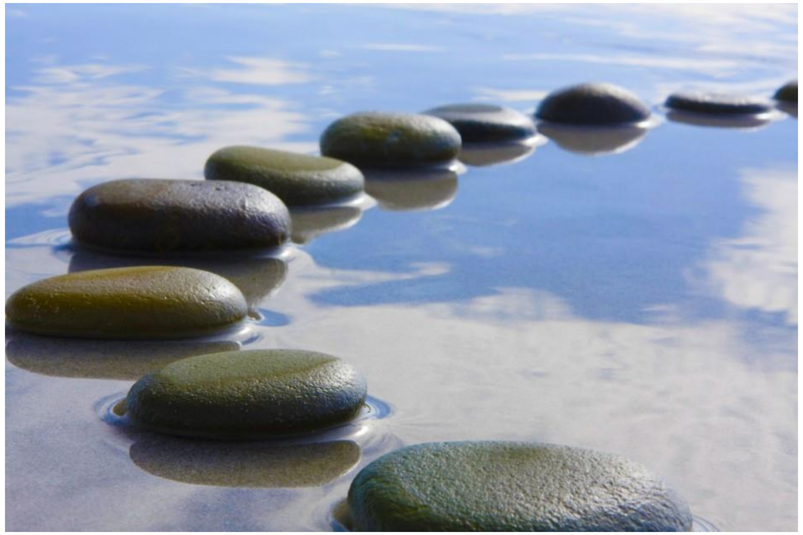
$\varepsilon$ absorption coefficient [-]
$F_{12}$ View factor [-]
A projected surface area [$m^2$]
$\sigma$ Stefan-Boltzmann constant [$W/m^2K^4$]
$T_1$ Surface temperature [K]
$T_2$ Ambient temperature [K]

# Surface emissivity coefficient ε

| | |
|---|---|
| Aluminium polished | 0.04 ~ 0.05 |
| Aluminium oxidized | 0.11 ~ 0.19 |
| Aluminium anodized | 0.6 ~ 0.8 |
| Aluminium black anodized | 0.7 ~ 0.9 |
| Copper polished | 0.04 |
| Copper rolled | 0.64 |
| Lead oxidized | 0.28 |
| Lead unoxidized | 0.05 |
| Nickel electrolytic | 0.04 |
| Chromium polished | 0.07 |
| Lacquer | 0.85 ~ 0.97 |

# Always use three steps

- Successful thermal engineering practice by:
  - Calculation (at least one-dimensional)
  - Simulate / Verify
  - Test / measure



THAL TECHNOLOGIES

# How can we help you?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Thank you!