Derating of Connectors

more than you expect

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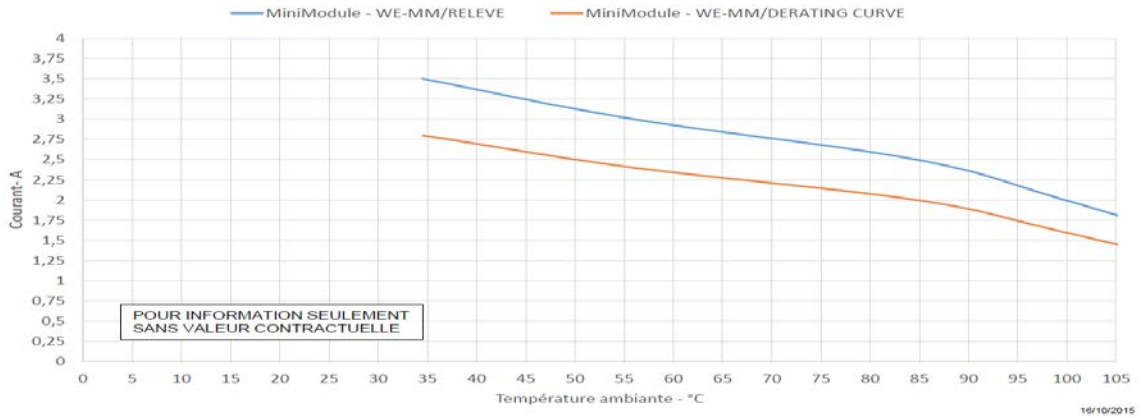
Agenda

- **Definition Derating**
- **Theoretical Calculation**
- **Derating Test**
- **Testequipment**
- **Rated Current Curve**
- **Derating Curve**
- **Error Images**
- **Designtipps for critical applications**

Definition Derating

- The derating curve describes the maximum permissible power dissipation of an electrical or electronic component depending on its ambient temperature. (Wikipedia)



- Derating literally means underloading, i.e. the affected component is operated below its maximum permissible load

Definition Derating

- **Influencing factors :**

  - Ambient-temperature according to DIN EN 60204-1
  - Maximum permissible self-heating of the component defined by UL or VDE(UL 30K, VDE 45K)
  - Number of poles

NB CIRCUITS	2-3	4-6	7-10	12-24
AMPERES	9	8	7	6

  - Current and Voltage

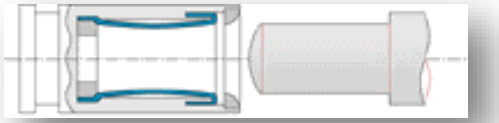
ELECTRICAL
CURRENT RATING: 3A MAX
WORKING VOLTAGE: 125V AC
INSULATOR RESISTANCE: >5000 MOHM
DIELECTRIC WITHSTANDING VOLTAGE: 1000V AC/MN

  - Limit temperature and temperature coefficient of the insulating material (if available)→Würth Elektronik = Maximum-Temperature

ENVIRONMENTAL
OPERATING TEMP:: -40°C UP TO 85°C
COMPLIANCE: LEAD FREE AND ROHS

Definition Derating

- **Additional influences:**
  - Mating cycles e.g. wear, contact normal force
  - Connection (transition resistances):
    - circuit board e.g. Solder joint, press-in zone
    - Cable e.g. tightening torque, crimp connection
  - Thermal management e.g. cooling, encapsulation, convection



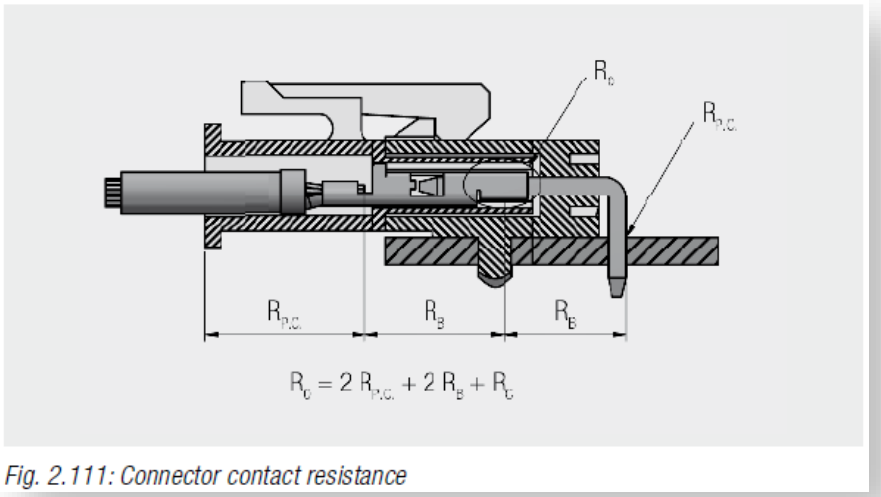


Fig. 2.111: Connector contact resistance

Theoretical Calculation

- **Electrical Power: $P = I^2 R$**

- Temperature rise is directly proportional to the electrical power :
- $\Delta T = I^2 R k$
- (k=Material Constant, ΔT = Temperature Rise in Kelvin)

- Temperature rise is directly proportional to the transition-resistance and to the square of the current

Theoretical Calculation

- **Thermal Energy W in Joule:**

- **$W = RI^2t$** (t= time in seconds)

- **Thermal energy is directly proportional to the transition-resistance and time as well as to the square of the current**

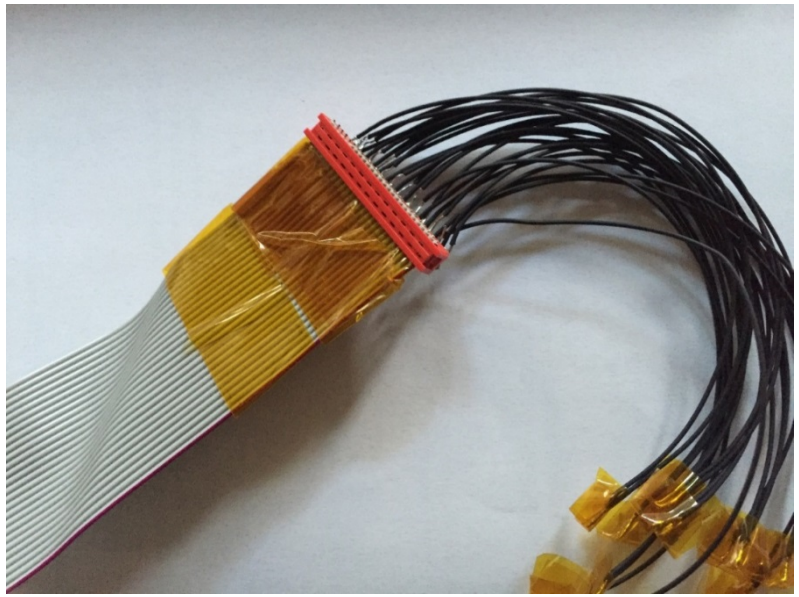
….. therefore ensure adequate ventilation / cooling of the system!…

Bildquelle: Würth Industries

Derating Test

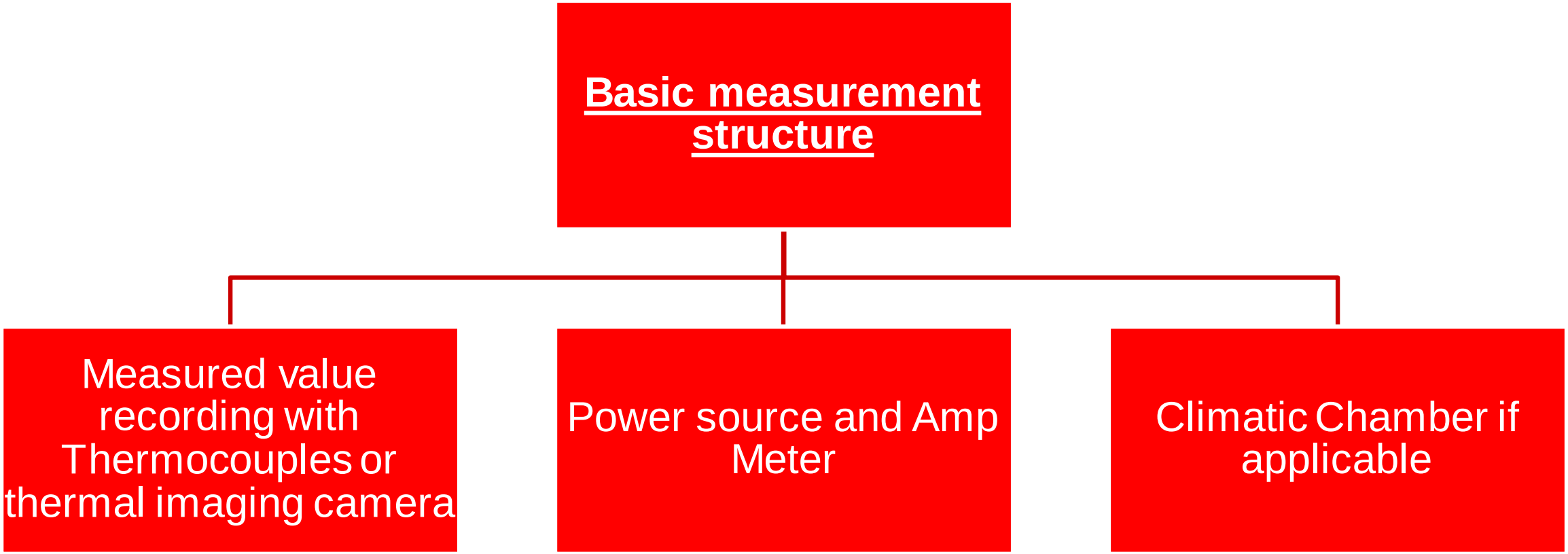
- **Test Methode:**
  - According to DIN EN 60512-5-1 (Tests of current carrying capacity)
    - **All contacts of the test specimen must be loaded at the same time with the specified current**

      (Connection in Series)

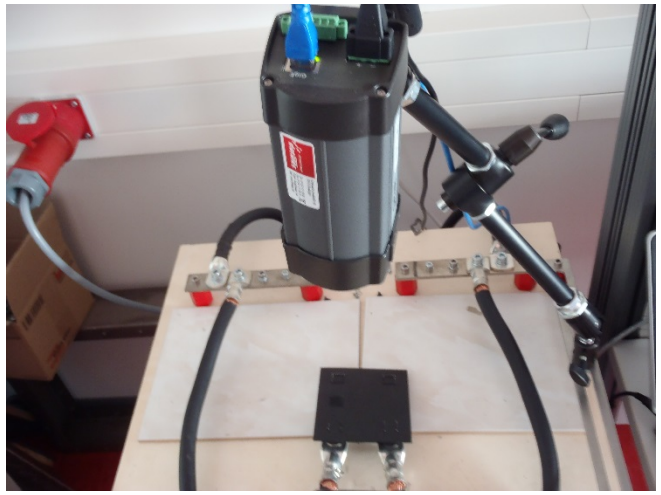


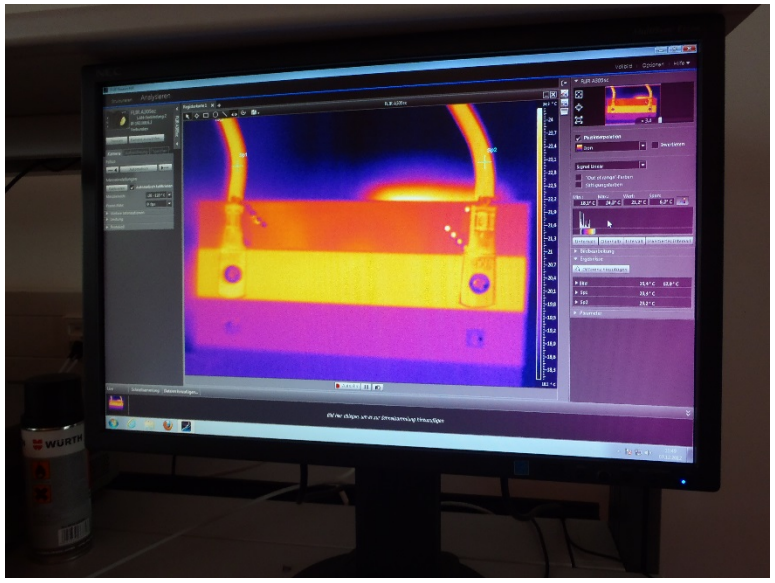
Source : WE-ArB

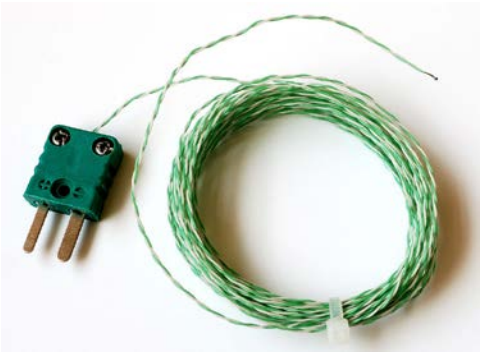
Testequipment



Testequipment







Source:electronicsandradios.com

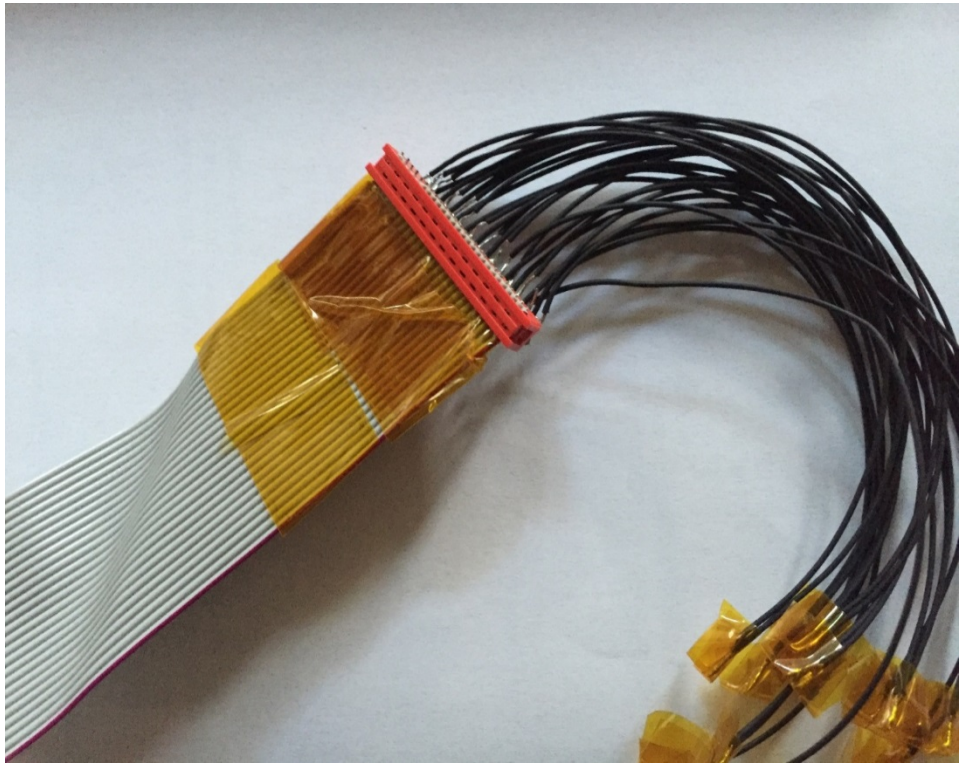
Source: sefelec.fr

Source:fluke.com

Testequipment

Source:frealchambers.com

Testequipment



Source:
WE-ArB

Measurement

- **Determination of current rating curve and derating**

The DUT is put under load step by step with increasing currend at ambient temerature.

During this process temerature will be permanently measured at defined points of measurement.

Temperature of the DUT has to be measured at the beginning of the test. As soon as the first current is applied, temperature has to be measured at least every 5 minutes.
If temperature rise does not exceed 2K during 3 measurements with 5 minutes in between each measurement, then the actual current has to be applied for one hour. This ensures that the DUT reaches thermal stability.

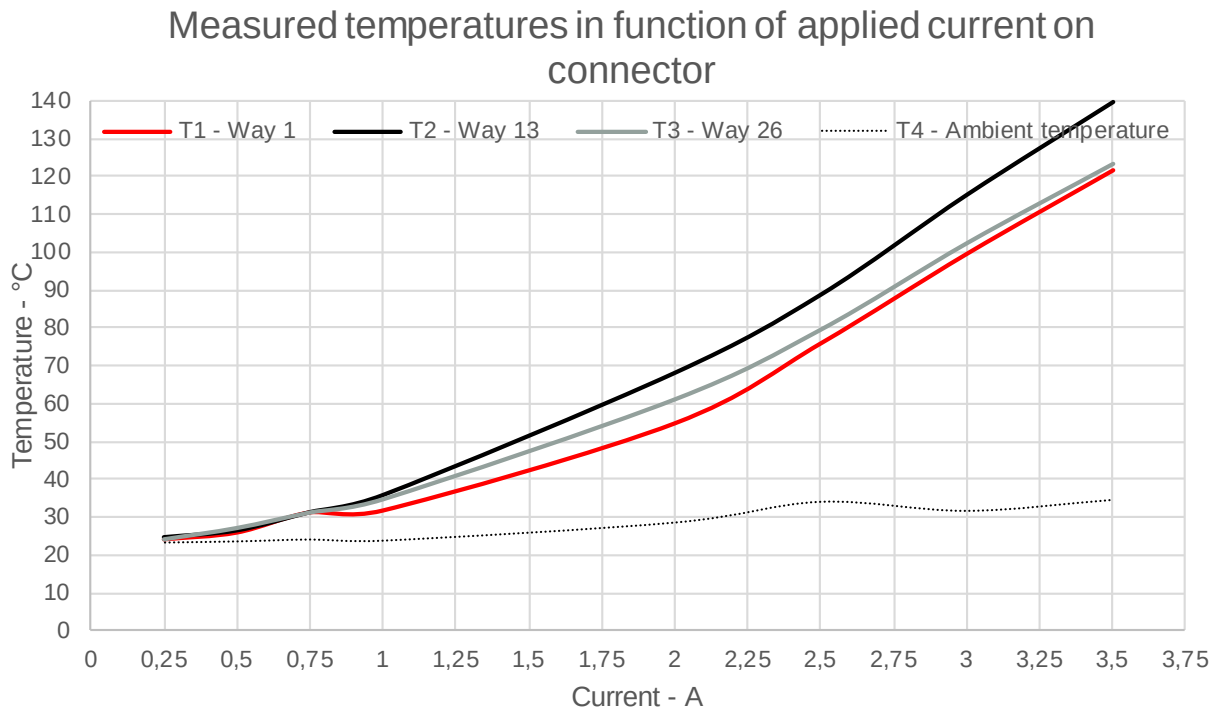
In the next step current can be raised again and the 3 measurements and the hold time must be proceeded.

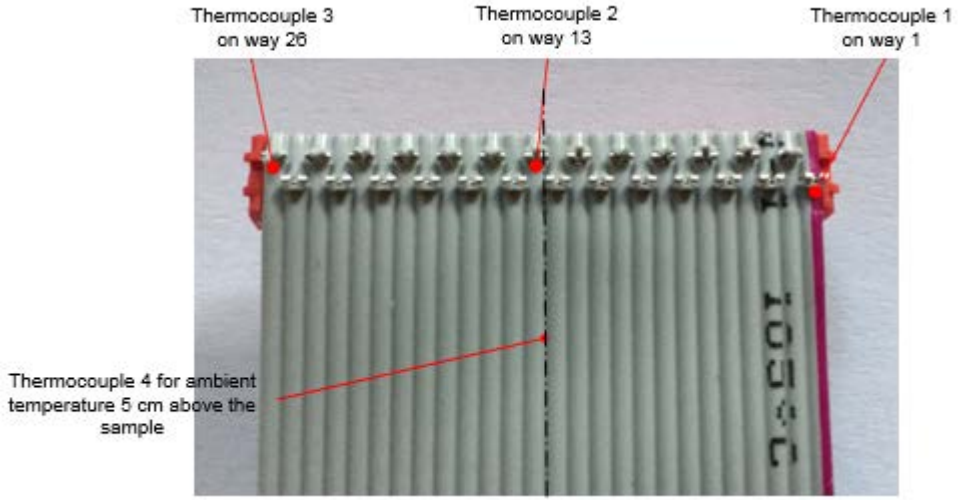
This loop will be continued until the temperature of the DUT reached ist maximum.
The whole process must be done with 3 samples.

According to the normative the base current will be multiplied by 0,8 to get the permitted load current.

Rated Current Curve

- Based on the maximum rated current, a base curve (rated current curve) can be determined.



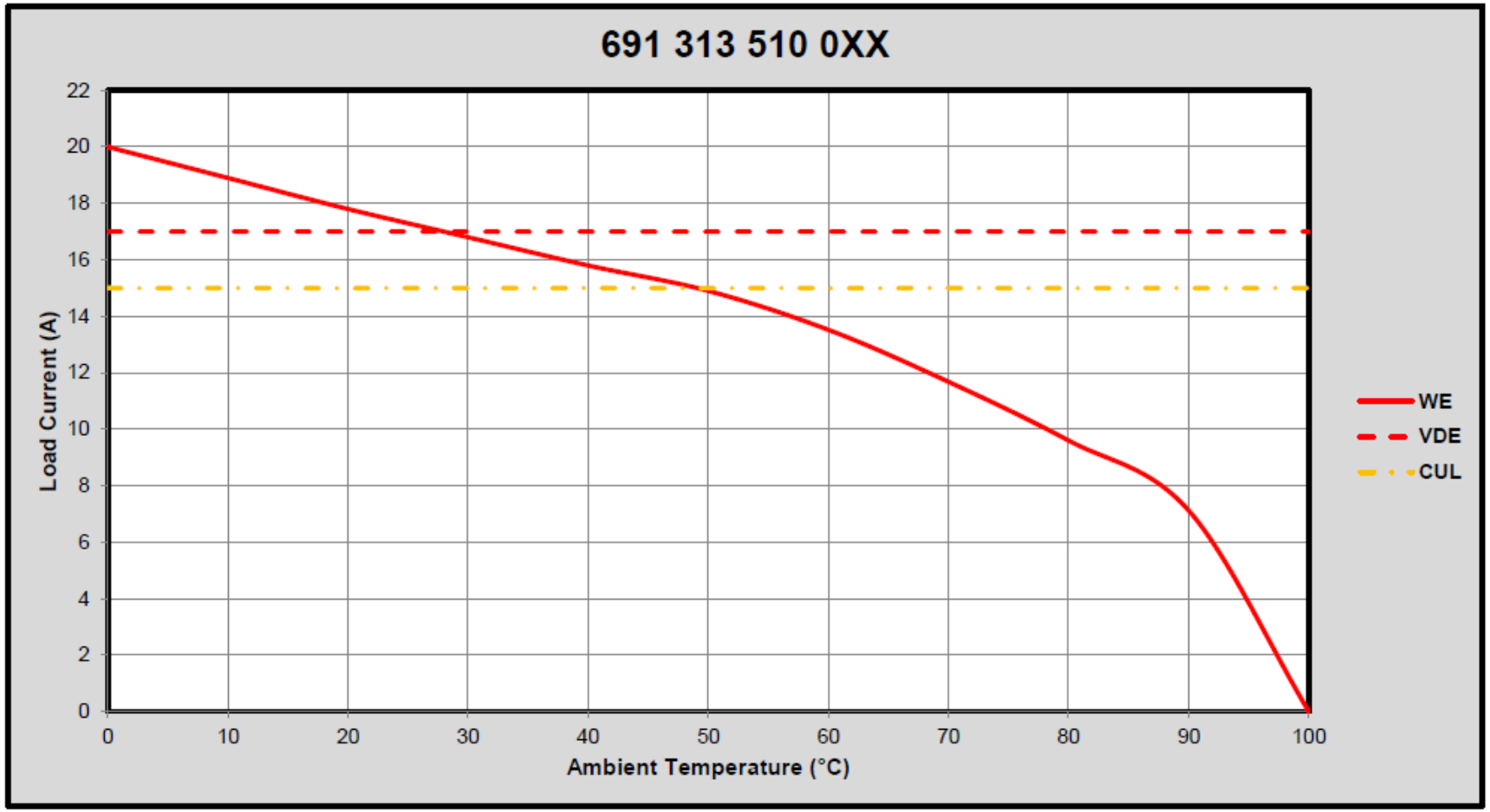


Source: WE-ArB

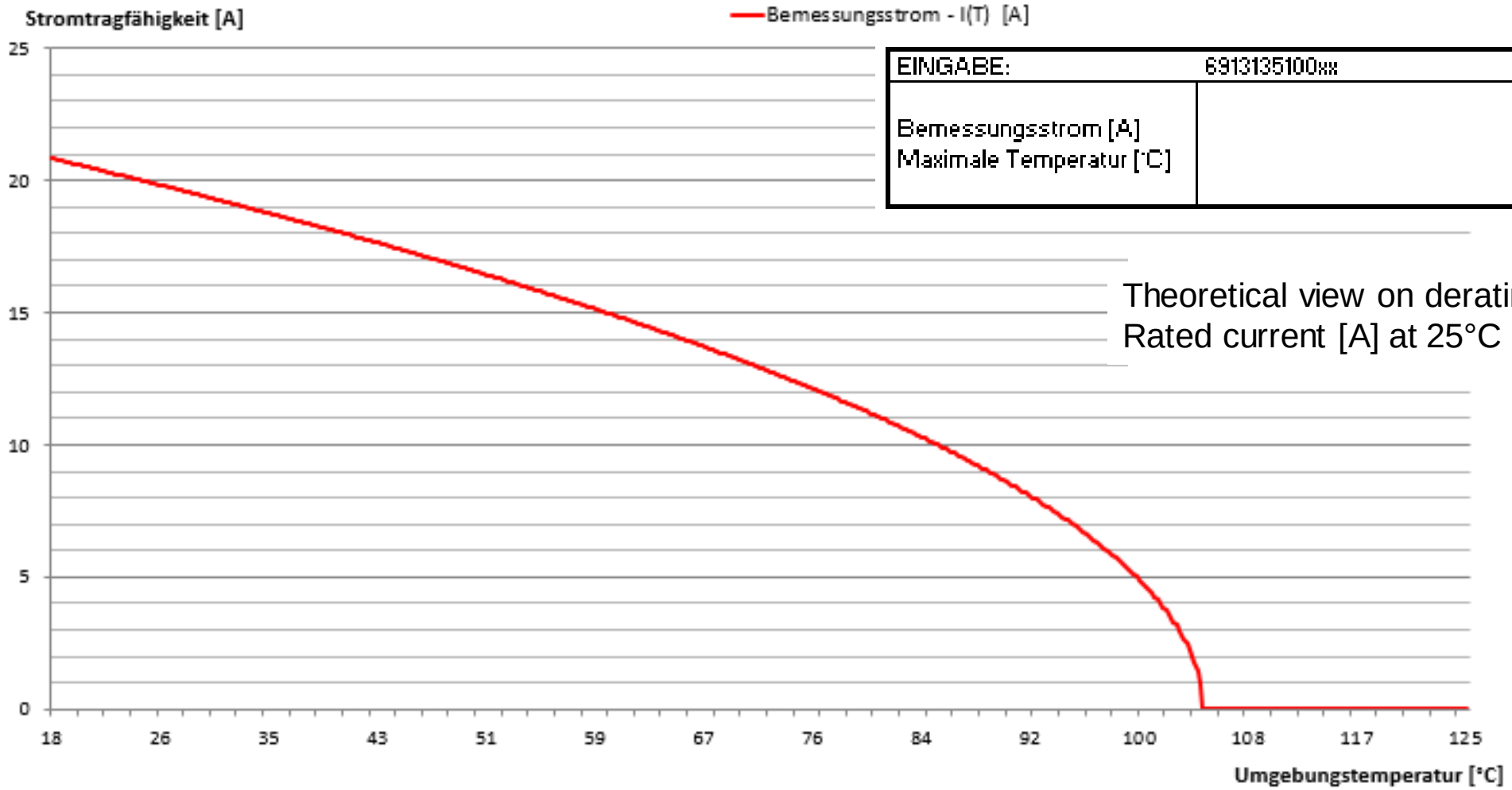
Derating Curve

- Ways of determining the rated current curve :
  - Measurement in a climatic chamber
    - Different defined temperatures
      - 1000sec. stabilizing at each point
  - Theoretical Calculation
    - Underlying load current
    - Empirically determined value
    - Maximum load current (Temperature Delta in Kelvin)
- The derating curve is derived from the rated current curve.

Derating Curve (measured)



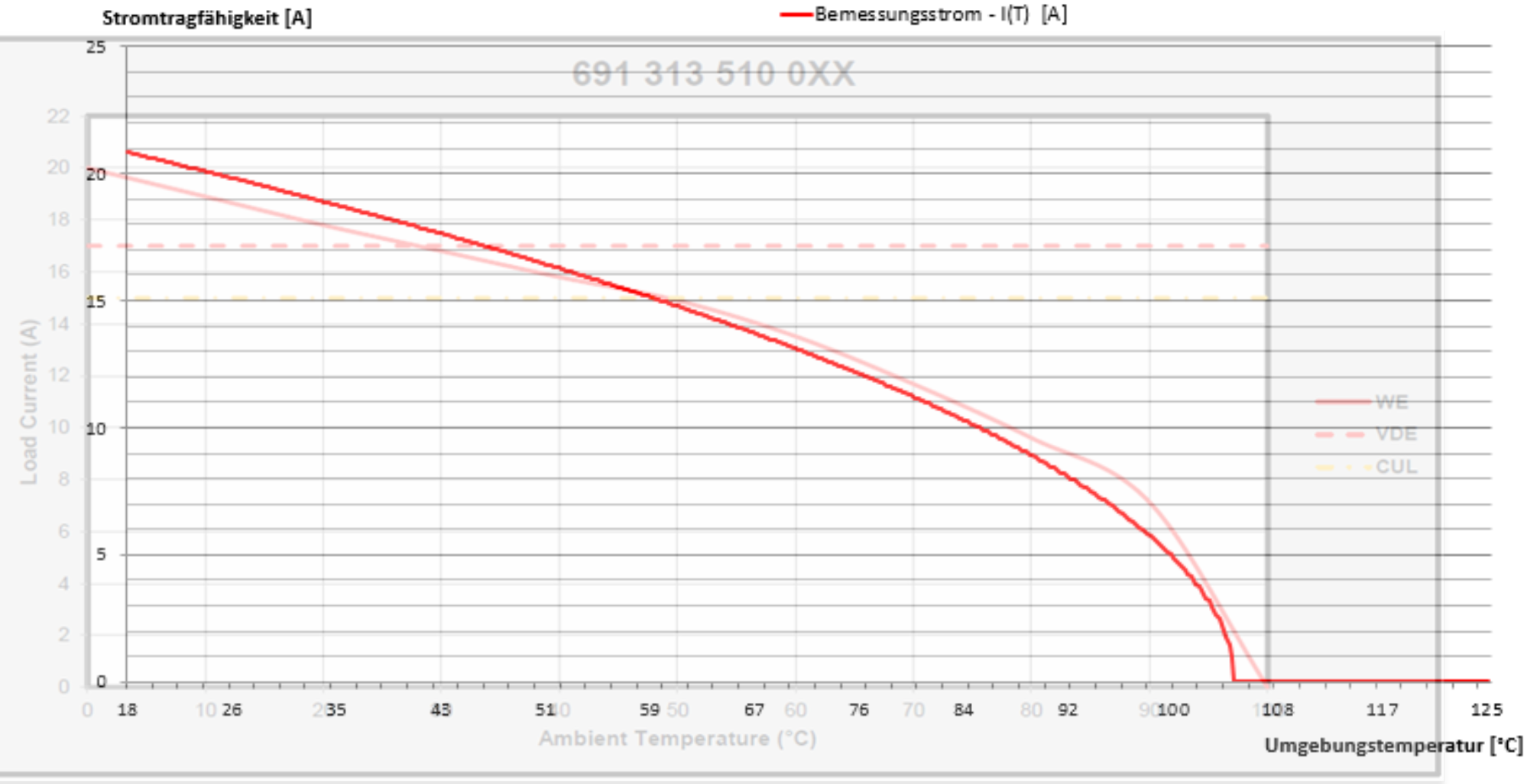
Derating Curve (calculated)



EINGABE:	6913135100xx
Bemessungsstrom [A]	20
Maximale Temperatur [°C]	105

Theoretical view on derating of WR-TBL Series 313
Rated current [A] at 25°C

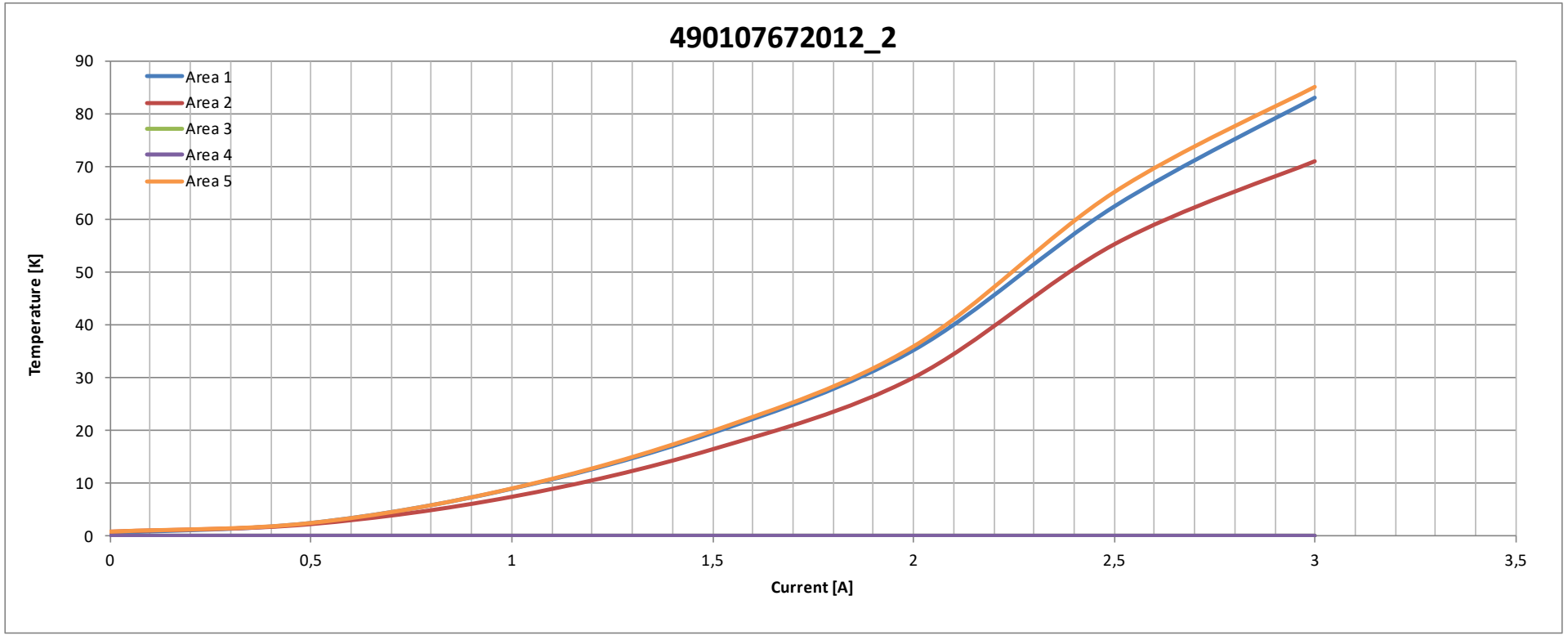
Derating-Curves comparison



Derating Proceedures

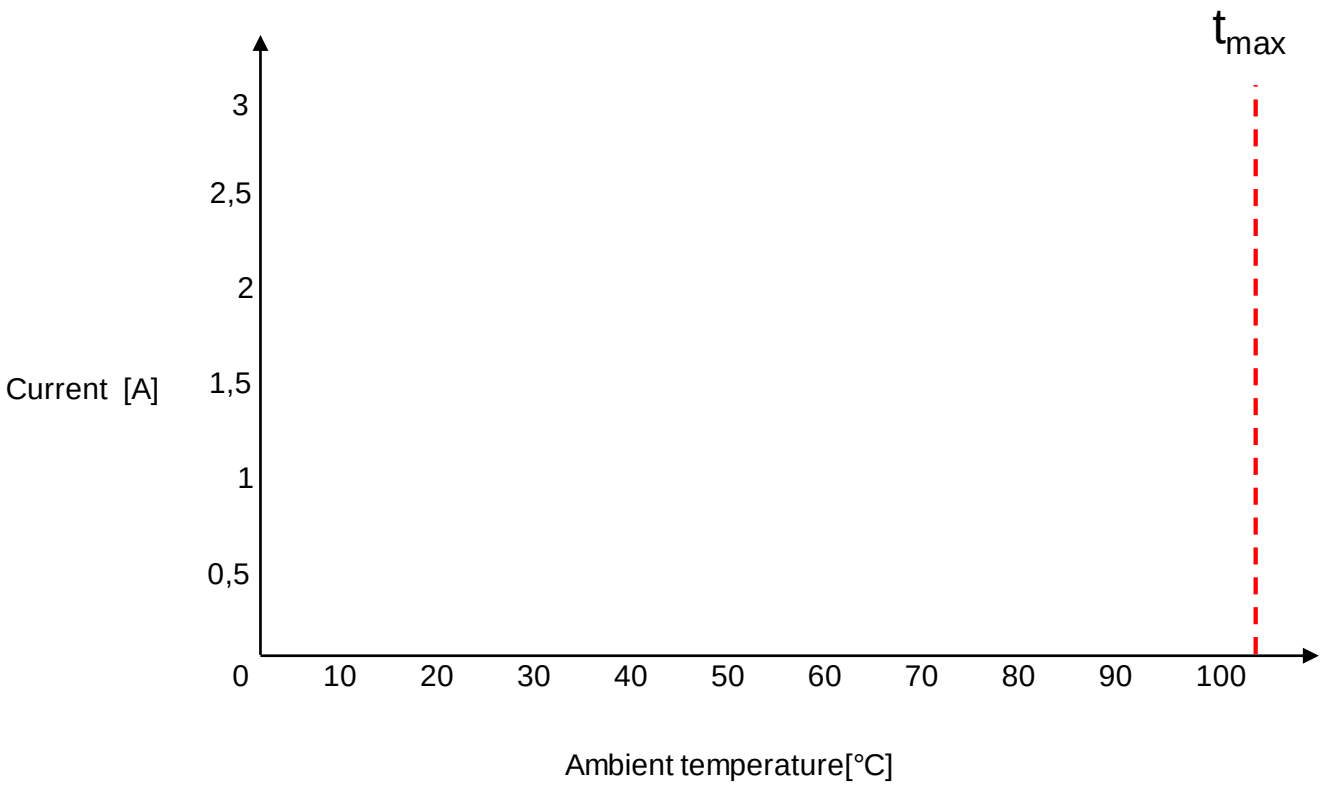
according to DIN EN 60512-5-2

Current Capacity Curve:



Derating Curve Calculation

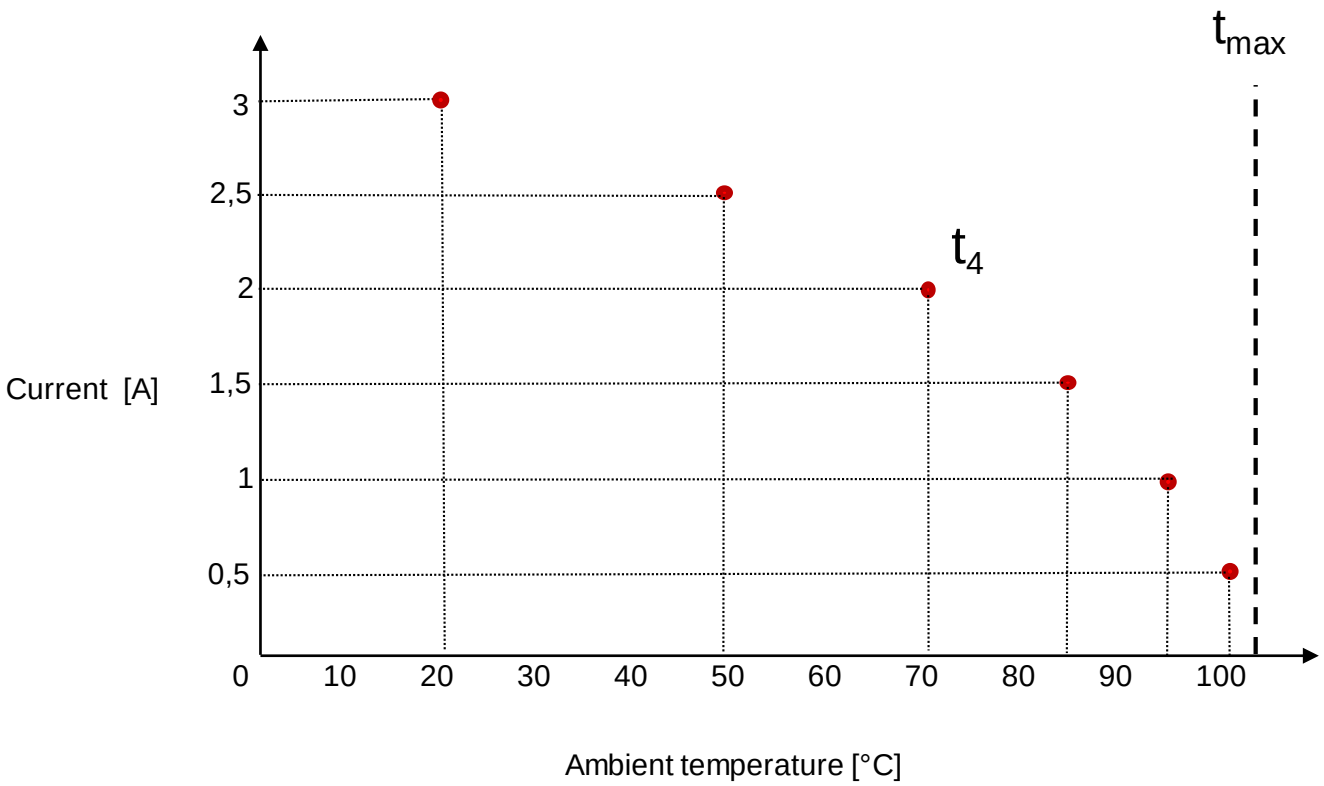
according to DIN EN 60512-5-2



- Enter the upper temperature limit t_{max}
- Most of the time it is the specified temperature for the plastic in use

Derating Curve Calculation

according to DIN EN 60512-5-2



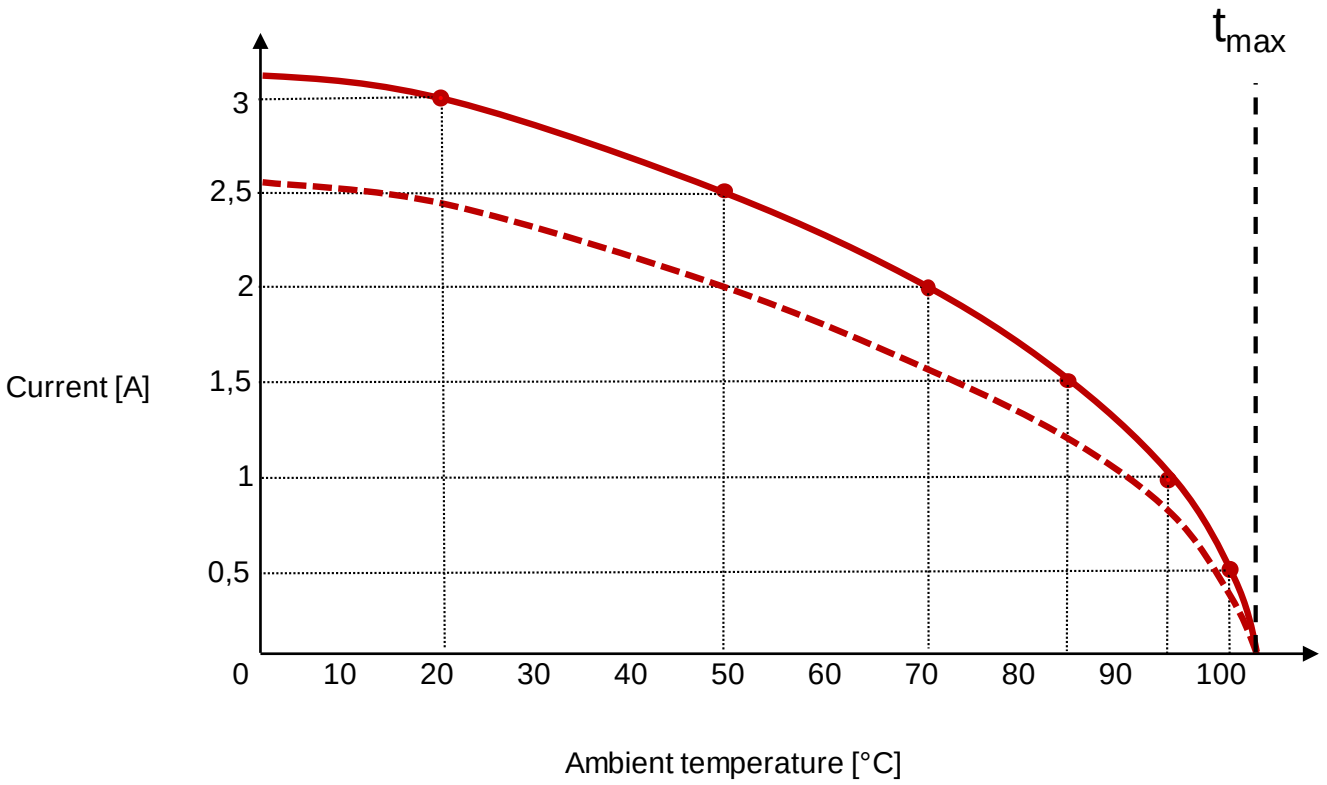
Current [A]	Δt [K]
0,5	2,47
1	8,95
1,5	19,51
2	35,15
2,5	56,34
3	82,95

- The t_{max} line minus Δt of the derating curve
- Minimum 3 steps

Example: $t_4 = t_{max} - \Delta t_4$; $I_4 = 105°C - 35{,}15K = 69{,}85°C$

Derating Kurve Kalkulation

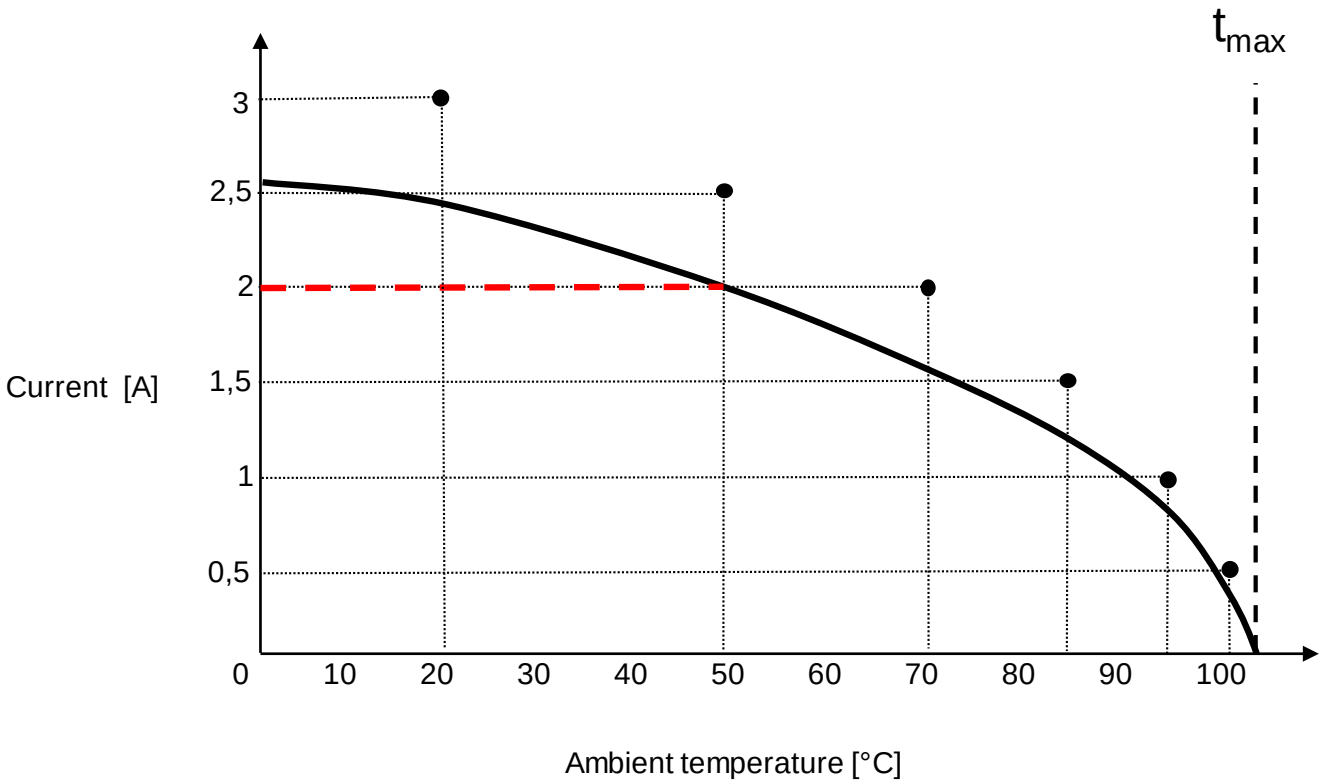
according to DIN EN 60512-5-2



- The line across the different points is the derating curve
- For safety and to compensate failures in measurement the resulting line must be multiplied by 0.8
- Finally this is the “correct” derating curve

Derating Kurve Kalkulation

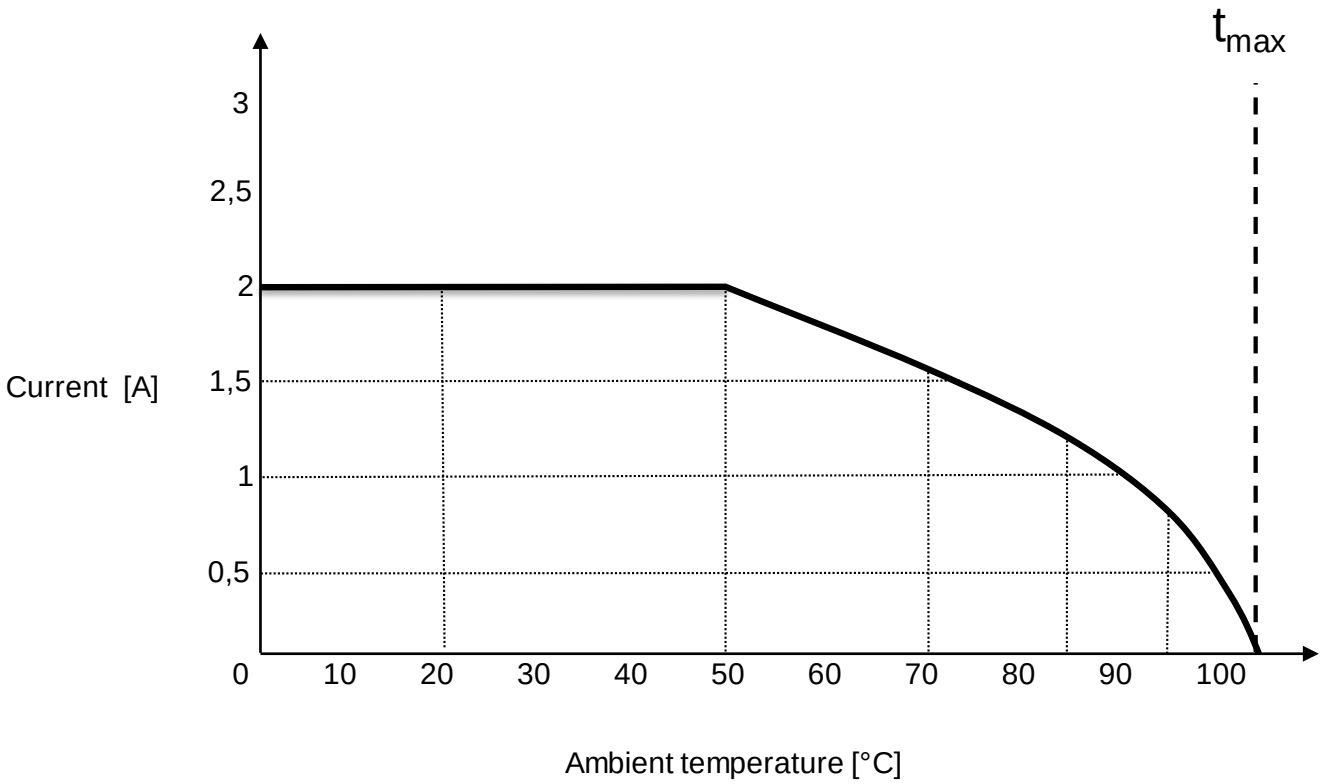
according to DIN EN 60512-5-2



- In some cases there is factors (e.g. cables) that may limit current
- The component itself could carry higher currents, but the transmission system is limited
- In this example the cable is limited to 2A

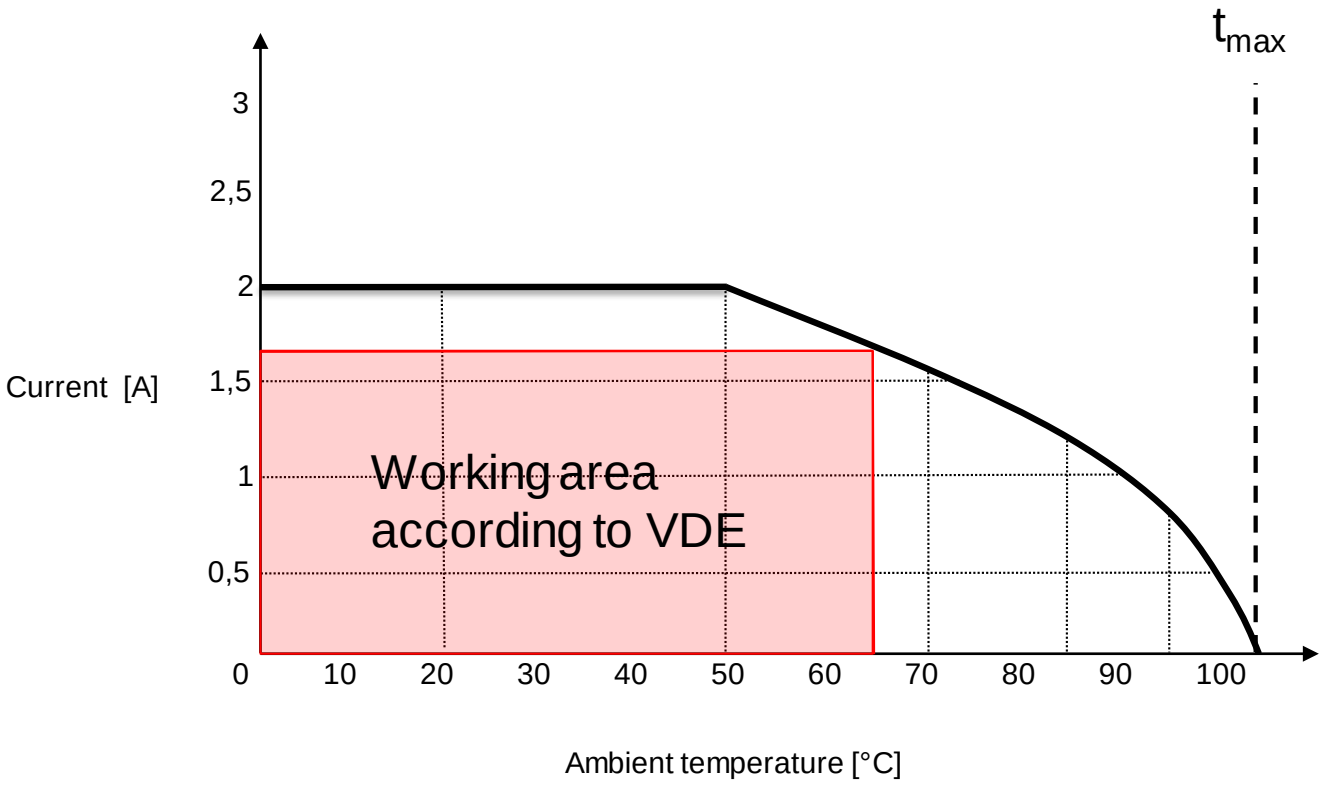
Derating Kurve Kalkulation

according to DIN EN 60512-5-2



- Final Derating Kurve

Arbeiten mit der Derating Kurve



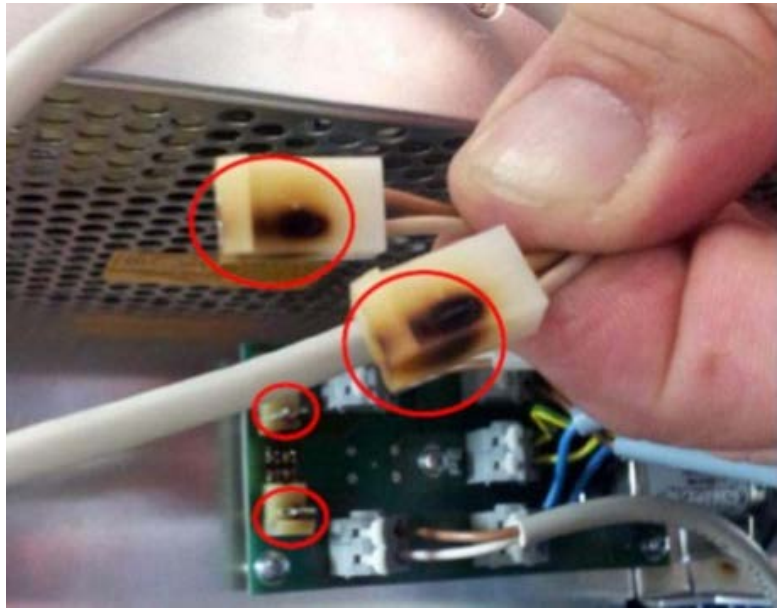
- According to UL or VDE normatives some components are limited in point of temperature rise
- E.g. Terminal Blocks:

  UL $\Delta t_{max} = 30K$

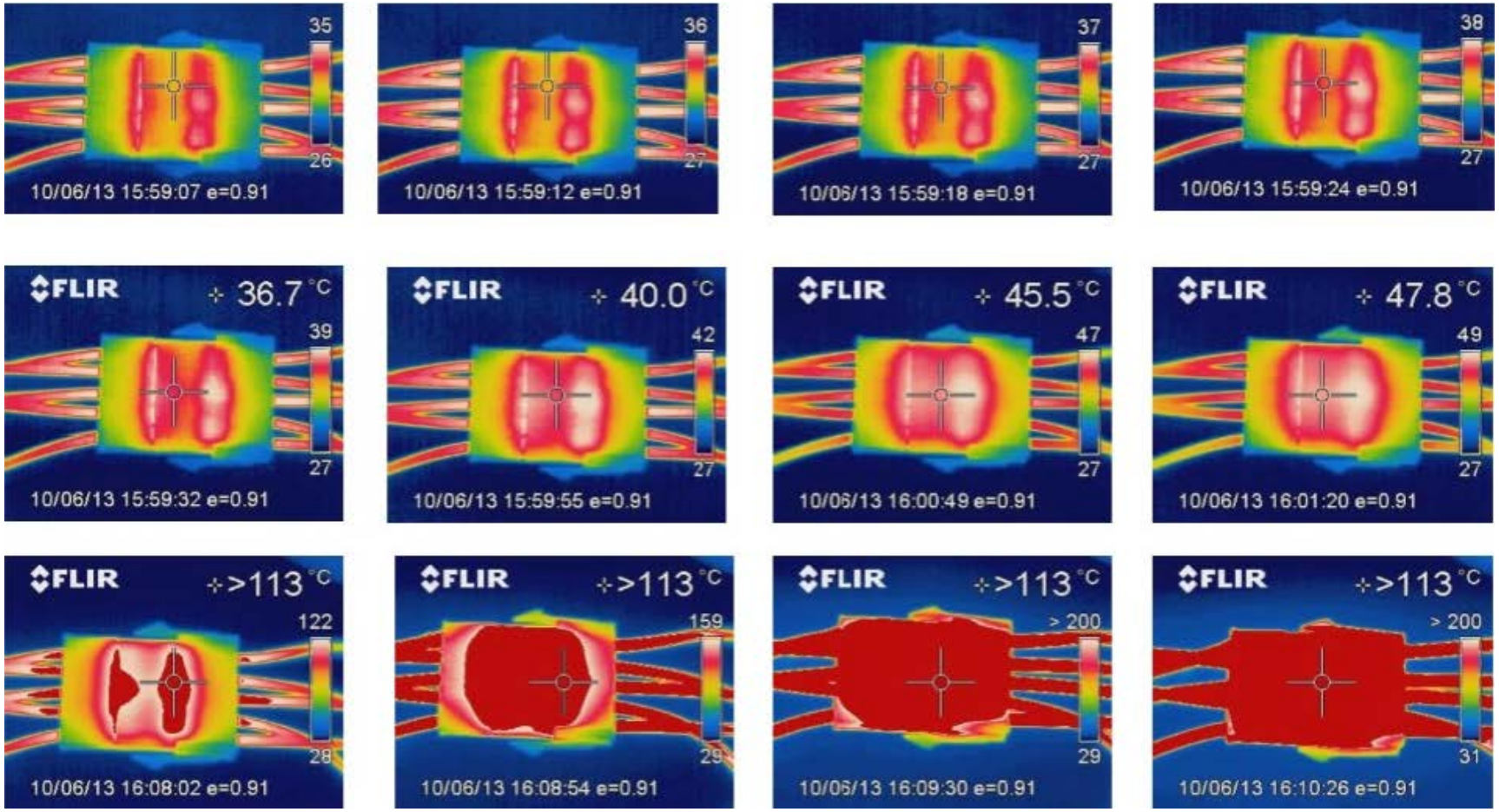
  VDE $\Delta t_{max} = 45K$
- In this example current is measured at 20°C ambient temperature

Error Images

- **Possible situations with non compliant derating:**
  - Oxidation of contact surfaces (overheating)
  - Yellowing of plastics
  - Loss of specific mechanical properties
  - Insulation material melts or burns
  - Complete failure of the component and the application



Error Images



MPC-4 / 5 poles

Permissible rated current : 8 A

Actual current : 25 A

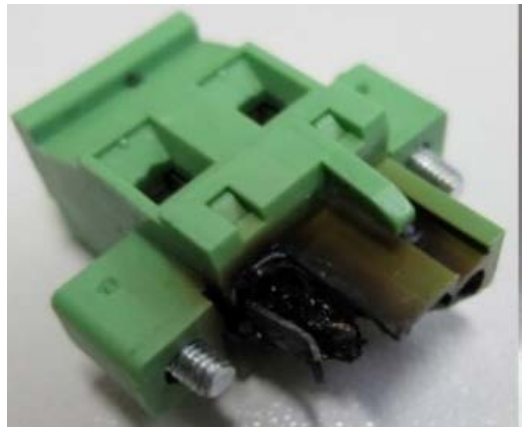
Time to fire : 10 min

Error Images

- **Not aware of derating**

  - Application: Continuous Heater
  - Max. Temperature in housing : 90°C
  - max. Current: 12 A
  - Specified current: 15 A at 20°C
  - Specified Temperature Range: -40°C – +105°C

  - Error Image:
    - Plastic melted, no open fire



Derating calculation: 90°C = max. Current 6,5 A

Designtipps for critical applications

Optimizing all parameters for critical applications :

- Use the largest possible cable cross-section
- Keep the cable as short as possible in the area of the plug connection
- Dimension all components as large as possible
- Optimize connection of Cable (Crimp, Rising Cage instead of WireGuard, Observe tightening torques)
- Establish ventilation, active cooling, metal surfaces for dissipation, convection
- Optimize connection to the PCB (Soldering connection, PressFit)

Questions

Thank you for your attention