CONNECTOR TEMPERATURE RISE AND DERATING

Goetz Schattmann Field Application Engineer

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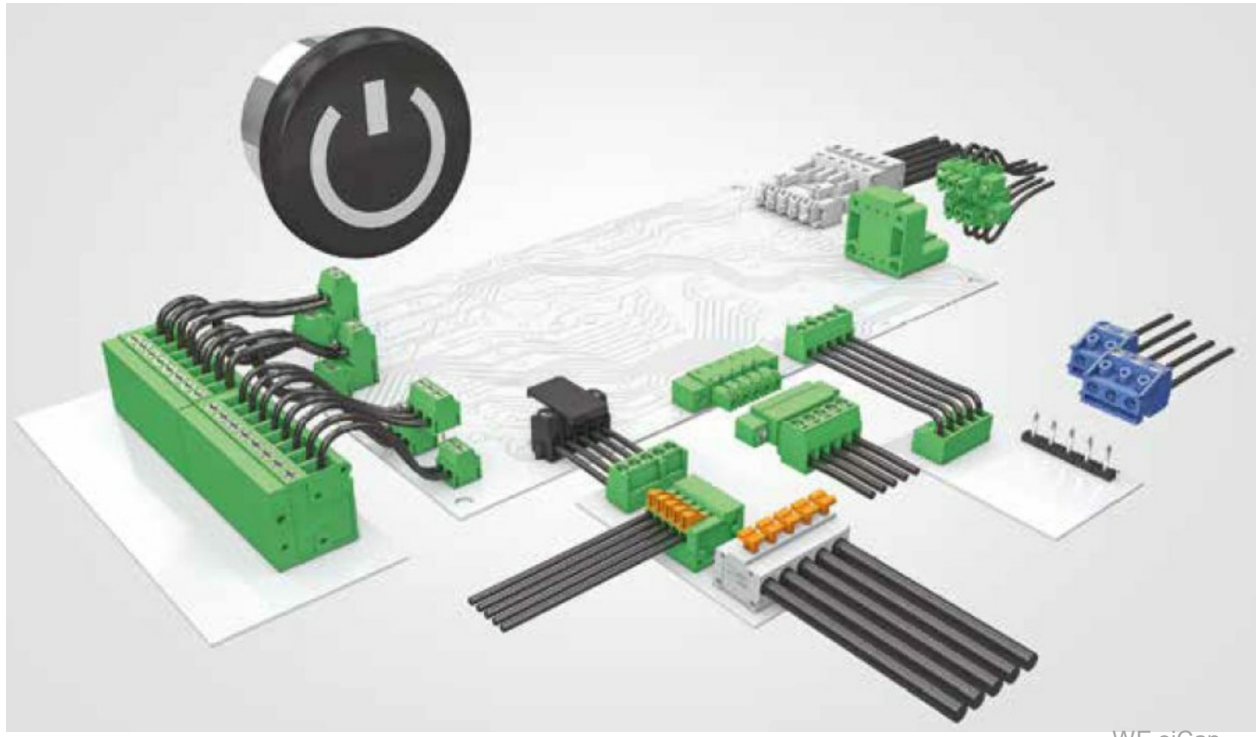
Agenda

- Current design for connectors
- Consequences of a too high temperature
- Temperature rise rule
- How heat is dissipated
- Heat in a cable
- Some tricks
- Derating curve
- Connector horror show

Basic connector use



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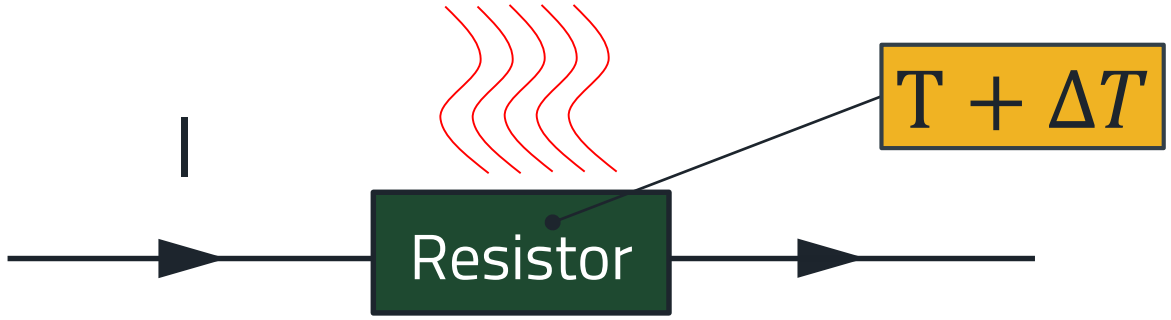
ENVIRONMENTAL

COMPLIANCE: LEAD FREE AND ROHS

ELECTRICAL	cULus
WORKING VOLTAGE:	300 VAC
WITHSTANDING VOLTAGE:	1.6 KV
CONTACT RESISTANCE:	20 mOhm max

Electricity and temperature rise



Joule's effect

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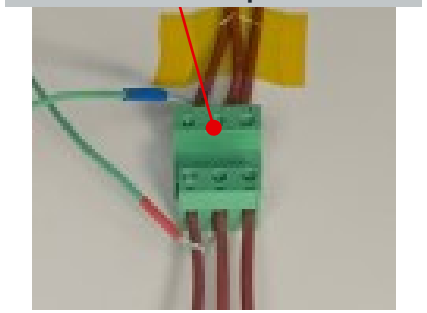
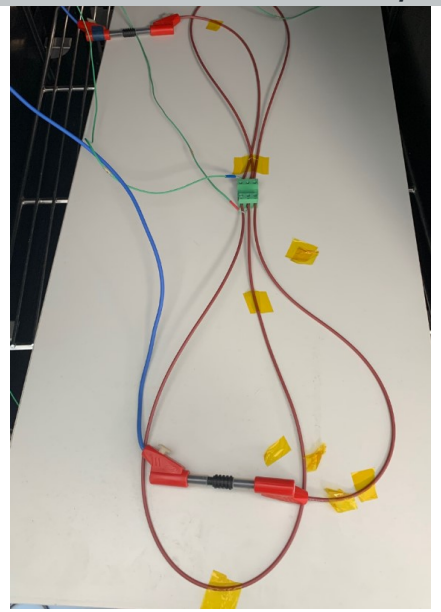
How working current is designed in WE

- **Testmethod**

Hottest point



Electrical assembly



ΔT < 30K at the hottest point

Ambient = 21,7 °C

→ ΔT=24,8K

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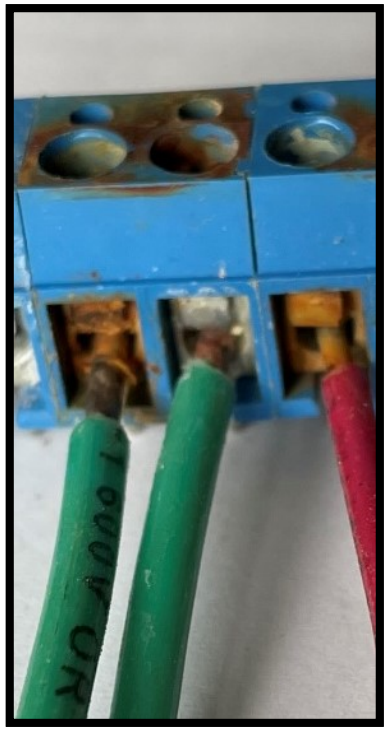
Temperature increase and connectors

Consequences of high temperature:

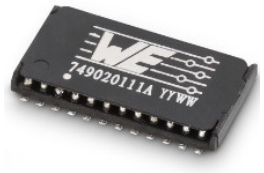
- Naturally increase contact resistance
- Increase corrosion speed and consequently increase contact resistance
  > Corrosion speed ~ doubles each 10°C
- Degradate solder joint
- Accelerate plastic aging
- Metal relaxation

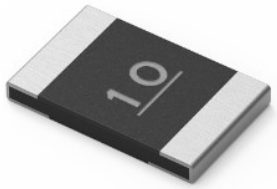


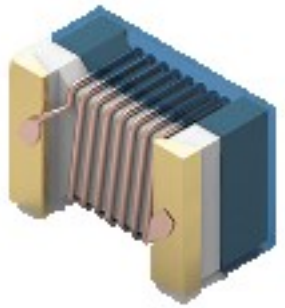
Temperature increase and connectors

Consequences of high temperature:

- Electronic devices lifespan







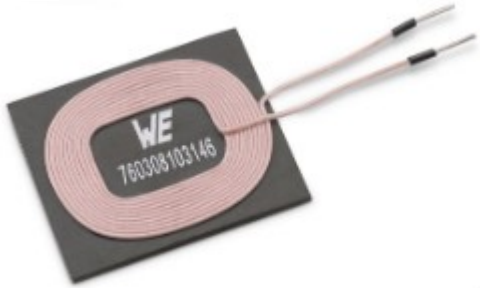
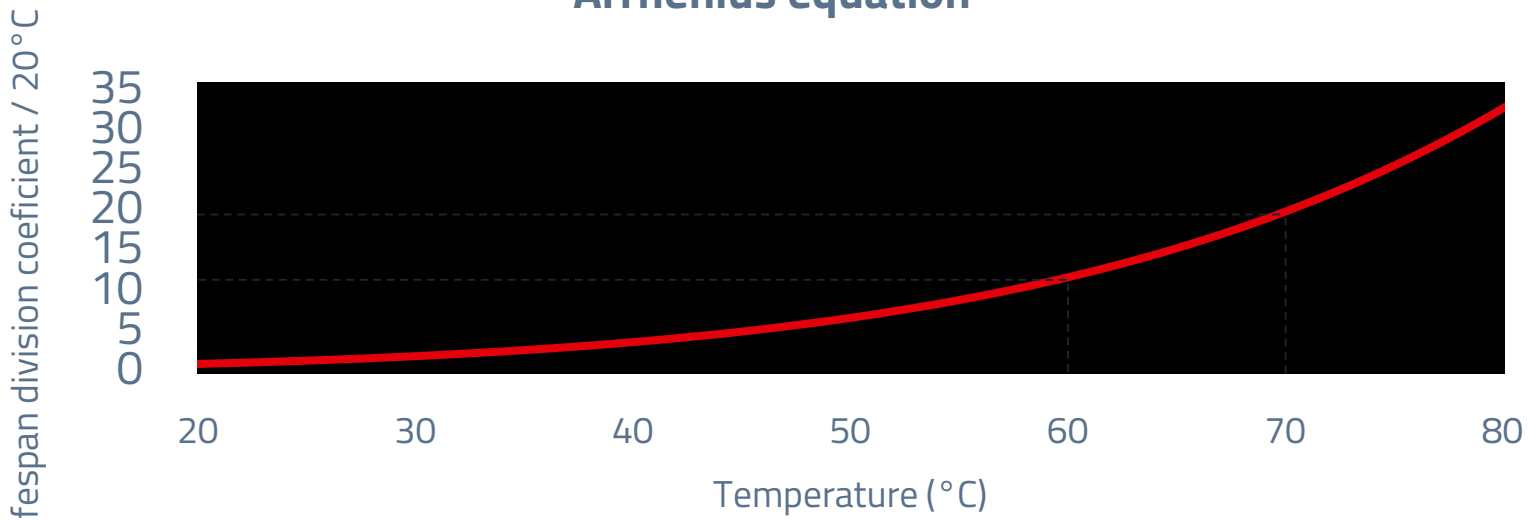


Image of lifespan reduction coeficient vs temperature

Arrhenius equation



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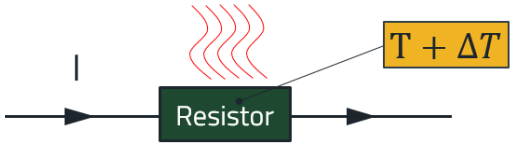
Electricity and temperature rise



Joule's law

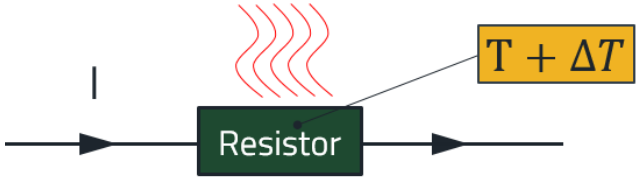
$$P = R \cdot I^2$$

$$\Delta T = k \cdot R \cdot I^2$$

- P (W): power dissipated by the resistor
- R (Ω)
- I (A)
- ΔT (K): data given usually in Kelvin
- k: constant defined by resistance material and environnement

Temperature rise is proportional to the square of the current

Theorical calculation



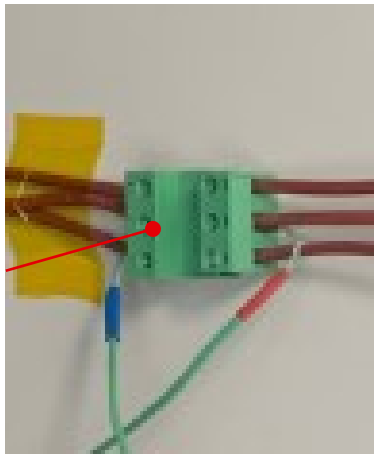
$$\frac{\Delta T_1}{\Delta T_2} \approx \frac{{I_1}^2}{{I_2}^2}$$

Example:

- Measurment: I_1=15A gives $\Delta T_1 \approx 15K$

$$\Delta T = k \cdot R \cdot I^2$$

- At I_2=30A → $\Delta T2 \approx \frac{30^2}{15^2} \cdot 15 \approx \mathbf{60K}$



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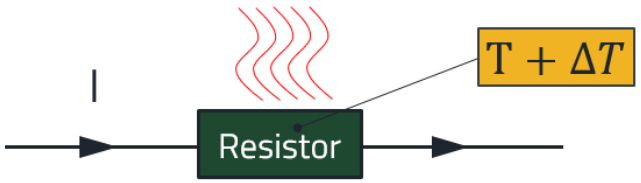
Theorical calculation



$$\frac{\Delta T_1}{\Delta T_2} \approx \frac{{I_1}^2}{{I_2}^2}$$

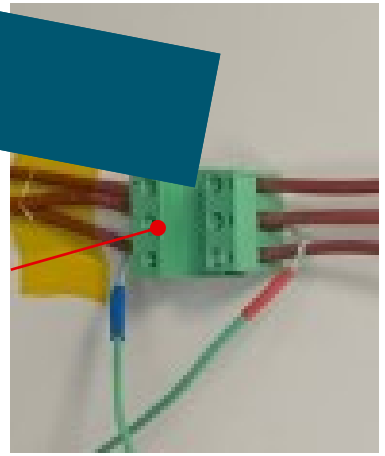
Example:

Current **x 2** → ΔT **x 4**

- Measurment: I_1=15A gi

$$\Delta T = k \cdot R \cdot I^2$$

- At I_2=30A → $\Delta T2 \approx \frac{30^2}{15^2} \cdot 15 \approx \mathbf{60K}$



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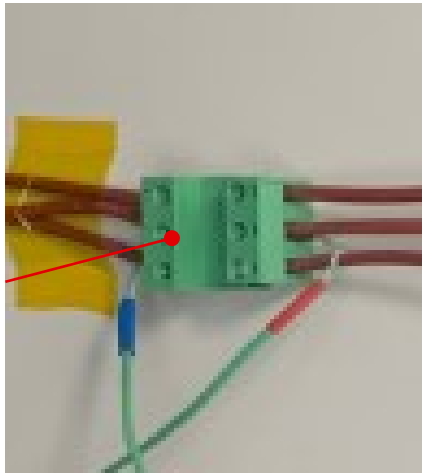
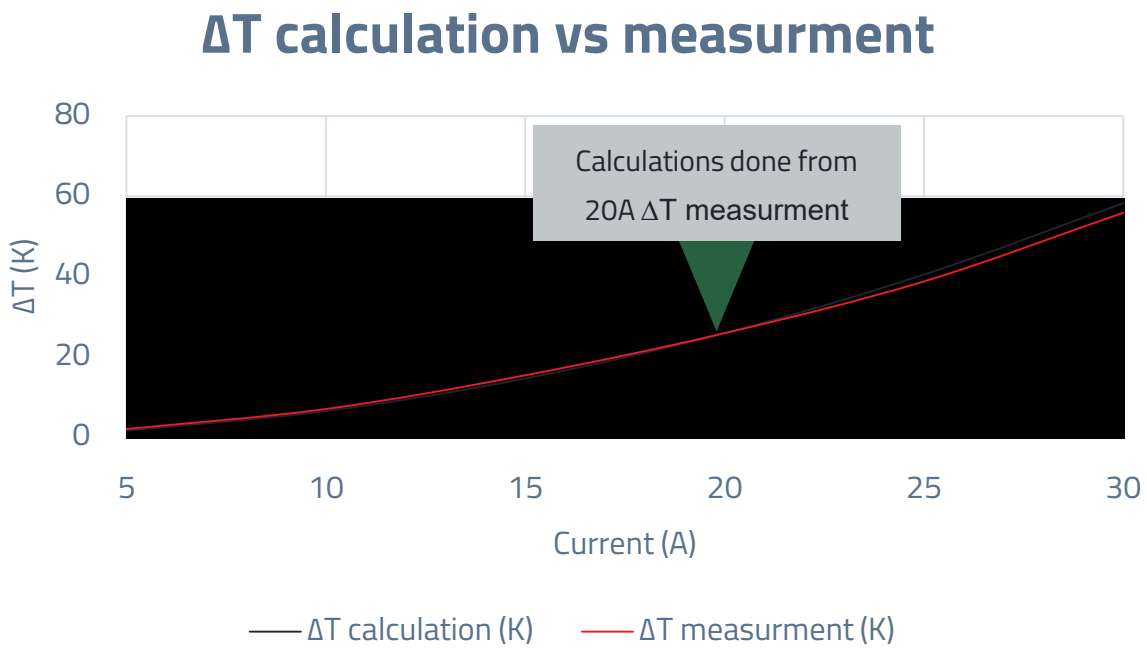
Theorical calculation: is it really true ?

Temperature rise test done at 20A





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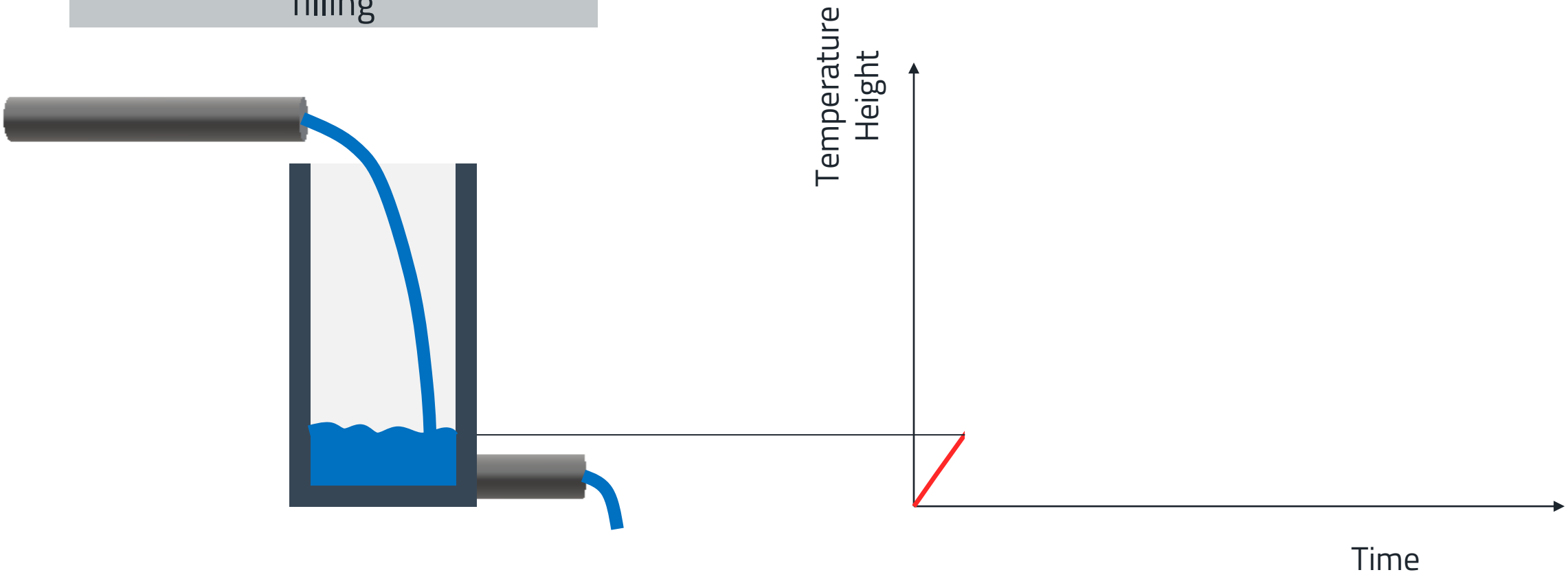
How ΔT is dissipated

Temperature rise analogy tank filling



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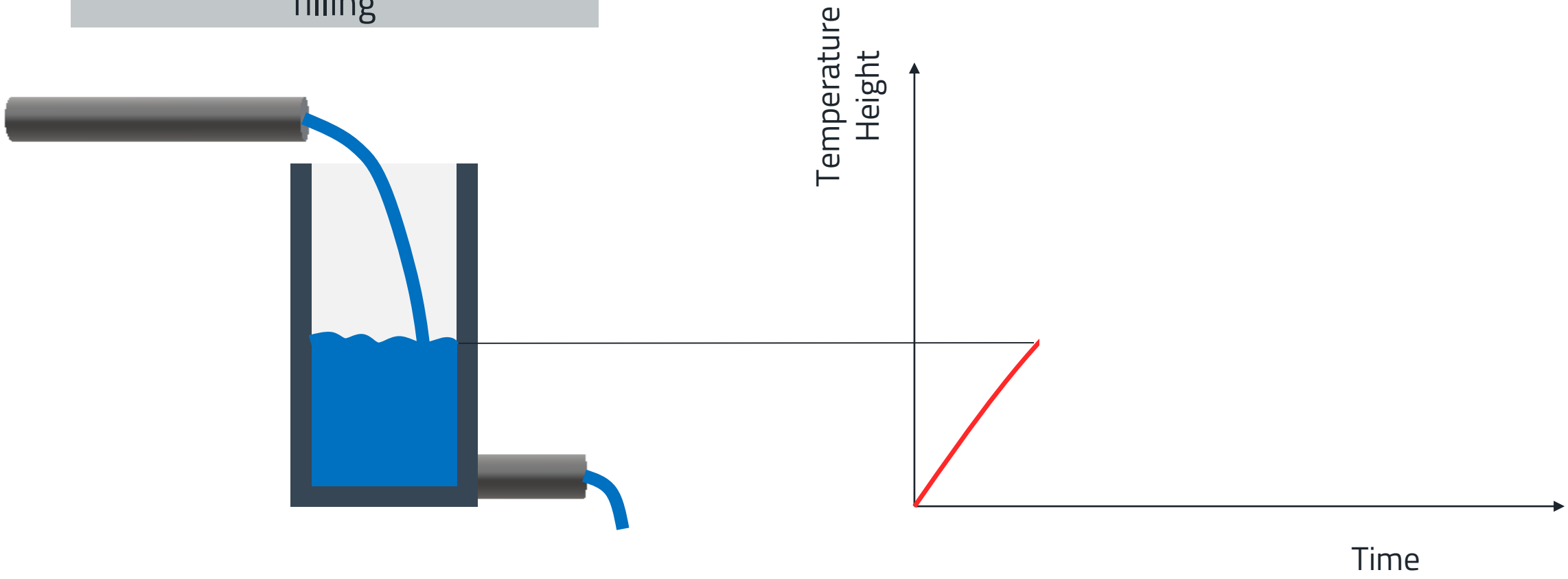

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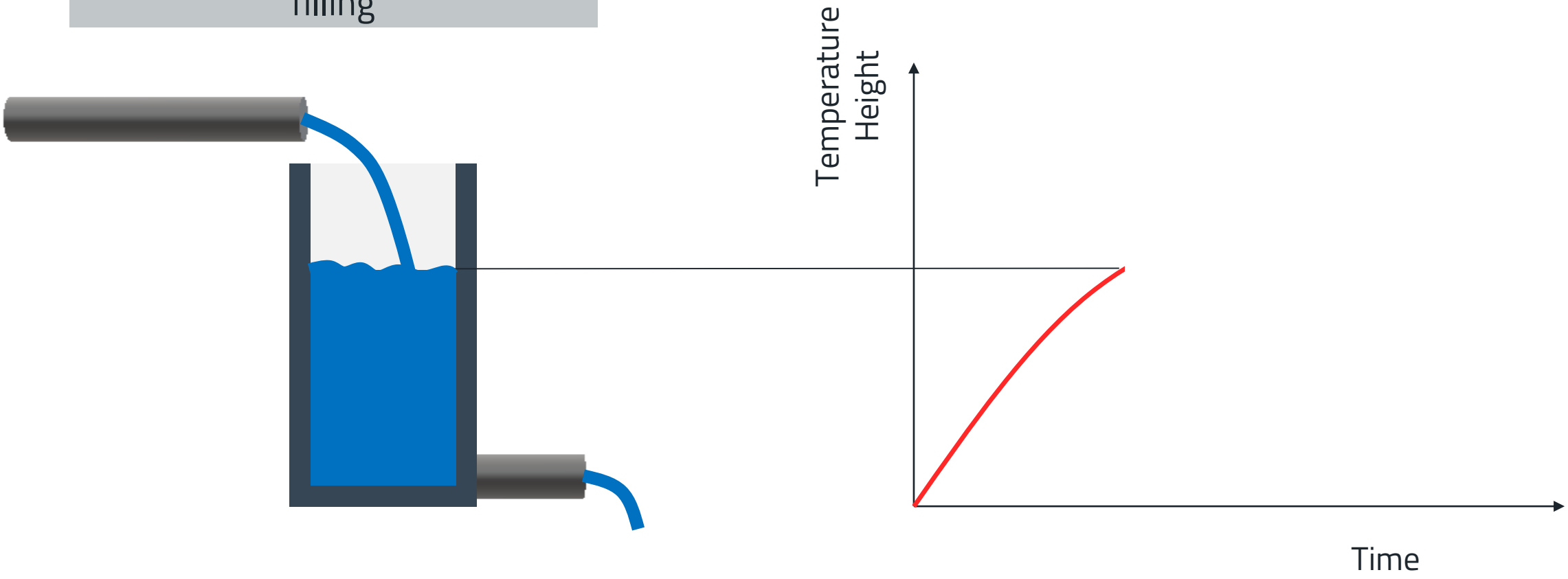

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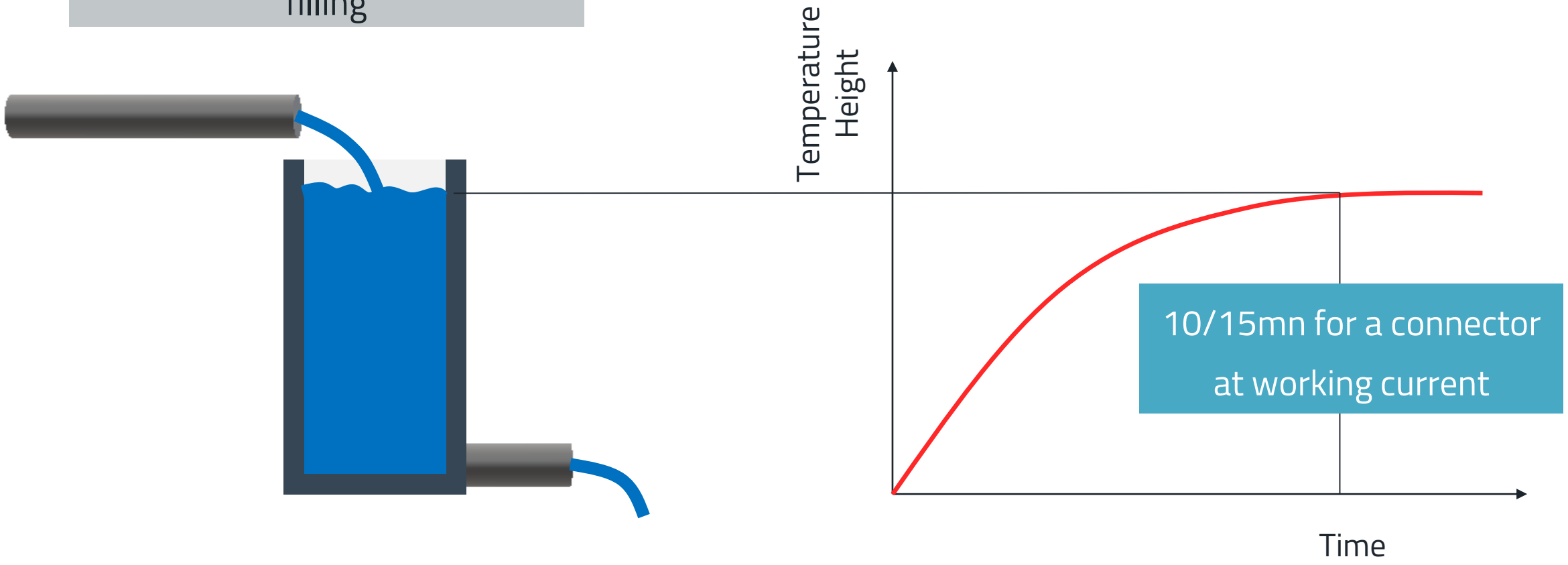

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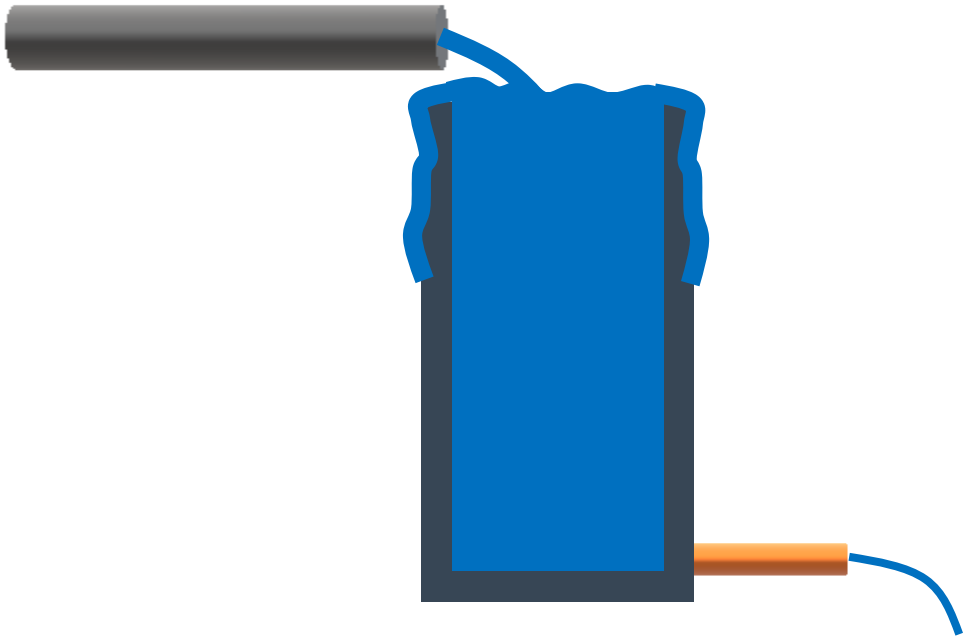

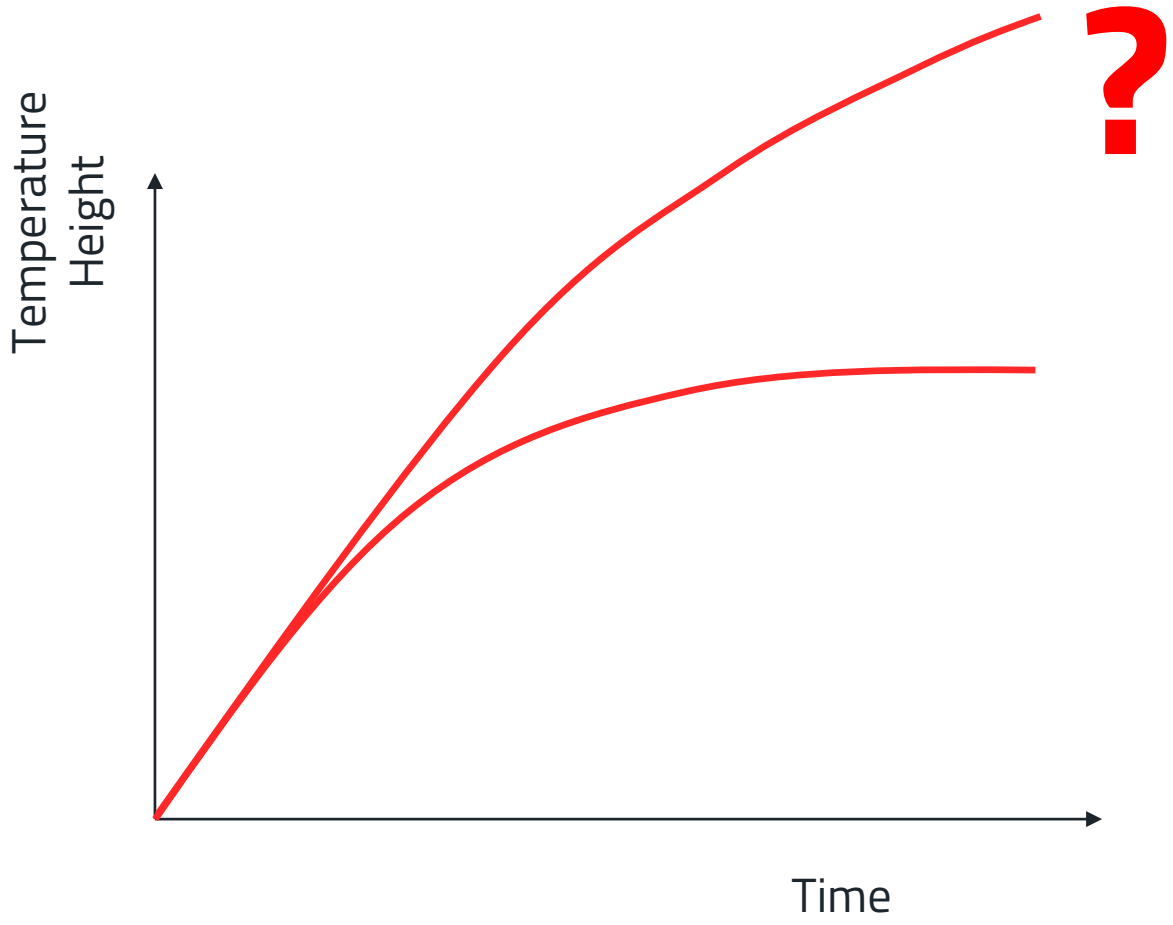

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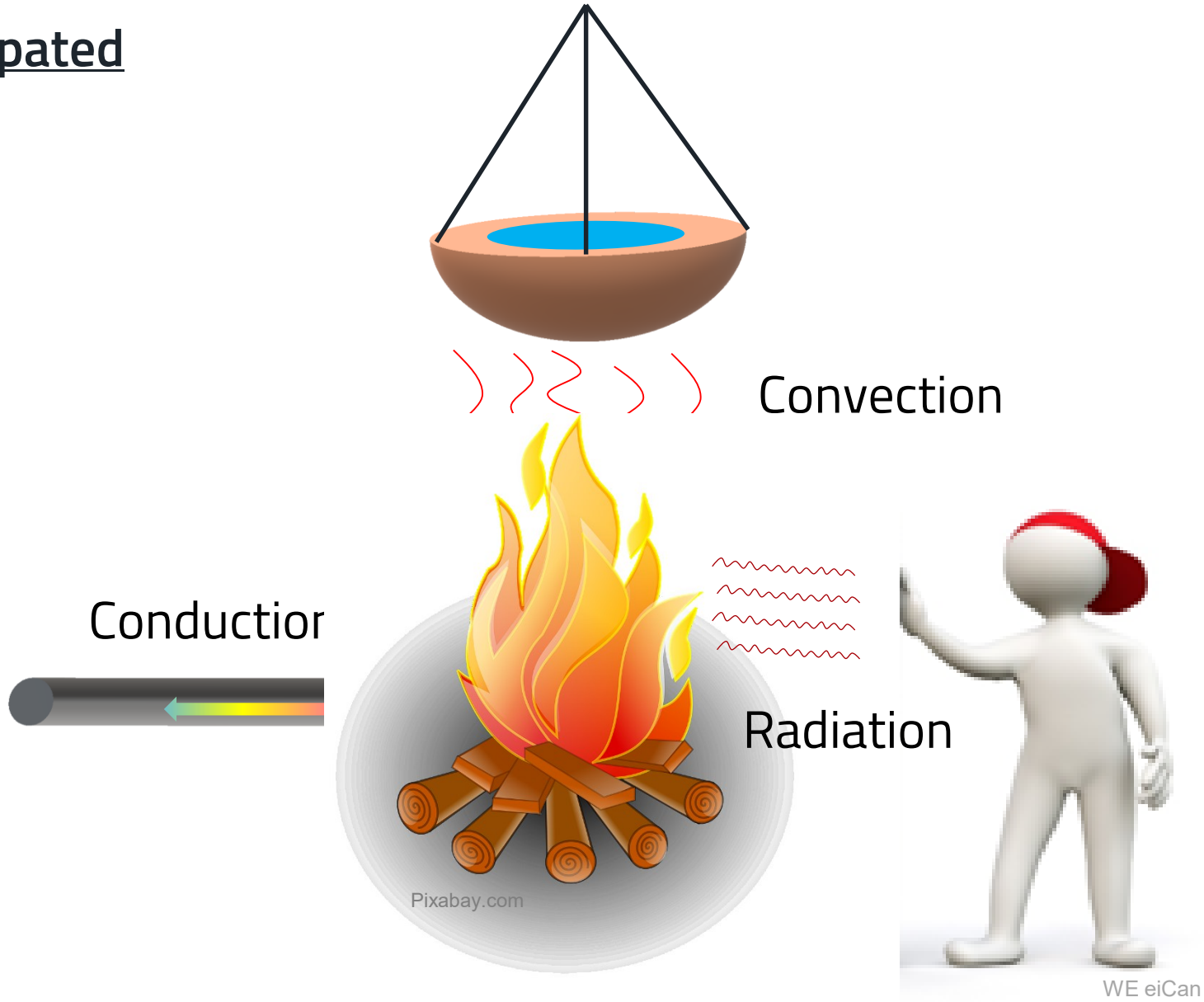

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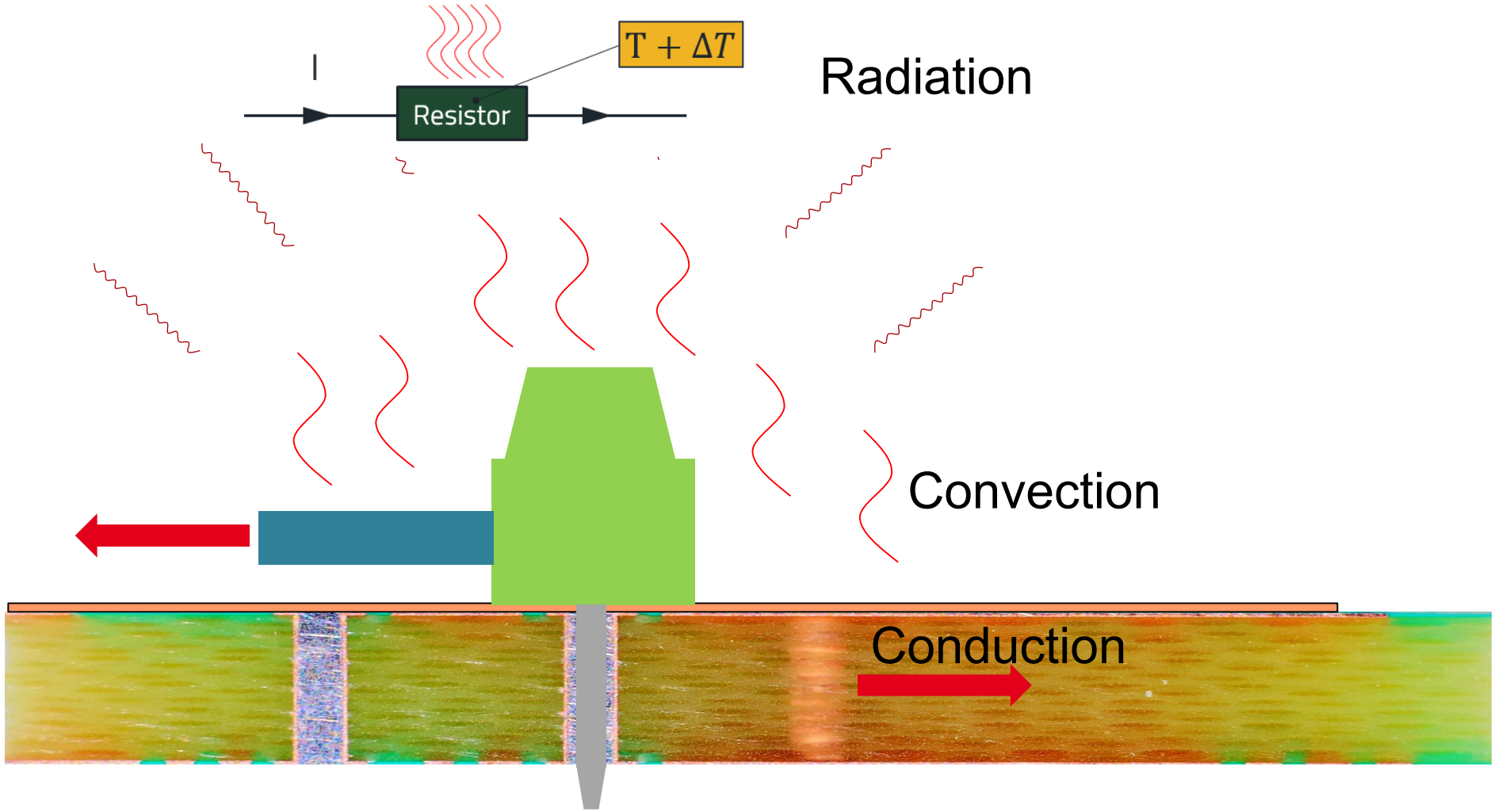

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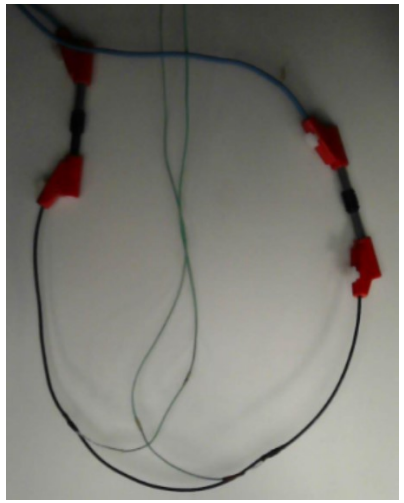
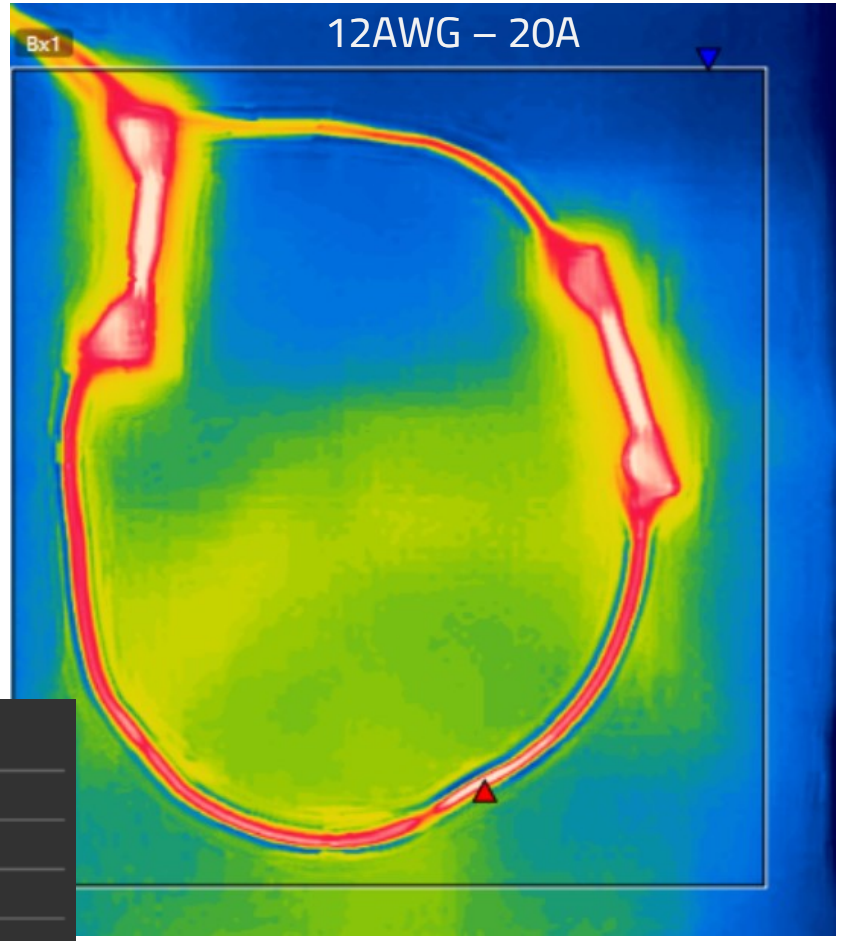
What is the temperature rise with wires ?

Test: **AWG**

- ΔT of 50cm wire
- 2 thermocouples sticked on the copper conductor





Mesures		
Bx1	Max	34,7 °C
	Min	23,5 °C
	Average	25,2 °C

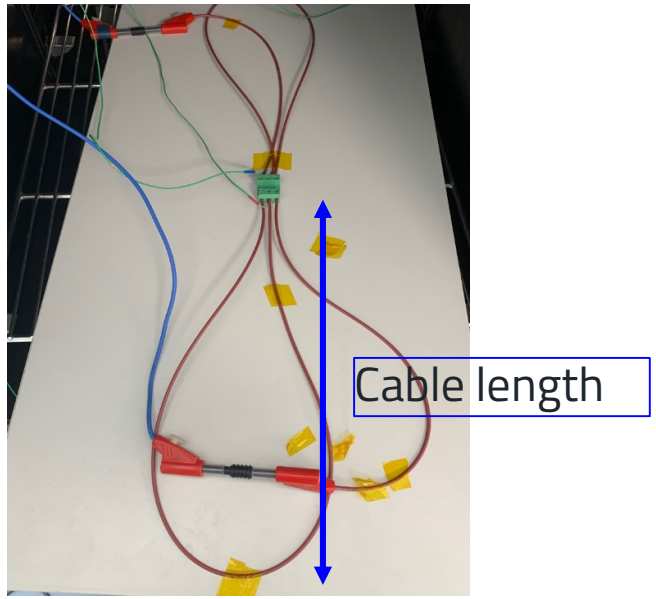
Wire size (AWG)	Current (A)	ΔT (K)
20	5	**5**
18	7	**6**
16	10	**7**
14	15	**10**
12	20	**11**
10	30	**16**

All pictures: WE eiCan

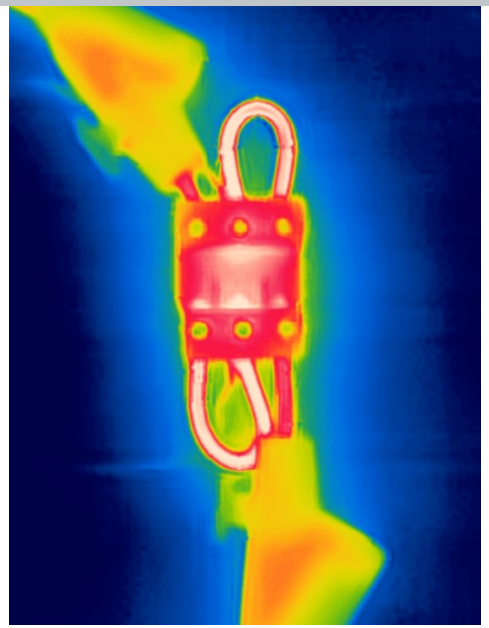
Wire heat dissipation: the right length ?

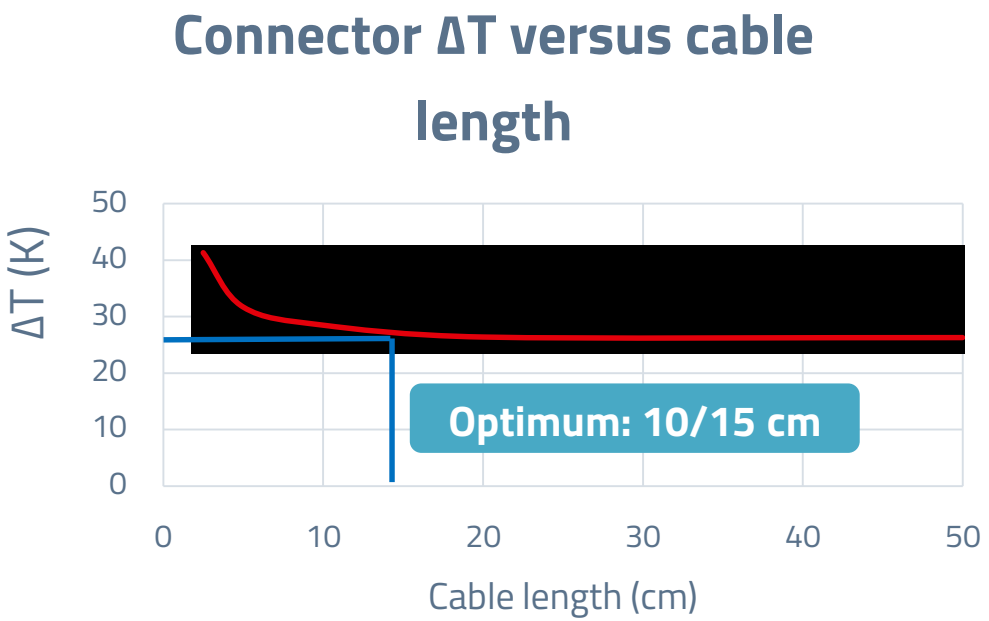
Test:

- ΔT 12AWG-20A
- TBL plug 3 poles 7,62
- Different wire length
- 2 thermocouples in 2 TBL clamps



12AWG – 20A – 2,5cm





All pictures: WE eiCan

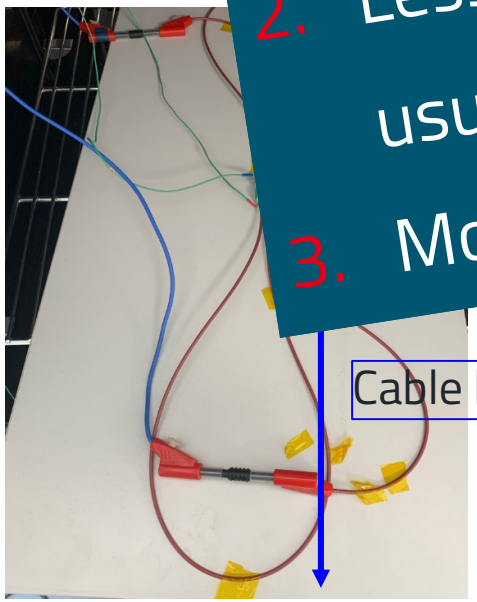
Wire heat dissipation: the right length ?

Test:

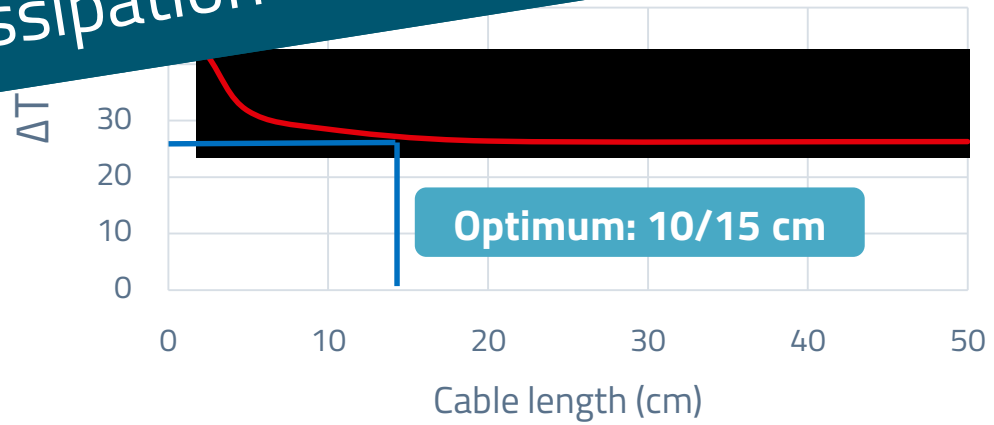
- ΔT 12AWG-20A
- TBL plug 3 poles 7,62
- Different wire length
- 2 thermocouples with clamps

12AWG – 20A – 2,5cm

1. Optimized length for heat dissipation: 10/15cm
2. Less will increase internal connector temperature above usual 30K
3. More is useless for thermal dissipation



Cable length



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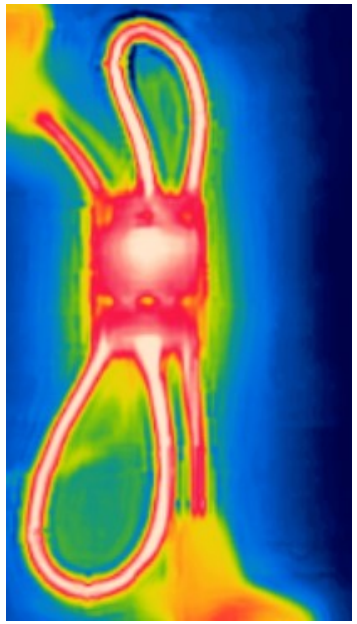
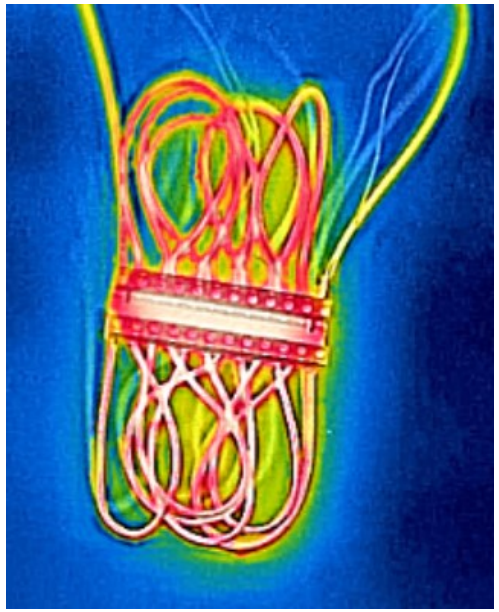
ΔT=30K ok but only with 3 poles ?

Test:

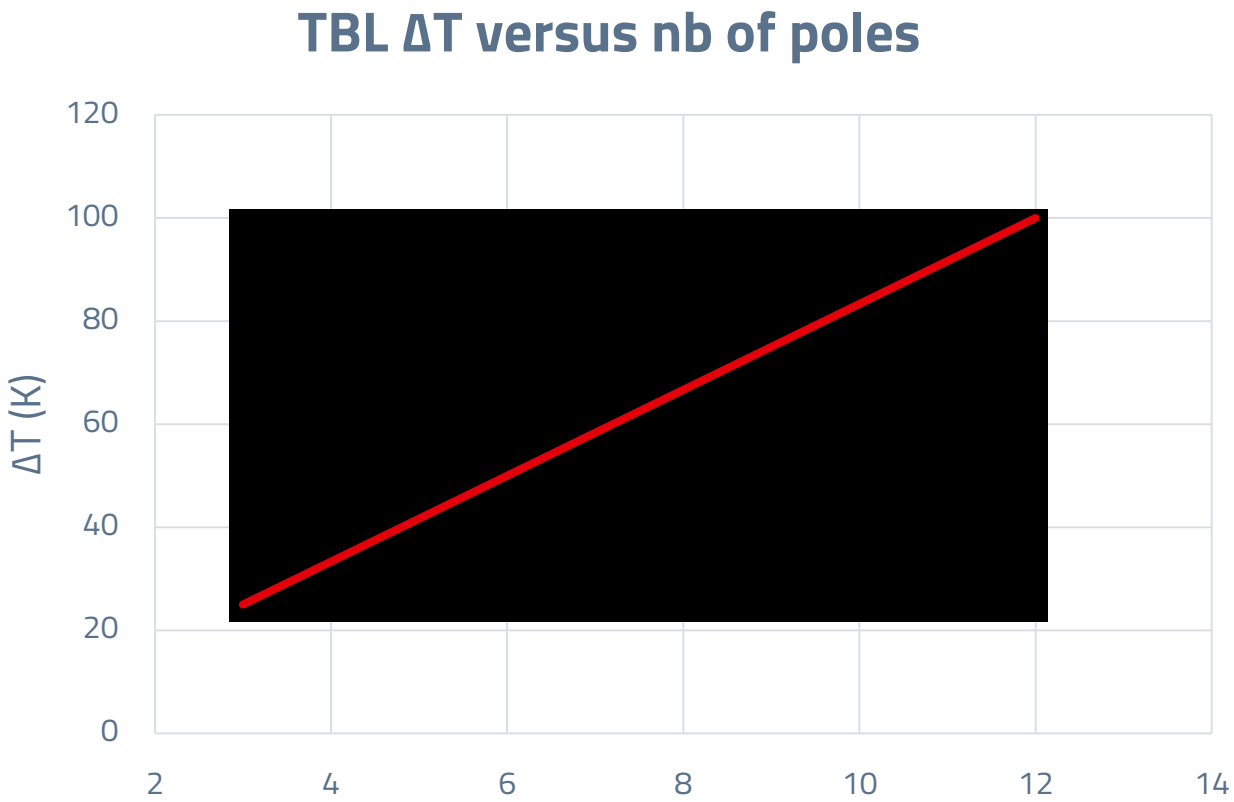
- Working current is tested at 3 poles
- Should we decrease current with more ?





12AWG – 20A – 10cm

This is what you expect ?



All pictures: WE eiCan

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Test:

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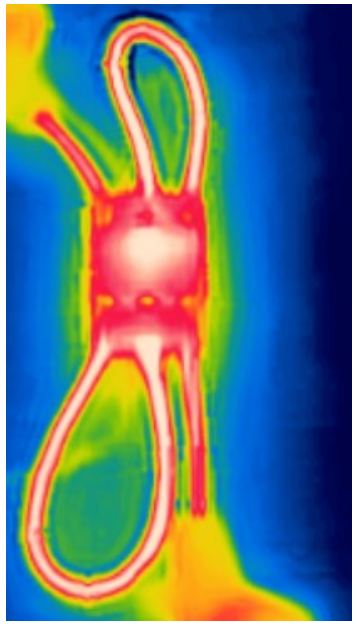
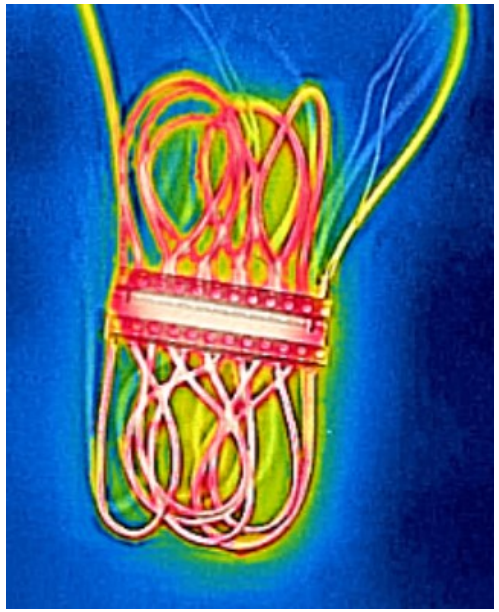
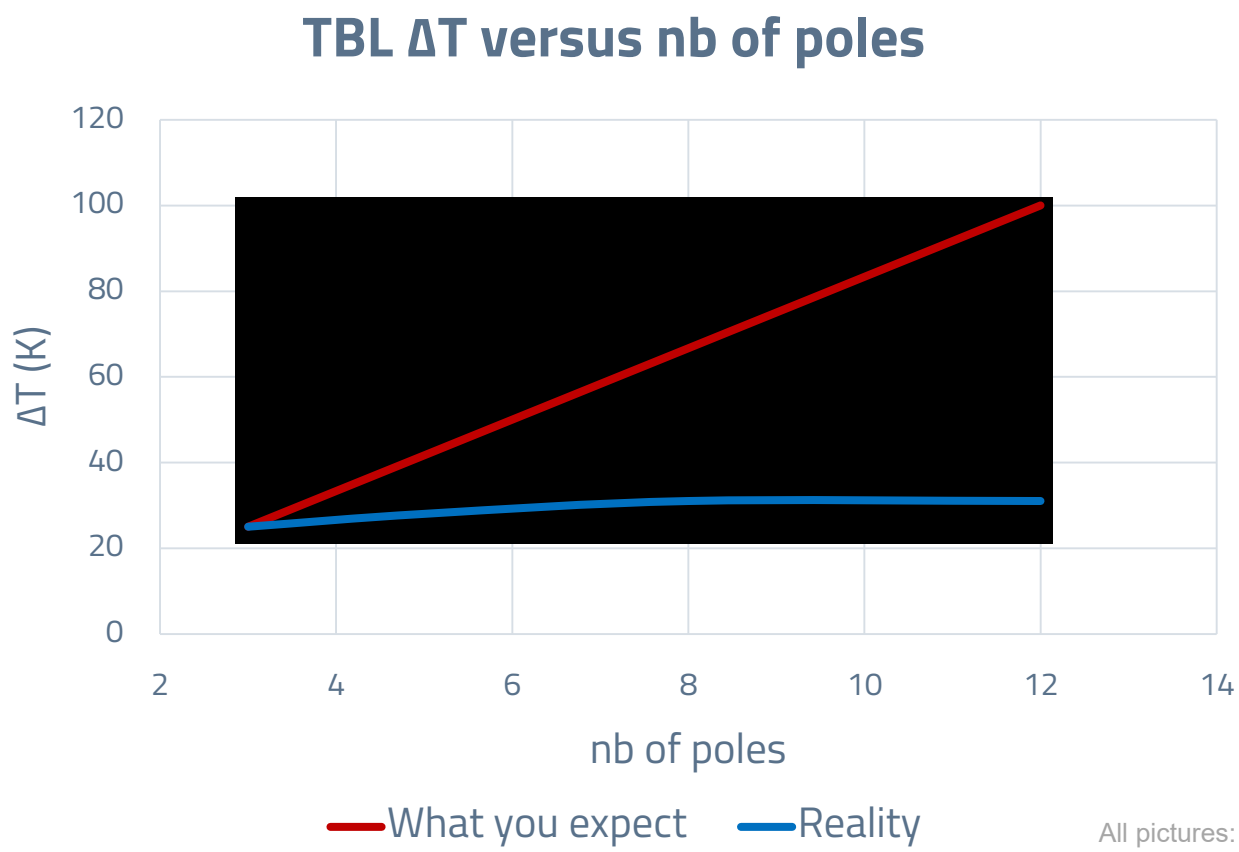




12AWG – 20A – 10cm

Expectation vs reality



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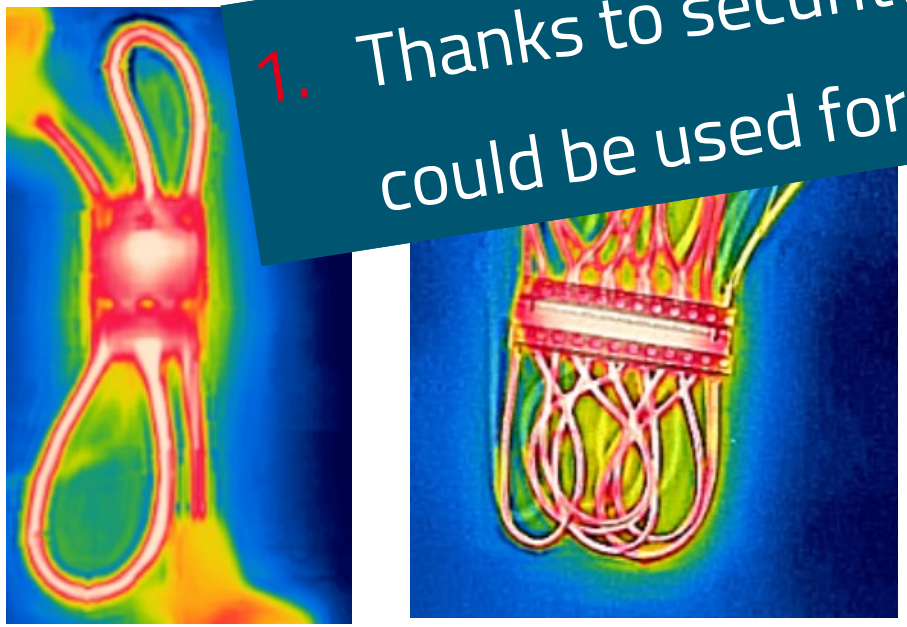
ΔT=30K ok but only with 3 poles ?

Test:

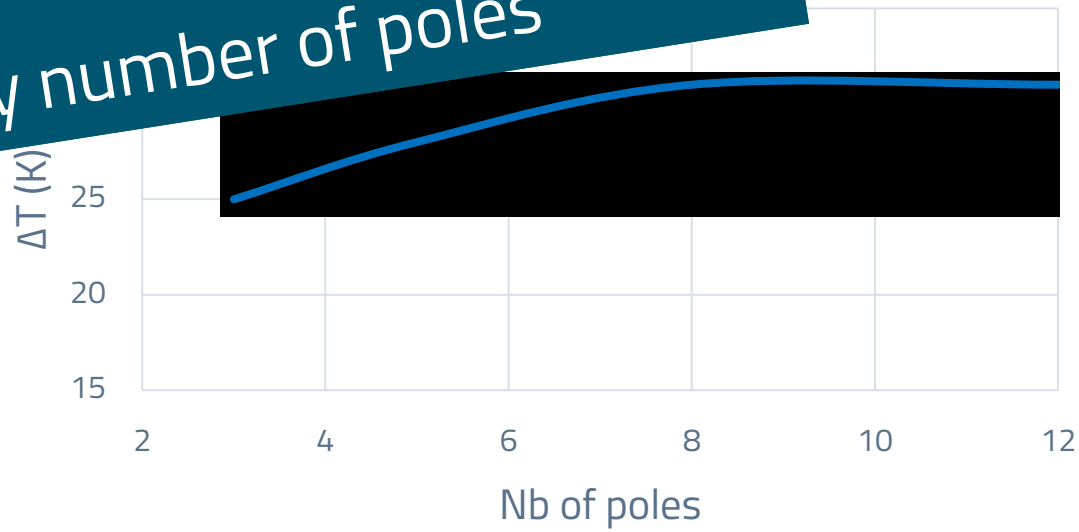
- Working current is tested at 3 poles
- Should we decrease current with more ?

1. Thanks to security margin, working current could be used for any number of poles



12AWG – 20A – 10cm

Reality

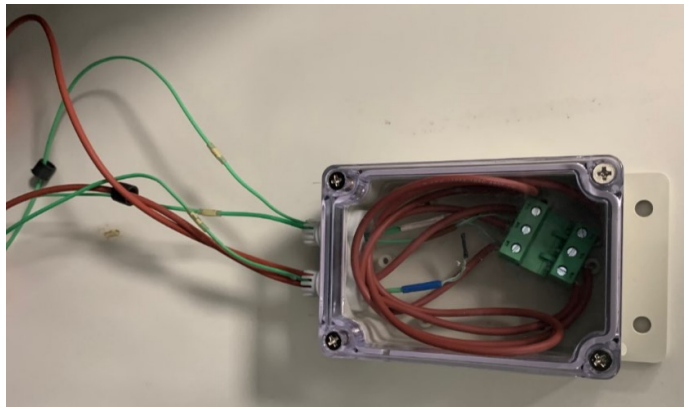


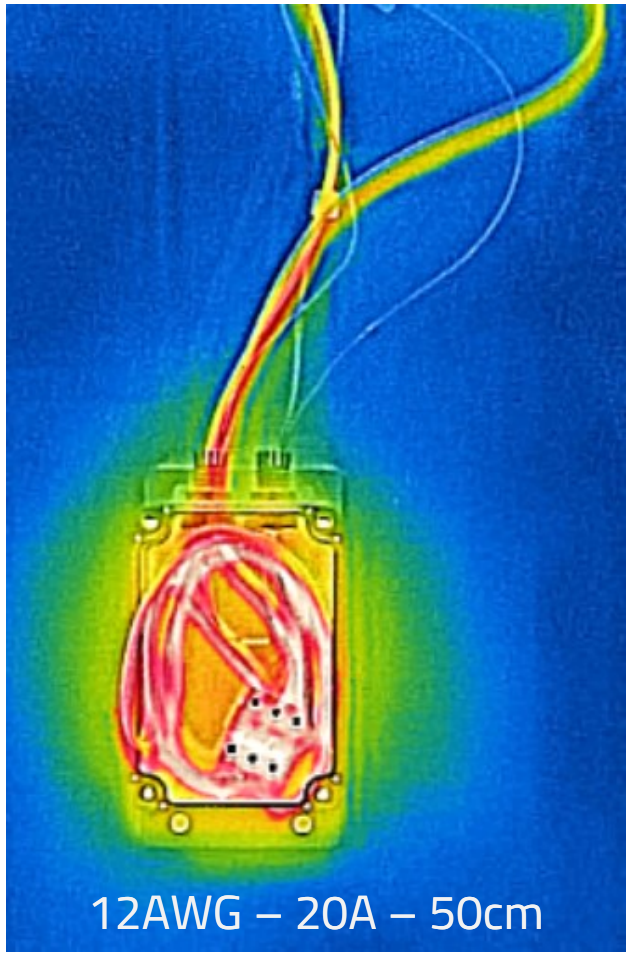
All pictures: WE eiCan

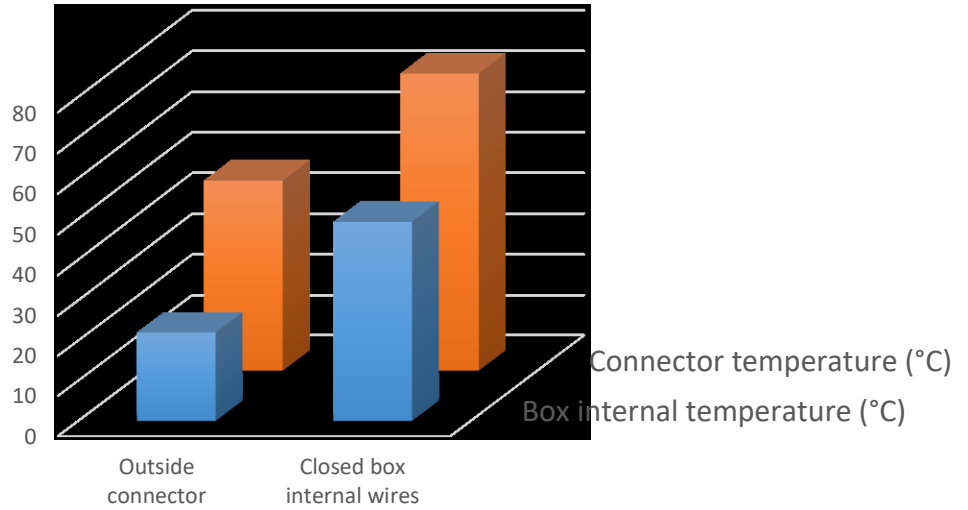
A connector in a closed box

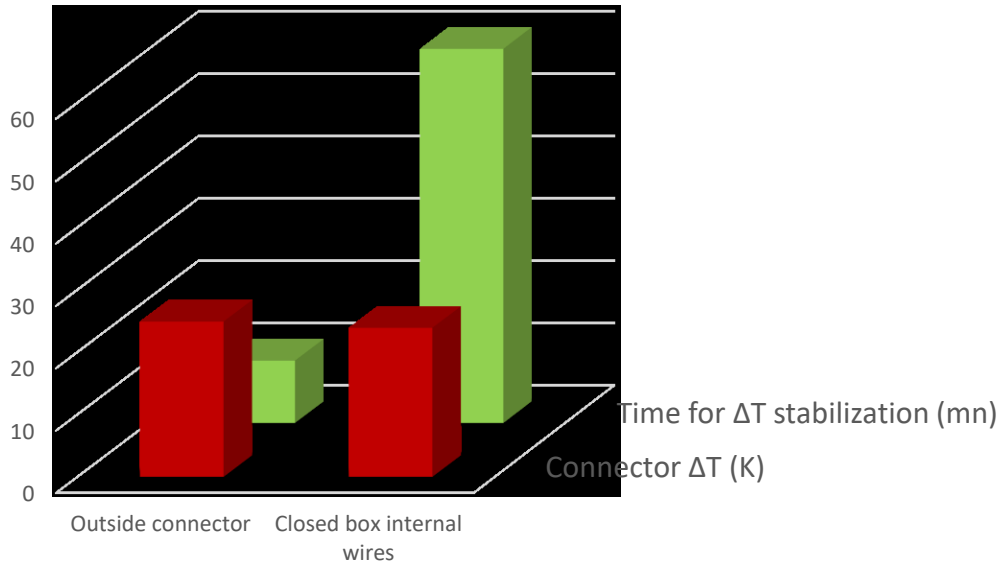
Test:

- TBL plug 3 poles 7,62
- Initial 12AWG - 20A
- 2 thermocouples in 2 TBL clamps + 1 for box ambient air
- Wire length 10cm









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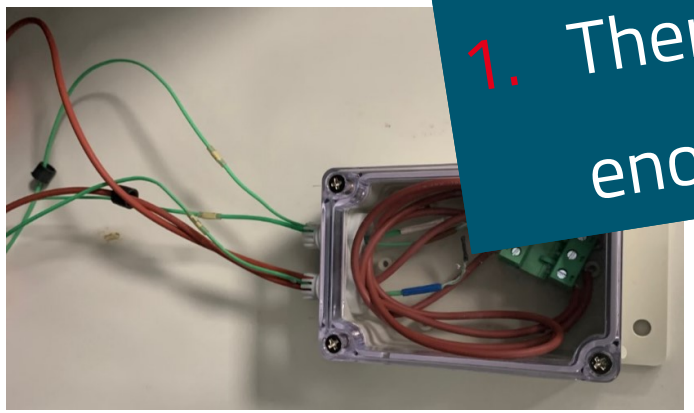
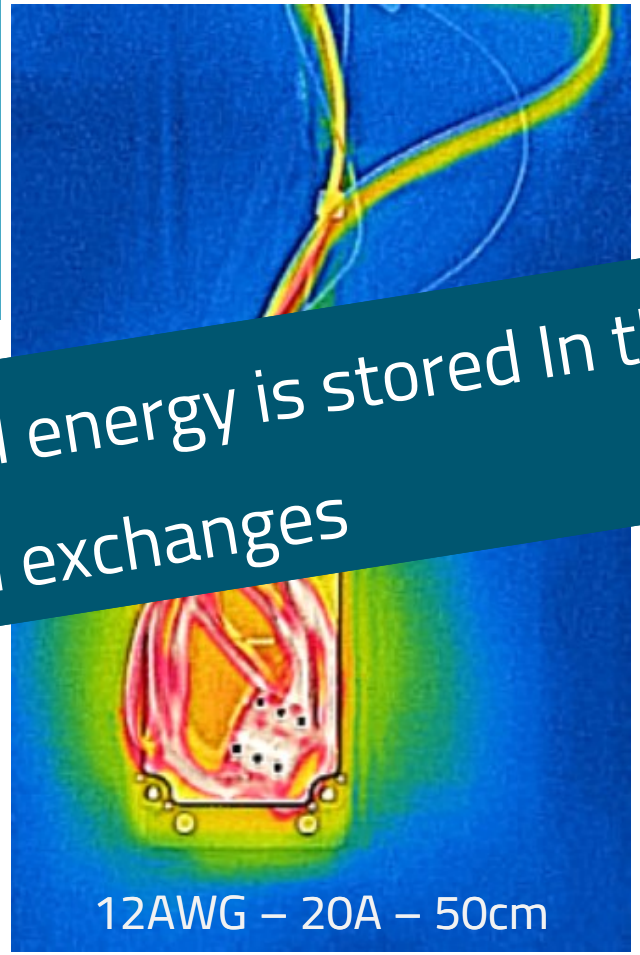
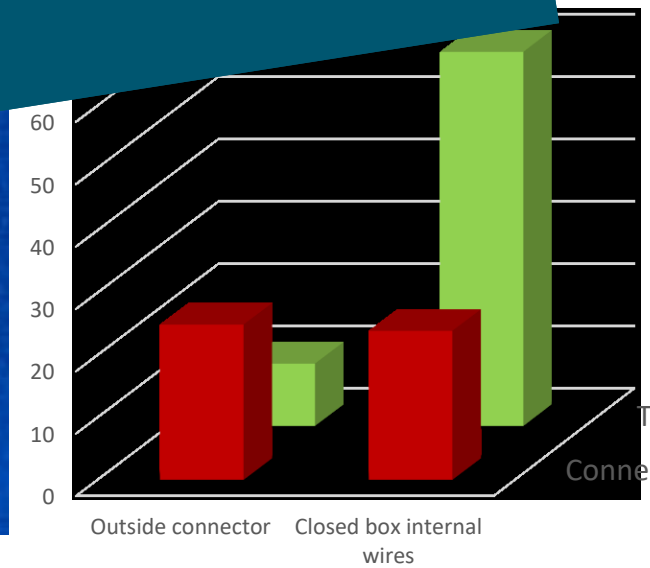




1. Thermal energy is stored In the box, not enough exchanges

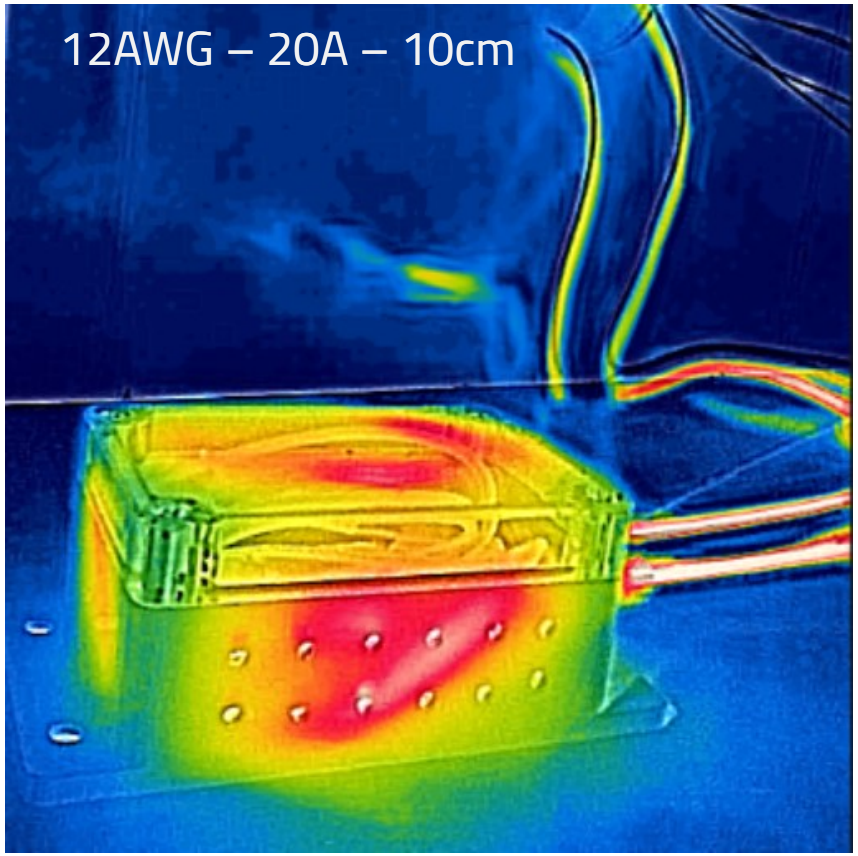


All pictures: WE eiCan

A connector in a closed box

Test:

- Same with closed box with holes



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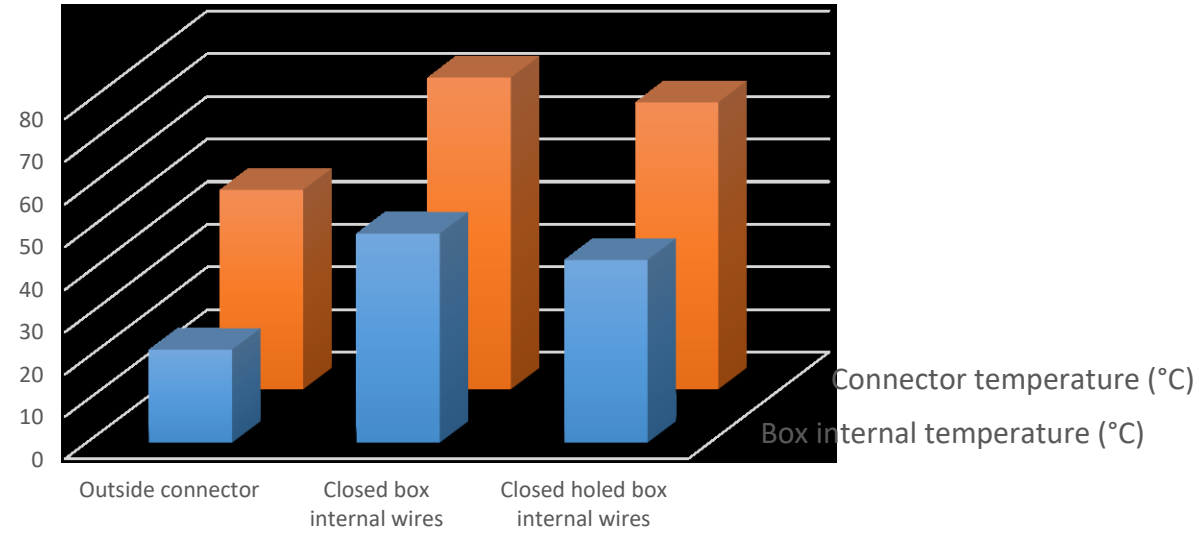
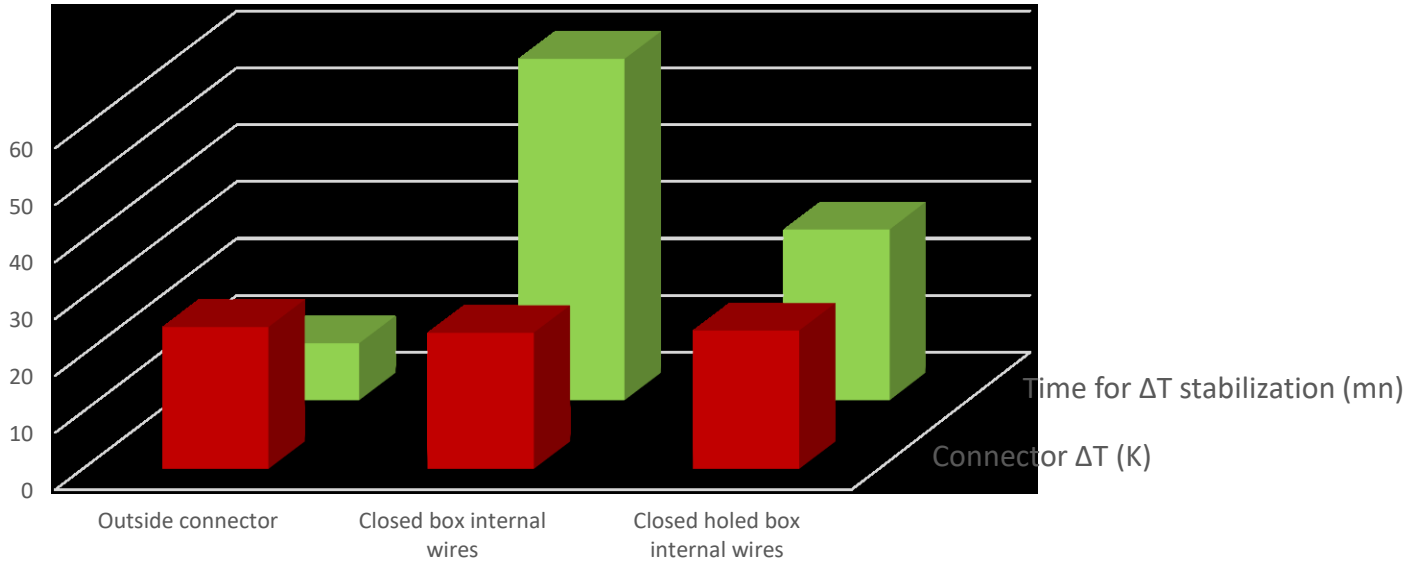
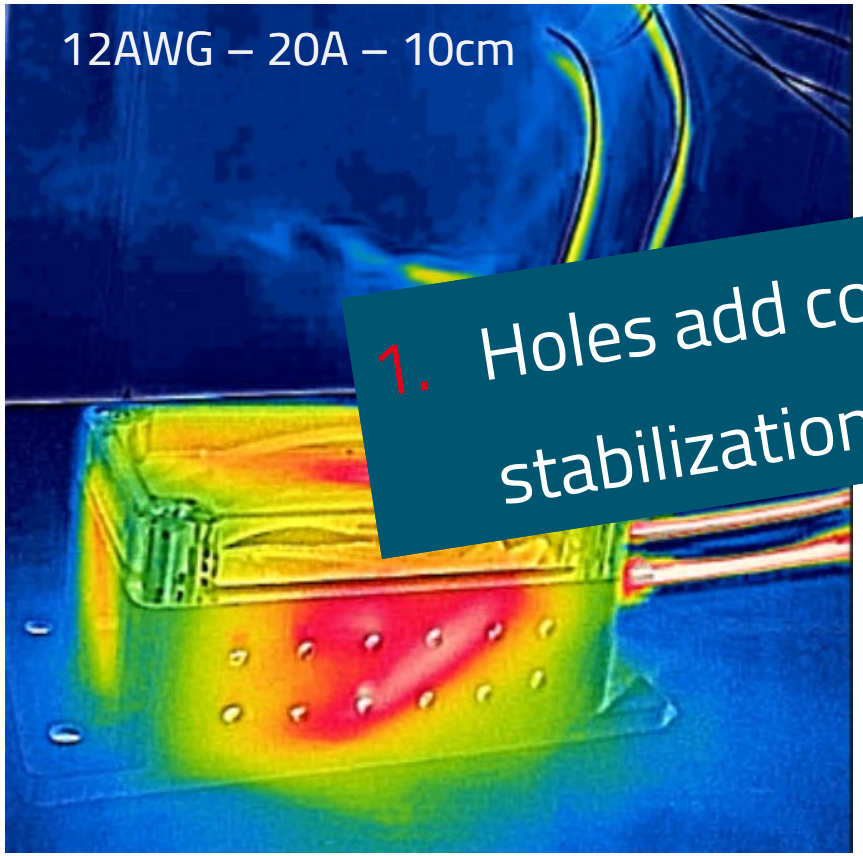




A connector in a closed box

Test:

- Same with closed box with holes



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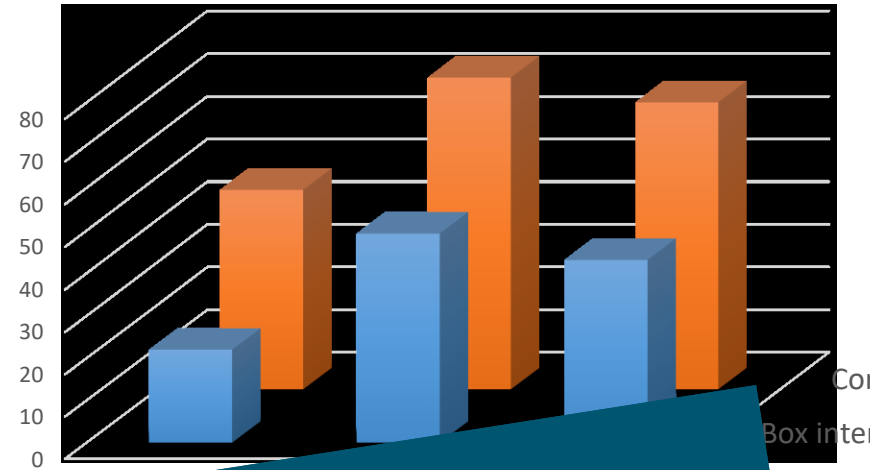
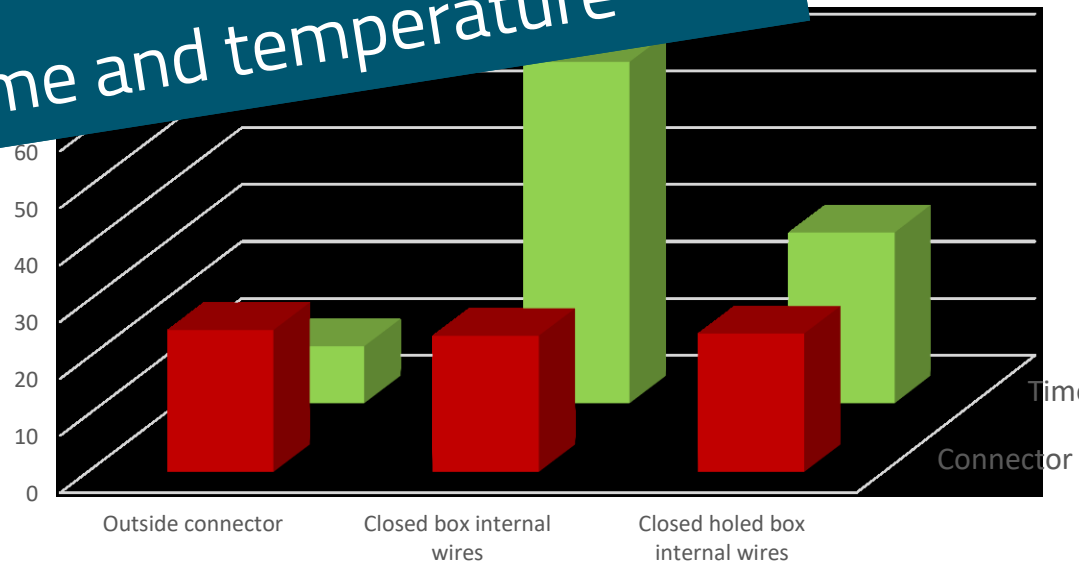


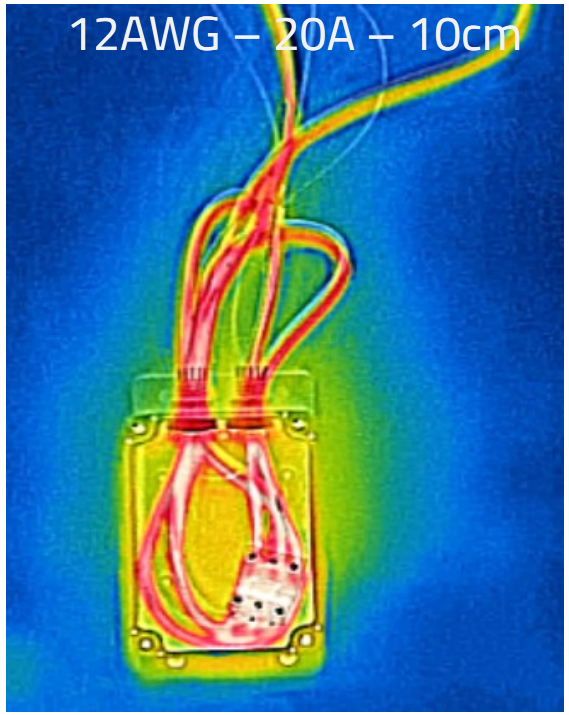
1. Holes add convection decrease stabilization time and temperature

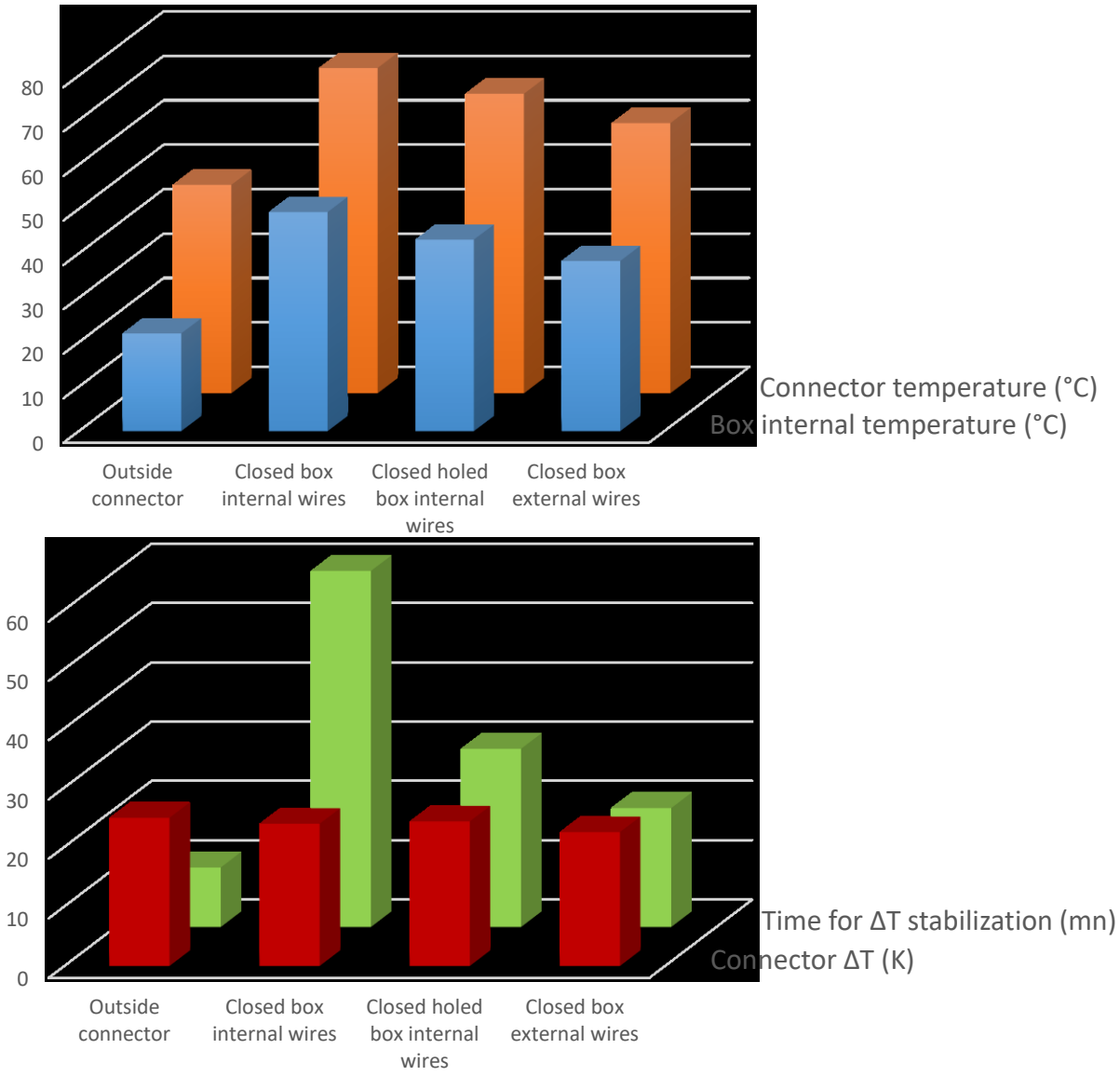


A connector in a closed box

Test:

- Same with closed box with holes and external wires

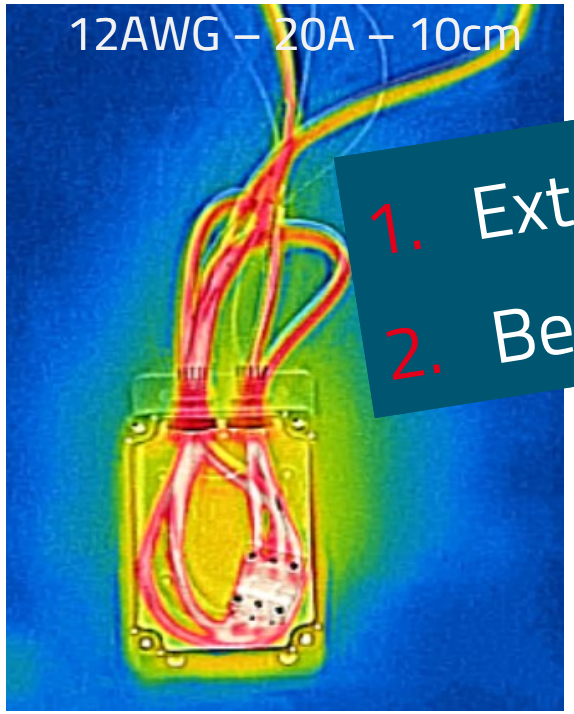




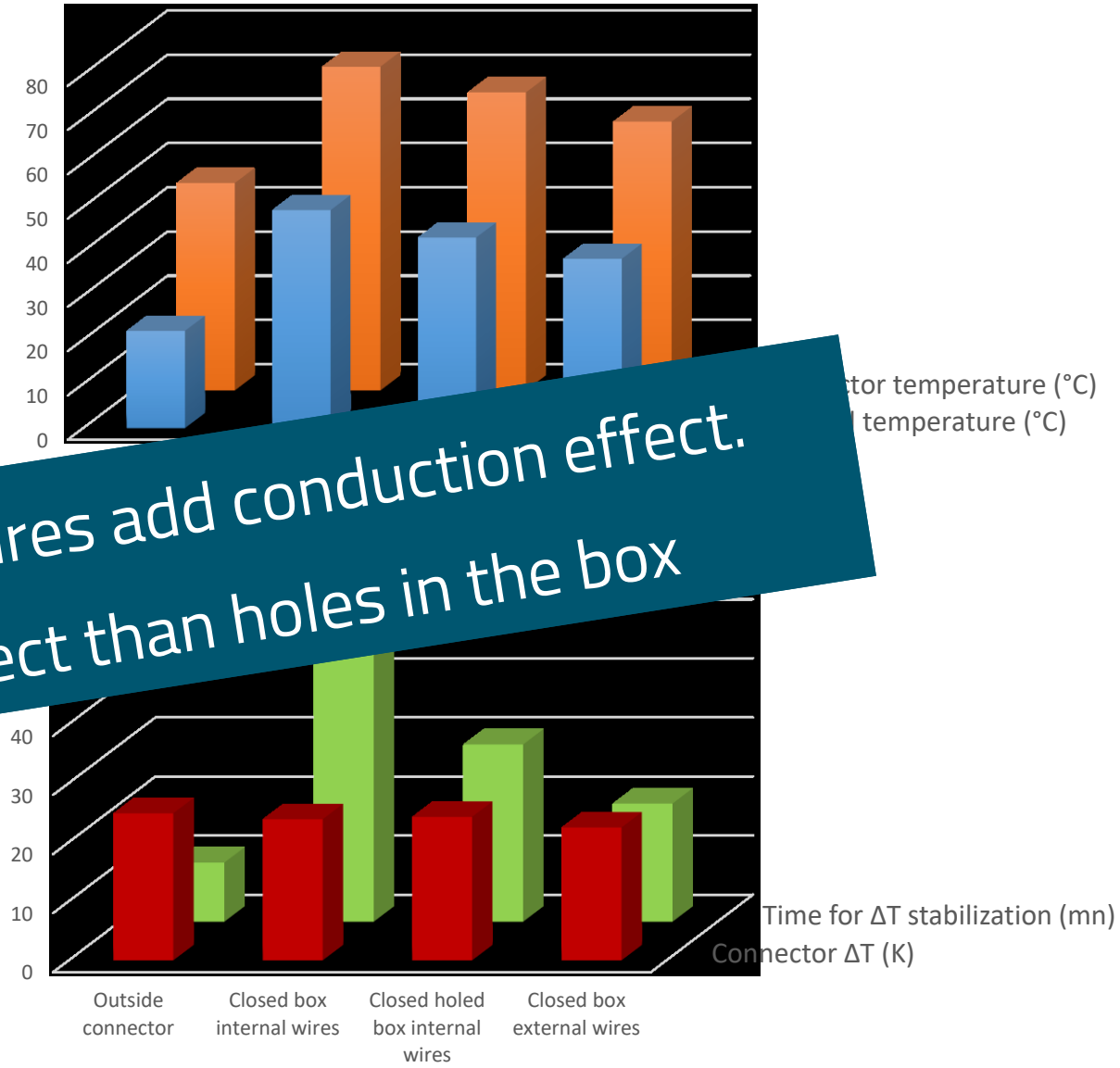
A connector in a closed box

Test:

- Same with closed box with holes and external wires



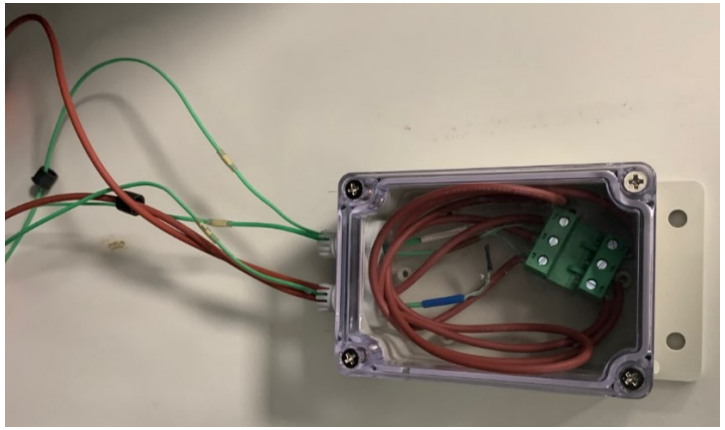
1. External wires add conduction effect.
2. Better effect than holes in the box



A connector in a closed box

Test:

- Closed box
- Internal wires
- No holes
- 15A instead of 20A



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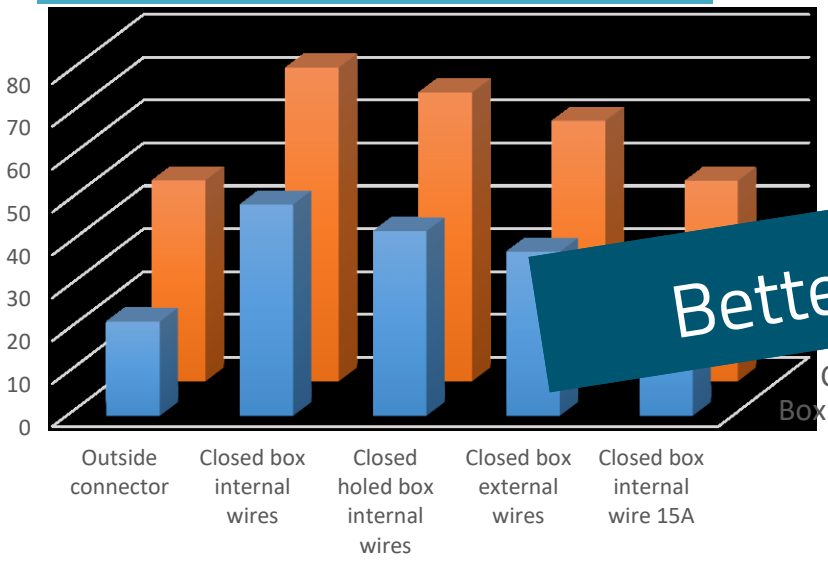
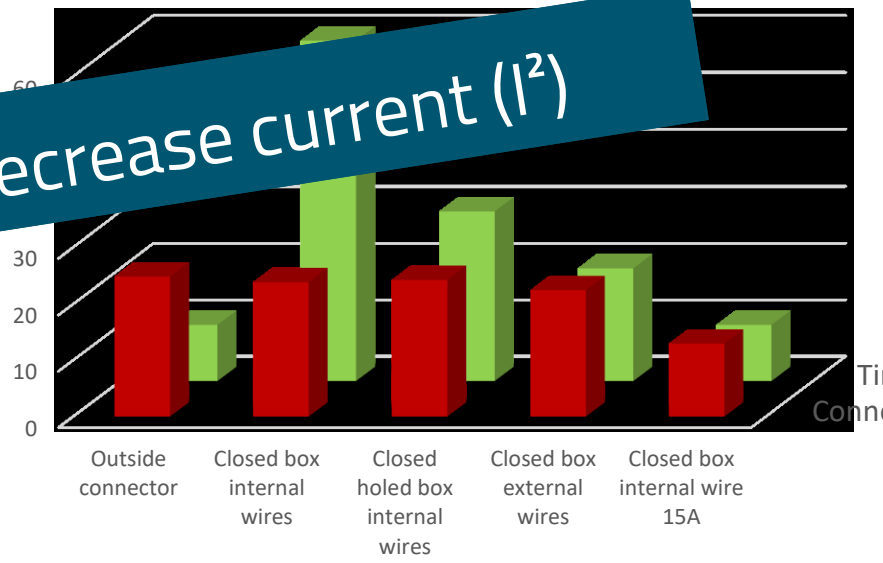


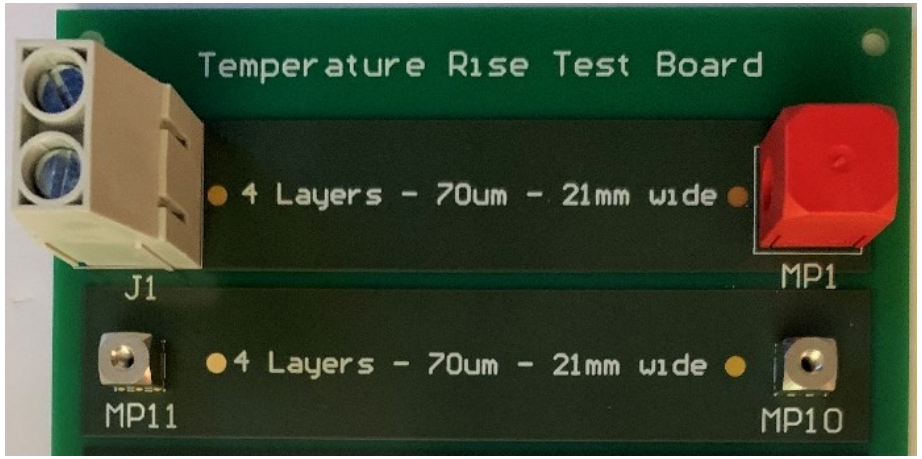
Better way is to decrease current (I^2)

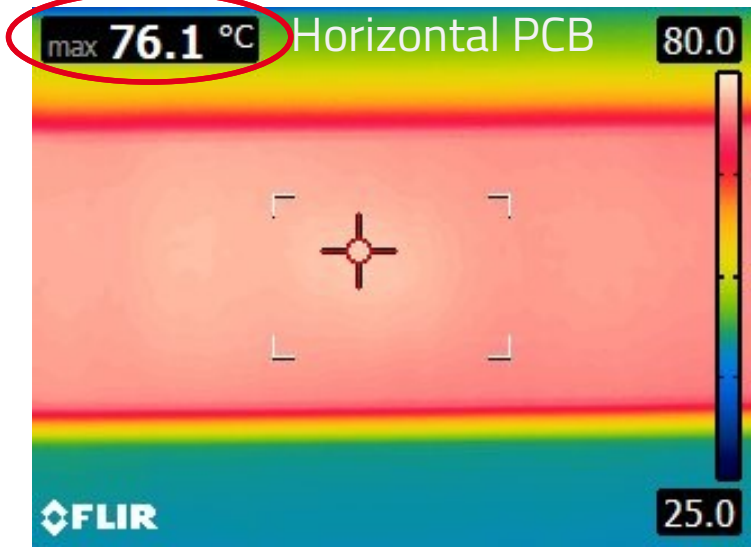


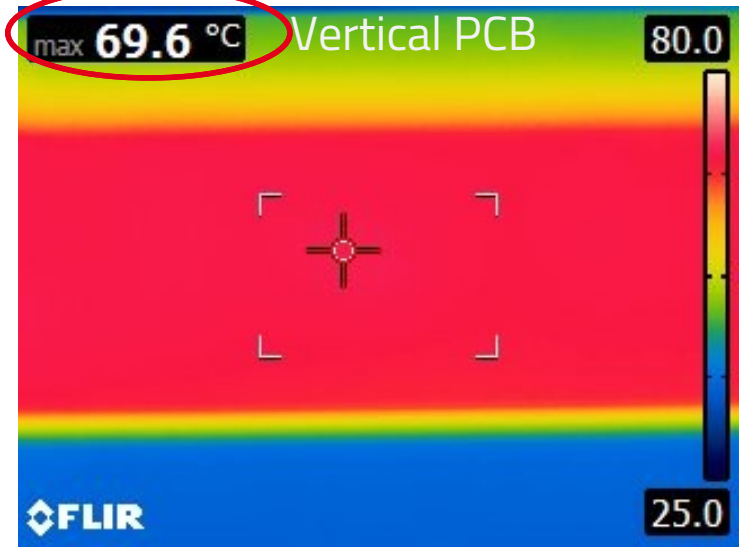
How to naturally cool down a PCB ?

Test:

- PCB redcube
- 100A
- Horizontal and vertical PCB



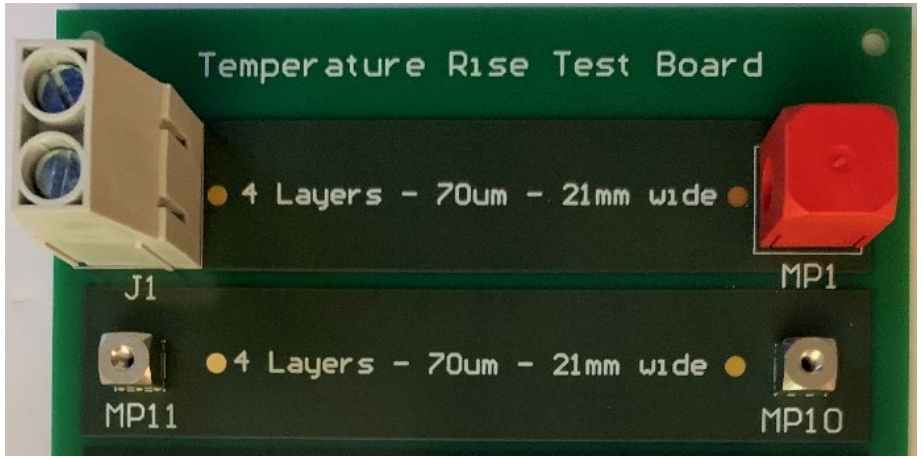


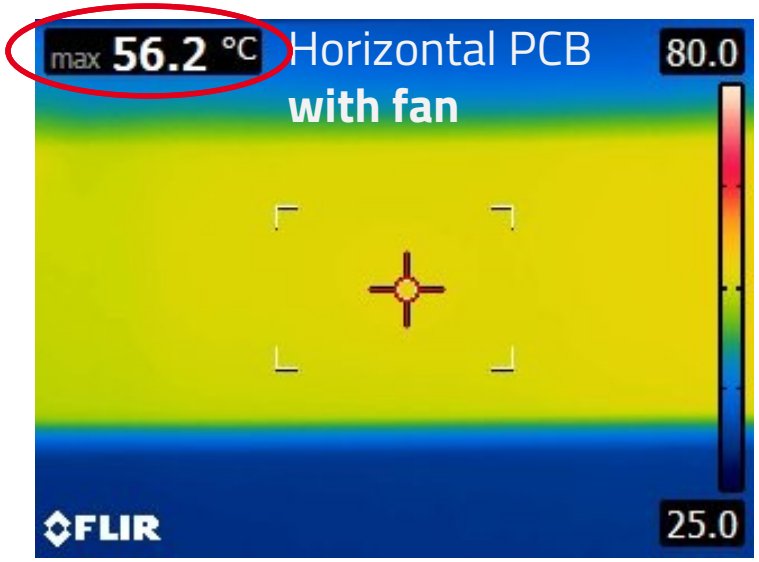


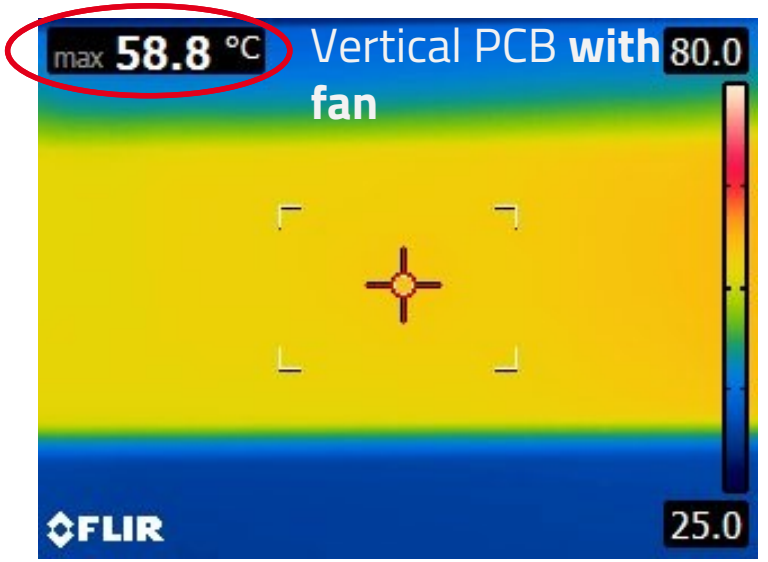
And now with a fan ?

Test:

- PCB redcube
- 100A
- Horizontal and vertical PCB
- With fan





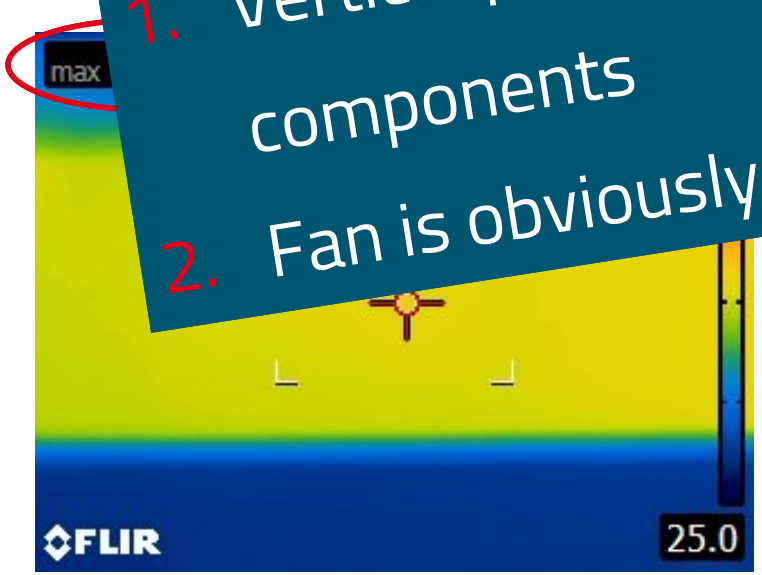


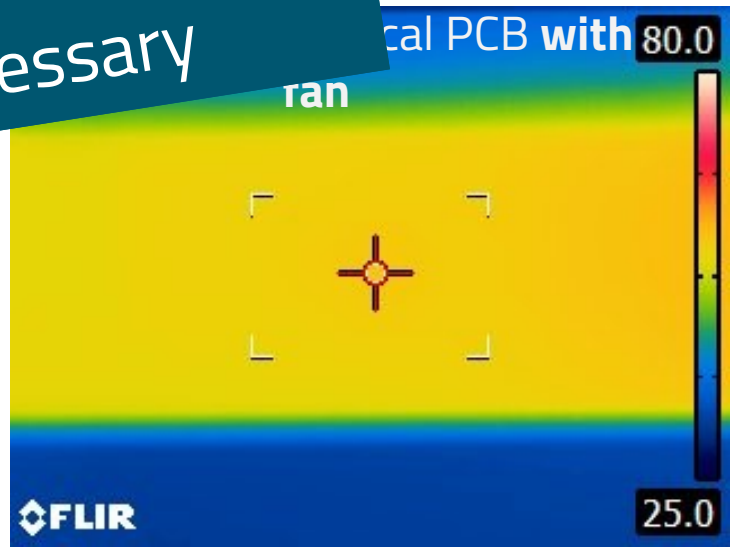
And now with a fan ?

Test:

- PCB redcube
- 100A
- Horizontal and vertical PCB
- With fan

1. Vertical position for a PCB naturally cool down components
2. Fan is obviously a good solution if necessary





Agenda

- Current design for connectors
- Consequences of a too high temperature
- Temperature rise rule
- How heat is dissipated
- Heat in a cable
- Some tricks
- Derating curve
- Connector horror show

Derating curve UL

How to decrease current when ambient temperature increase:

- Maximum connector temperature
- **ΔT ≤ 30K**
- ΔT proportional to I^2

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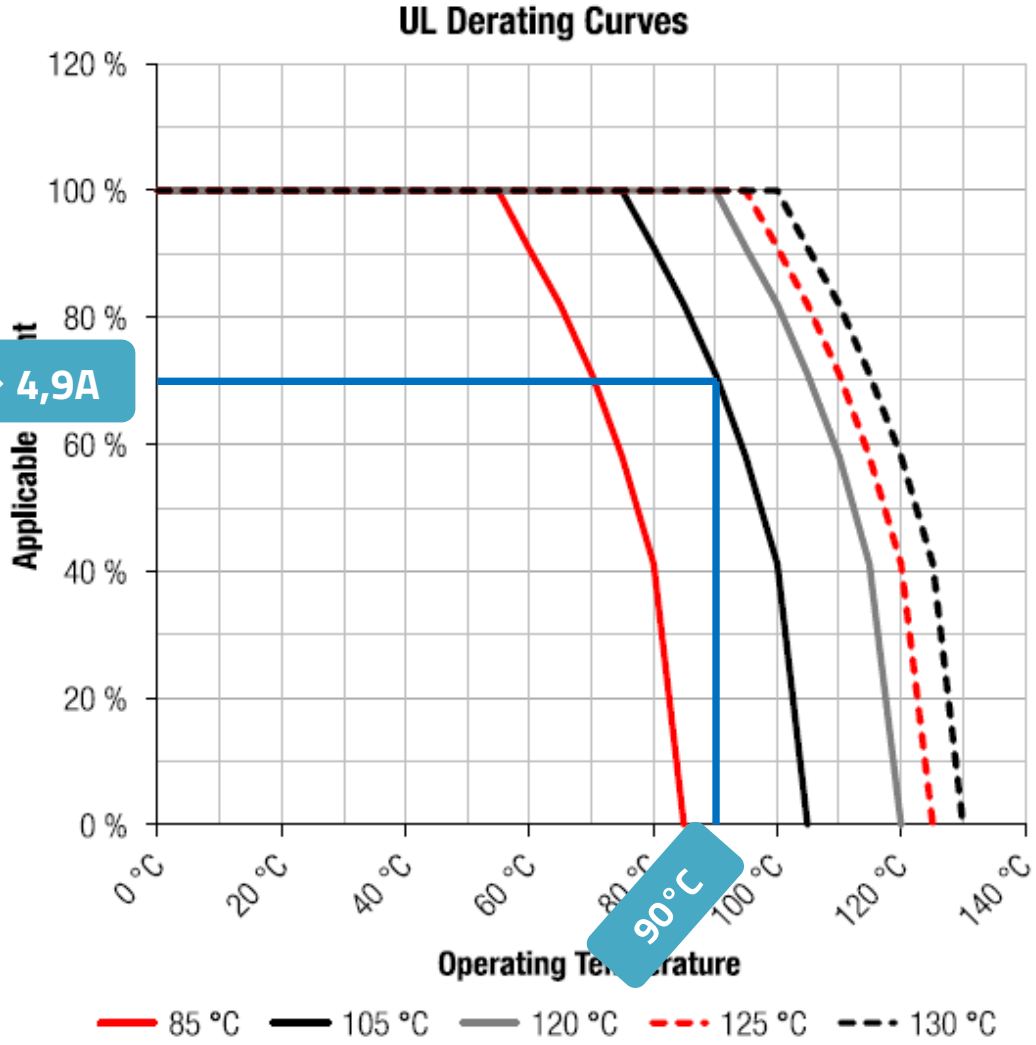
ELECTRICAL

WORKING VOLTAGE: 250 VAC
INSULATOR RESISTANCE: >1000 MOHM
DIELECTRIC WITHSTANDING VOLTAGE: 1500 VAC/MN
CONTACT RESISTANCE: 20 mOHM MAX



Derating curve VDE

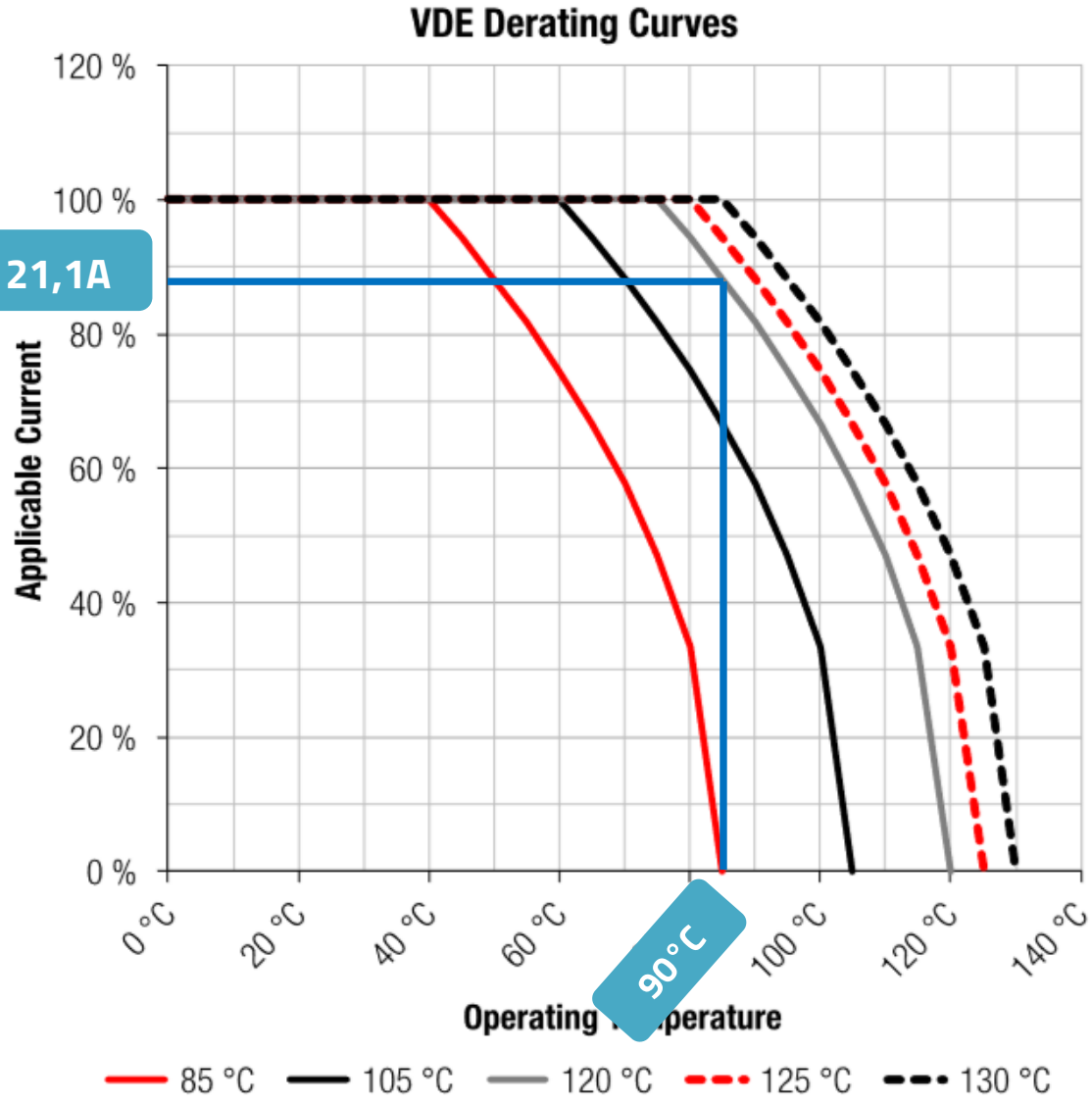
How to decrease current when ambient temperature increase:

- Maximum connector temperature
- **ΔT ≤ 45K**
- ΔT proportional to I²

ENVIRONMENTAL

COMPLIANCE: LEAD FREE AND ROHS

ELECTRICAL	UL	
CURRENT RATING:	16A	
WORKING VOLTAGE:	300VAC	750VAC
WITHSTANDING VOLTAGE:	1,6KV	3KV
CONTACT RESISTANCE: 20 mΩ MAX		



Agenda

- Current design for connectors
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- Heat in a cable
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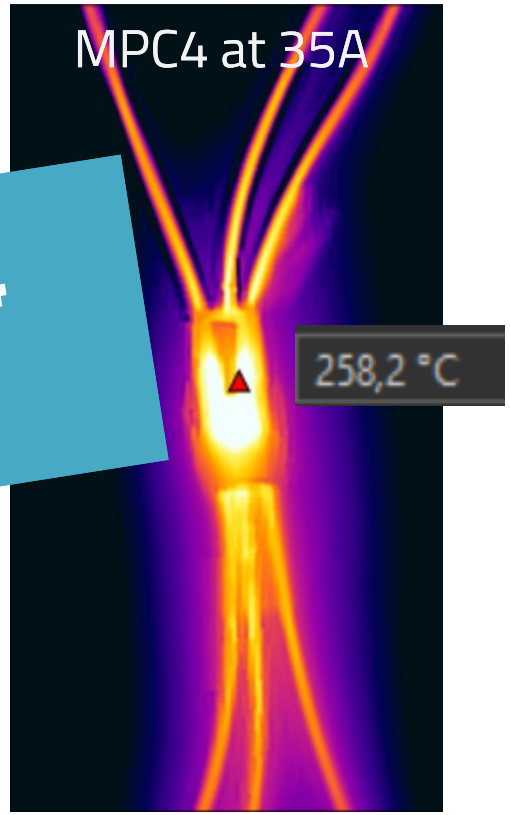
- Derating curve
- Connector horror show

Connector horror show

What happens when you increase current ? MPC4:
9A - max +105°C

Horror current > working current **x4**

No fire



All pictures: WE eiCan

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