HOW TO DEAL WITH HIGH INRUSH CURRENT AND DERATING OF CONNECTORS

Goetz Schattmann
Field Application Engineer eiCan

- Derating repetition
- What about inrush currents?

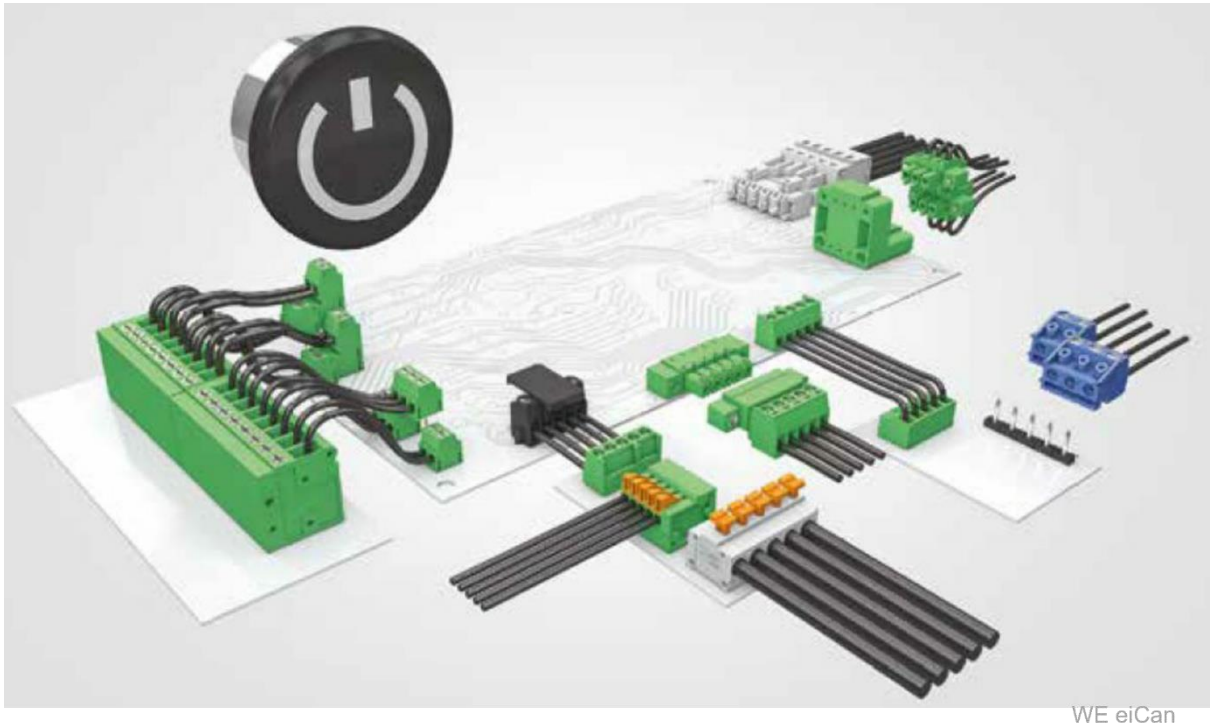
A DERATING SUMMARY

Basics

CURRENT DESIGN FOR CONNECTORS

CURRENT DESIGN FOR CONNECTORS

Datasheet



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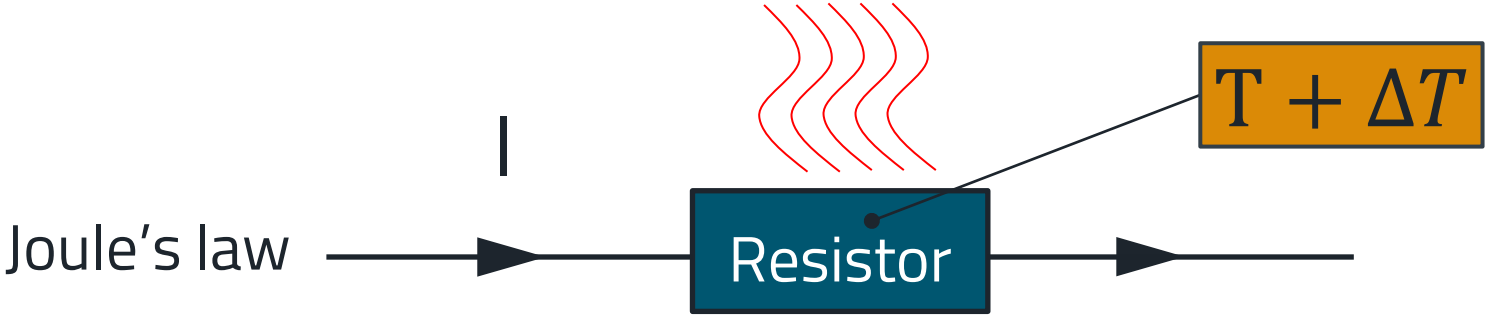
ENVIRONMENTAL	
OPERATING TEMPERATURE: -40 UP TO 105°C	
COMPLIANCE: LEAD FREE AND ROHS	
ELECTRICAL	cULus
CURRENT RATING:	20 A
WORKING VOLTAGE:	300 VAC
WITHSTANDING VOLTAGE:	1.6 KV
CONTACT RESISTANCE:	20 mOhm max

CURRENT DESIGN FOR CONNECTORS

Electricity and temperature rise



CURRENT DESIGN FOR CONNECTORS

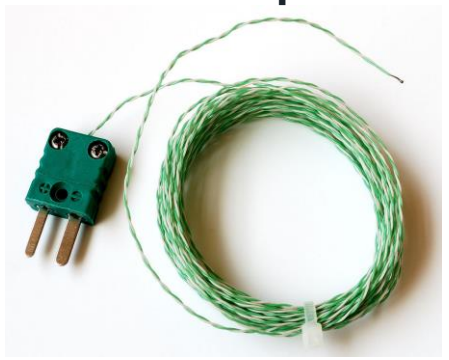
How working current is designed in WE

Temperature rise test

- Standard used EIA364-70
- 3 poles (choice as UL1059)
- Working current in series
- Reach stable temperature (3 measurements each 5 mn equal ±1°C)
- **At the hottest point**
  - **UL: ΔT ≤ 30K** (choice as UL1059)
  - **VDE: ΔT ≤ 45K** (VDE063)

Chamber

Thermocouple



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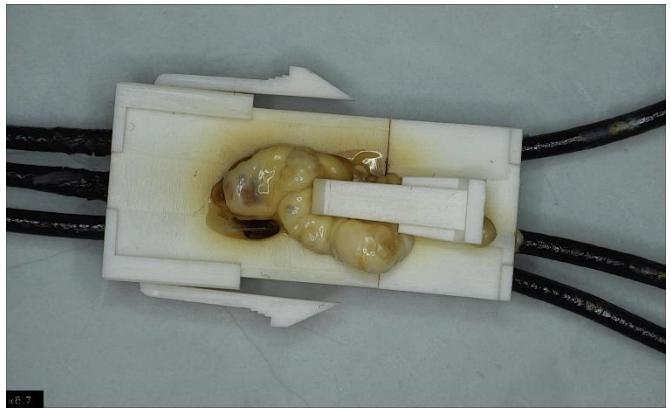
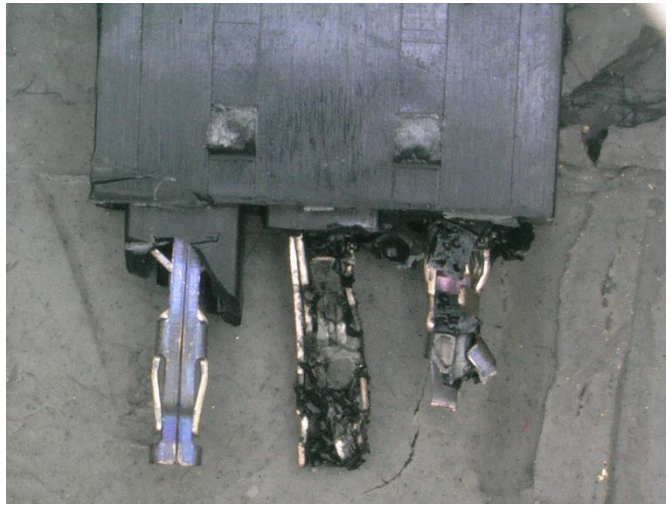
CONSEQUENCES OF EXCESSIVE TEMPERATURE

- Heat development
- Increase corrosion speed (doubling every 10°C)
- Plastic aging
- Metal relaxation
- consequently increase of contact resistance

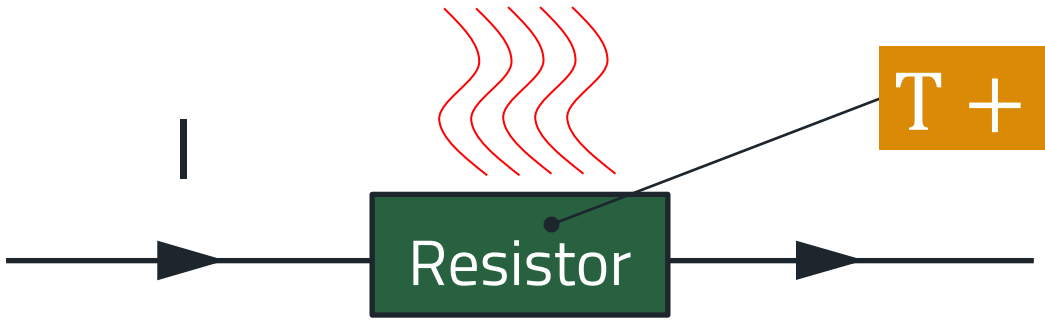




CURRENT RATED TEMPERATURE RISE

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

Joule's effect

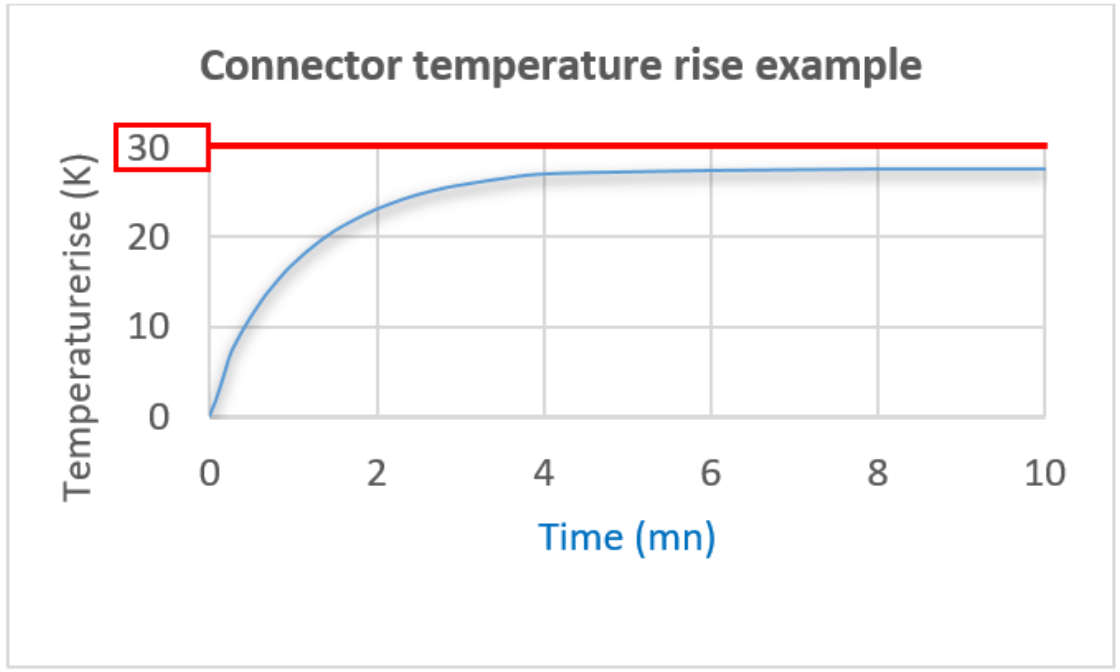


$$\frac{\Delta T_1}{\Delta T_2} \approx \frac{{I_1}^2}{{I_2}^2}$$

Connector T (°C) = ambient T (°C) + ΔT (K)

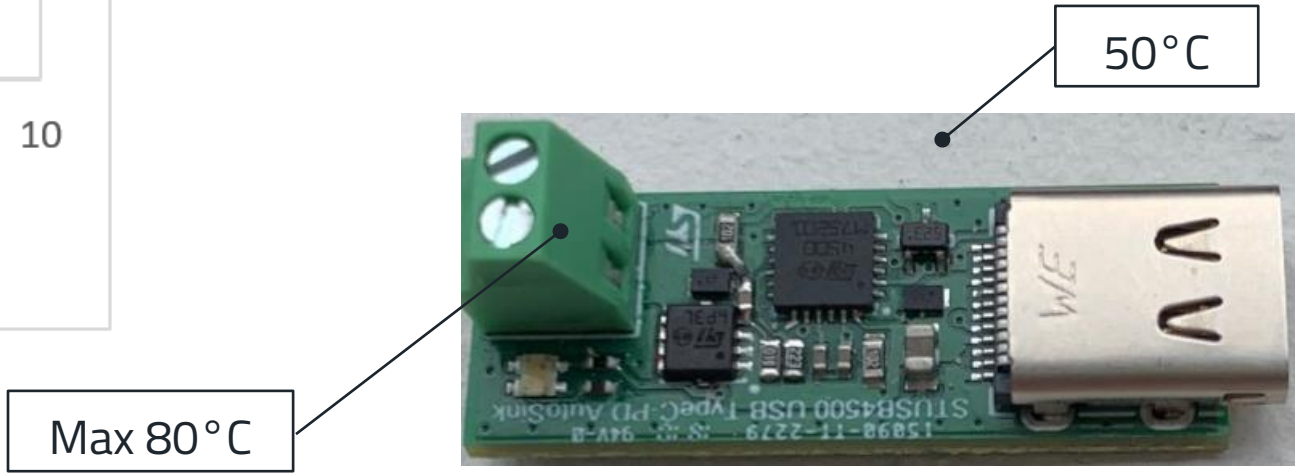
CURRENT RATED TEMPERATURE RISE

In still air



connector temperatre rise in mn

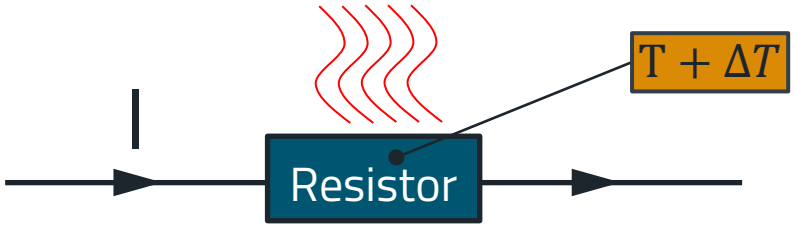
UL standard ΔT < 30K



Pictures from WE

TEMPERATURE RISE RULE

Electricity and temperature rise



- P (W) Power dissipated by the resistor
- R (Ω) Resistance
- I (A) Current
- ΔT (K) Data given usually in Kelvin
- K Constant defined by resistance, material and environnement

Joule's law

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

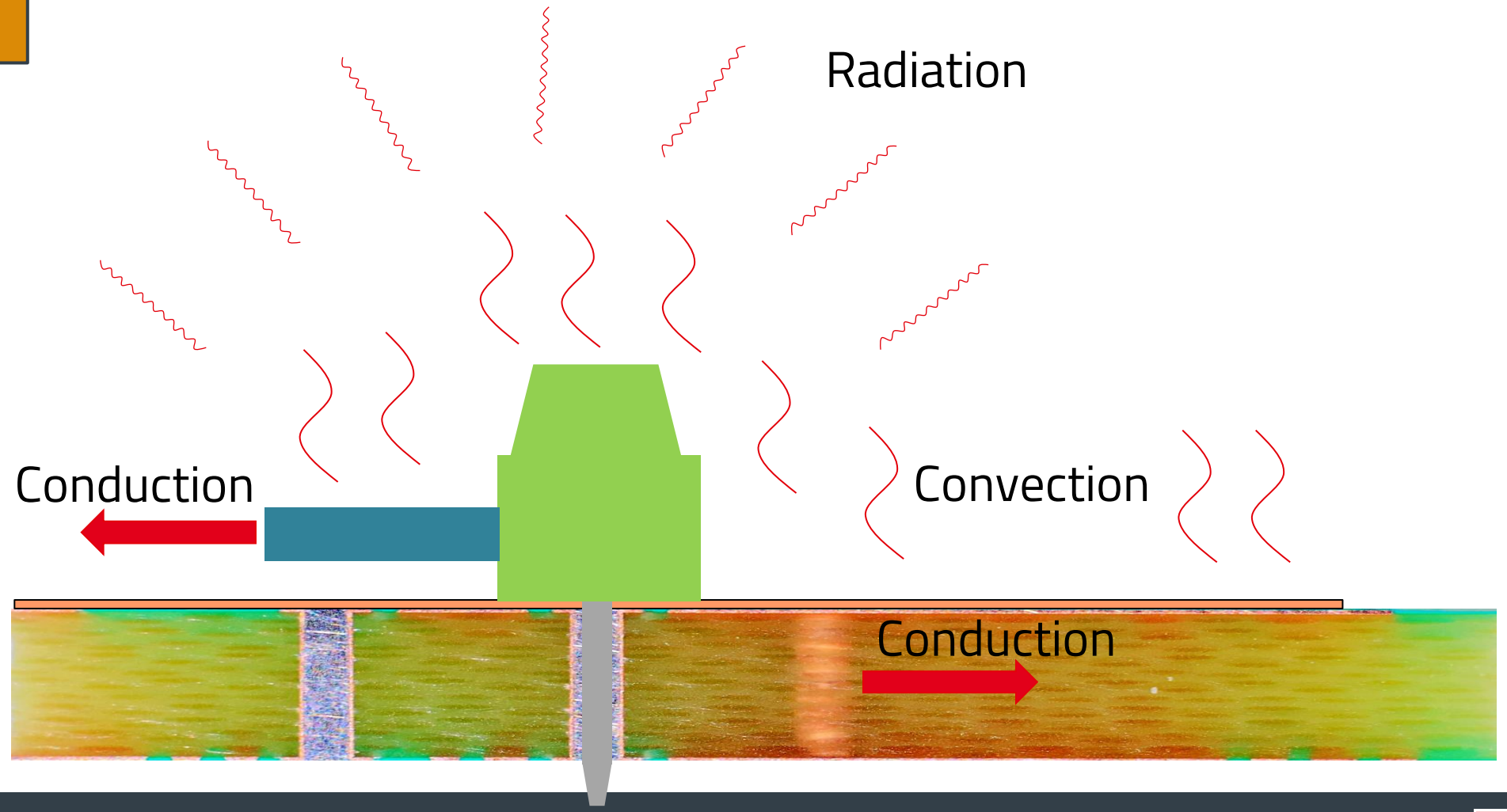
$$\Delta T = k \cdot R \cdot I^2$$

Temperature rise is proportional to the square of the current

HOW HEAT IS DISSIPATED

Dissipation types

$$W = P \cdot t$$

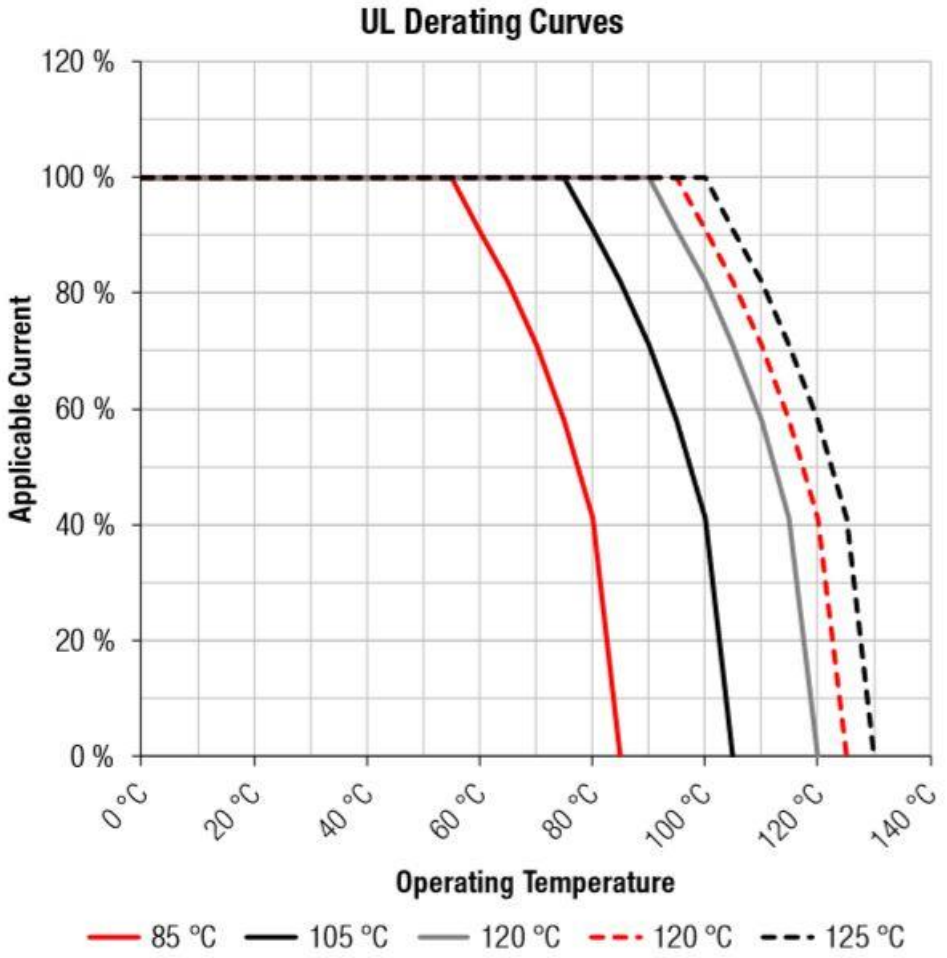


DERATING CURVE

Limits

- TBL

- Operating temperature max 105 °C
- Current rating 20A
- ΔT **≤ 30K UL**
- ΔT **≤ 45K VDE**



INRUSH CURRENT

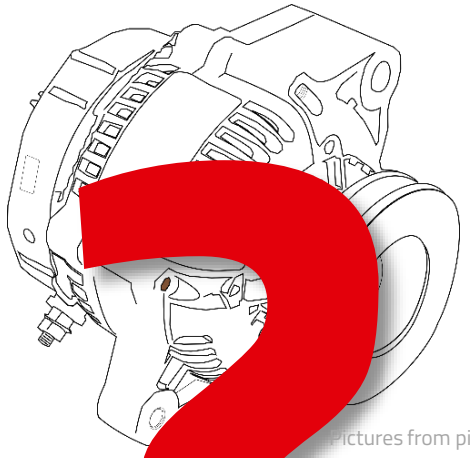
What’s different ?

THE GOOD QUESTION

Pitch 2,54mm

€

ELECTRICAL	cULus
CURRENT RATING:	6 A
WORKING VOLTAGE:	150 VAC
WITHSTANDING VOLTAGE:	1.3 KV
CONTACT RESISTANCE:	20 mOhm MAX



Pictures from pixabay

Current x 6 during short time ?

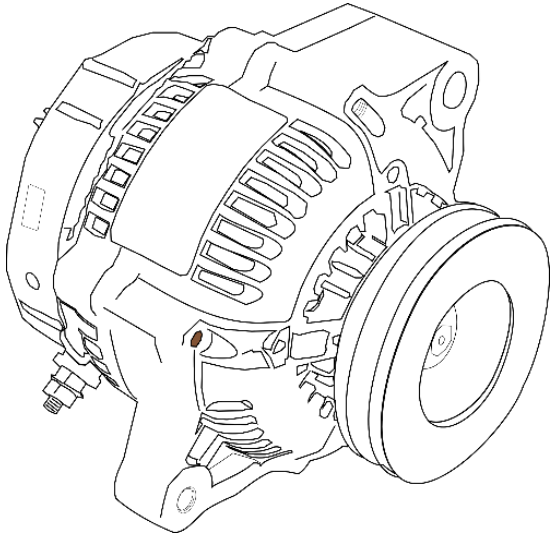
Pitch 10,16mm

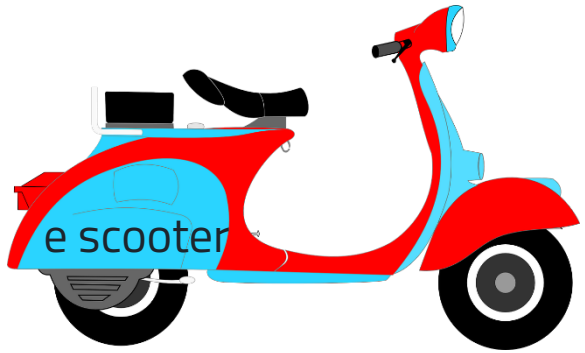
€€€

ELECTRICAL	cULus
CURRENT RATING:	57A
WORKING VOLTAGE:	300VAC
WITHSTANDING VOLTAGE:	1.6KV
CONTACT RESISTANCE:	20 mOhm max

Pictures from WE

APPLICATION ISSUE



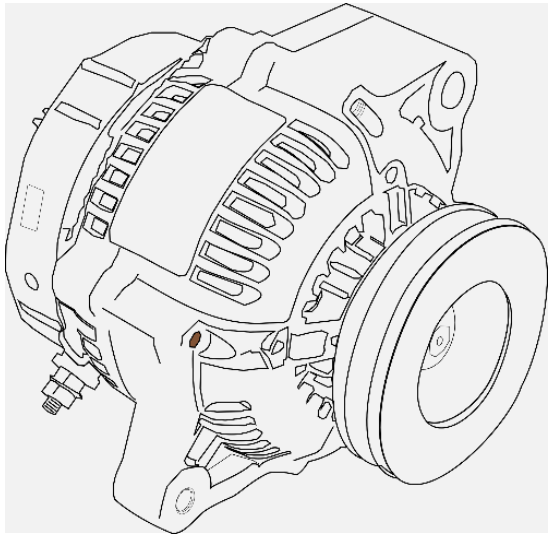


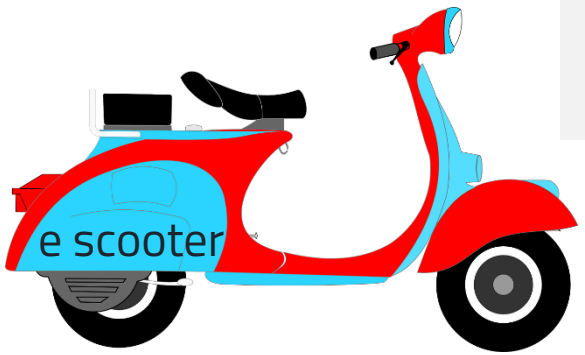
Pictures from pixabay.com

Pictures from WE

INRUSH CURRENT NEED

INRUSH CURRENT NEED





Pictures from pixabay.com

Table 102 – Test loads for electrical endurance tests for a.c. circuits

Type of circuit as classified in 7.2	OPERATION of contacts	Test voltage	Test current r.m.s.	Power factor[c)]
Substantially resistive (classified in 7.2.1)	Making and breaking	Rated voltage	*I-R*	≥0,9
General Purpose (classified in 7.2.10)	Making and breaking	Rated voltage	*I-GP*	≥0,75 (+0,05)
Resistive and/or motor (classified in 7.2.2)	Making[b)]	Rated voltage	6 × *I-M* or	0,60 (+0,05)
			I-R[a)]	≥0,9
	Breaking	Rated voltage	*I-R* or	≥0,9
			I-M[a)]	≥0,9
Circuit for specific load of motor with a locked rotor and with a power factor not less than 0,6 (classified in 7.2.9)	Making	Rated voltage	6 × *I-M*	0,60 (+0,05)
	Breaking	Rated voltage	6 × *I-M*	0,60 (+0,05)
Circuit for an inductive load (classified in 7.2.8)	Making[2)]	Rated voltage	6 × *I-I*	0,60 (+0,05)
	Breaking	Rated voltage	*I-I*	0,60 (+0,05)

INRUSH CURRENT NEED

Pictures from WE

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Circuit for an inductive load (classified in 7.2.8)	Making[2)]	Rated voltage	6 × *I-I*	,60 +0,05)
	Breaking	Rated voltage	*I-I*	,60 +0,05)

INRUSH CURRENT NEED

Tungsten filament lamp load (classified in 7.2.4)	Making and breaking	Tested in a circuit as shown in Figure 8[d]	
		Rated voltage ≥ 110 V a.c., X = 16	
		Rated voltage < 110 V a.c., X = 10	
Circuit for specific lamp load (classified in 7.2.7)	Making and breaking	Rated voltage	As determined by load
Specified declared (classified in 7.2.5)	Making and breaking	Rated voltage	As determined by load

I-I: inductive-load current

I-M: motor-load current

I-R: resistive-load current

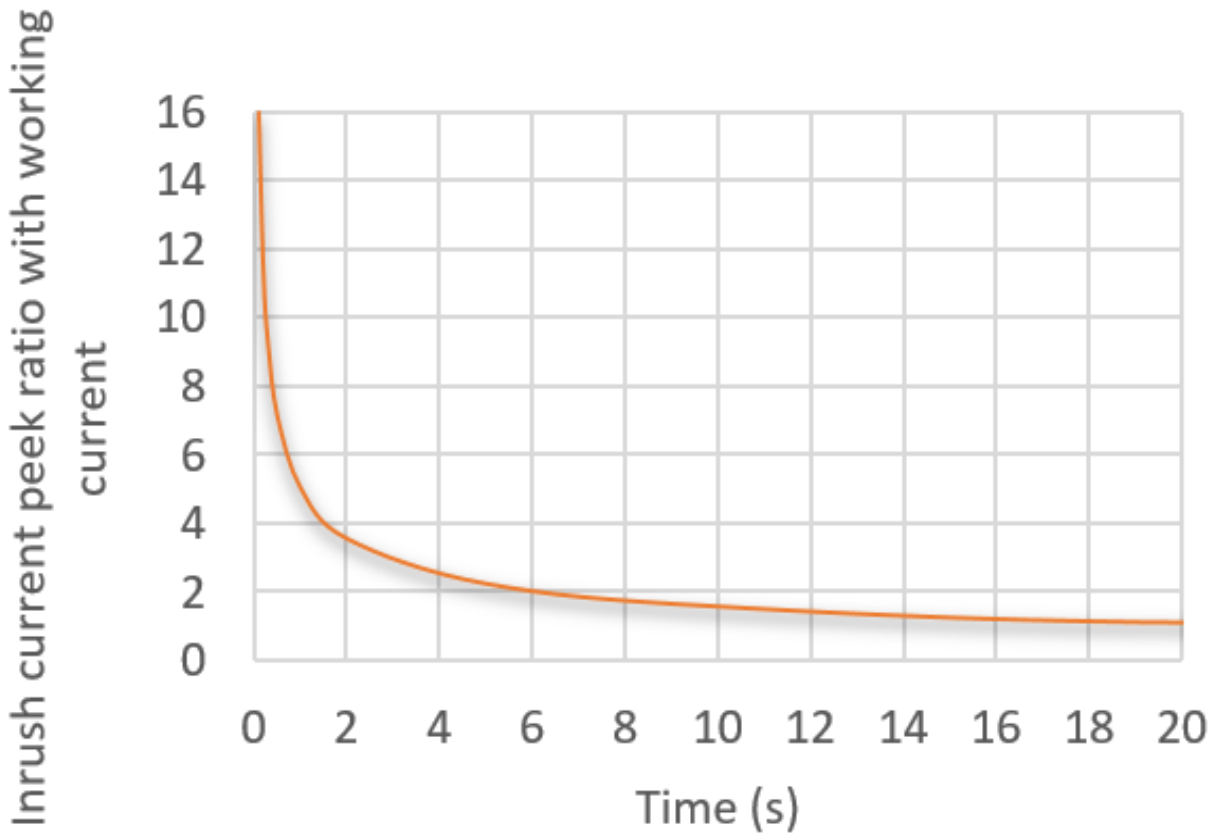
a) Whichever is arithmetically greater or the most unfavourable value in case of equal values.

b) The specified making conditions are maintained for a period between 50 ms and 100 ms, and are then reduced by an auxiliary switch to the specified breaking conditions.

Capacitance discharging

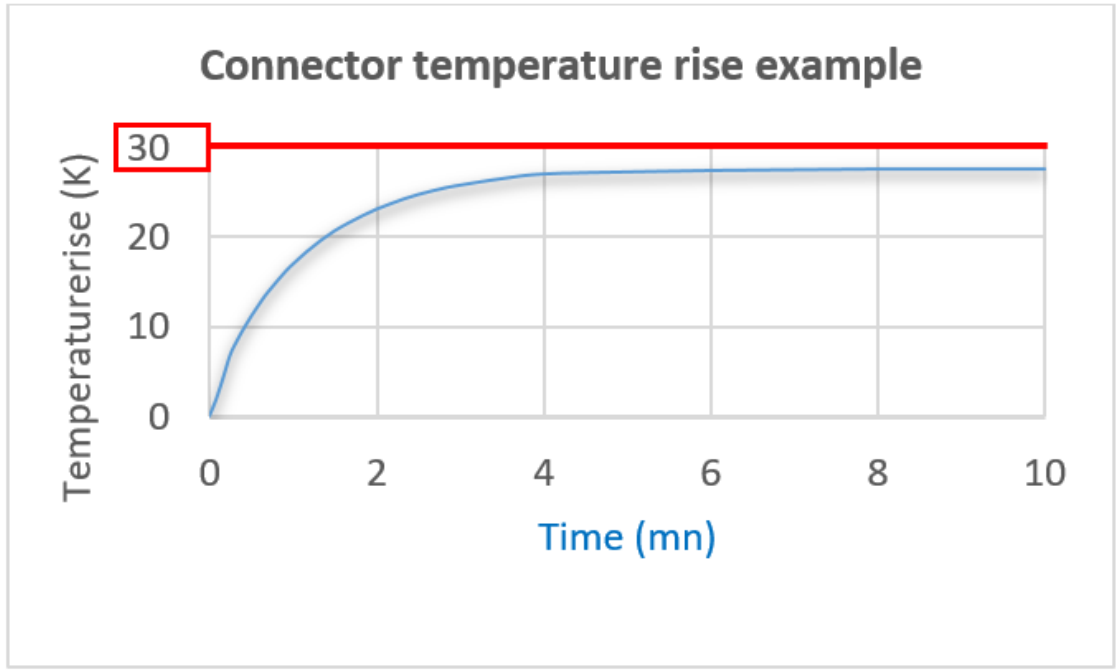
Pictures from WE

WHAT WE NEED


Inrush current peek ratio with working current
16
14
12
10
8
6
4
2
0
0
2
4
6
8
10
12
14
16
18
20
Time (s)

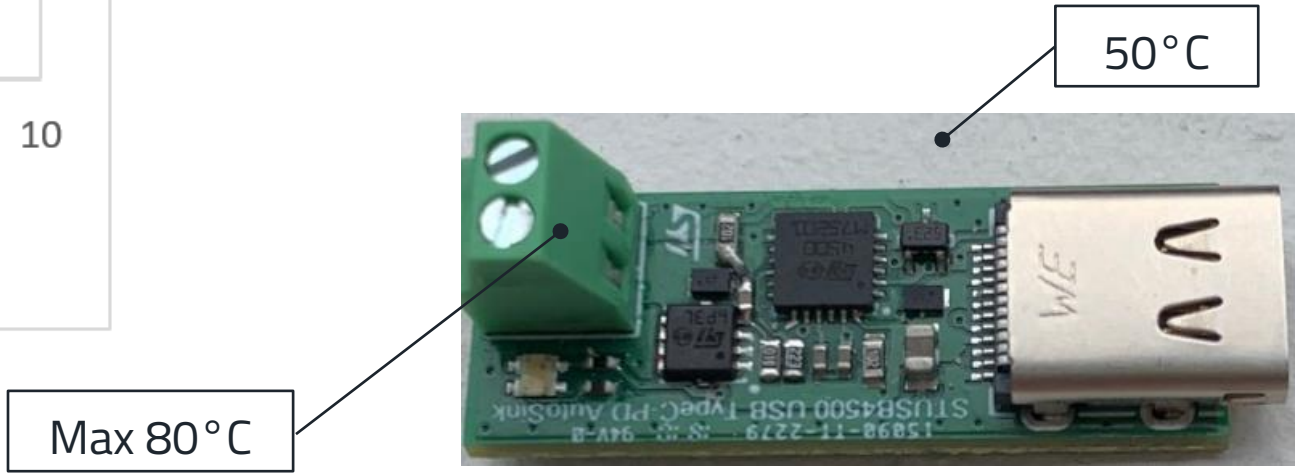
CURRENT RATED TEMPERATURE RISE

In still air



connector temperatre rise in mn

UL standard ΔT < 30K



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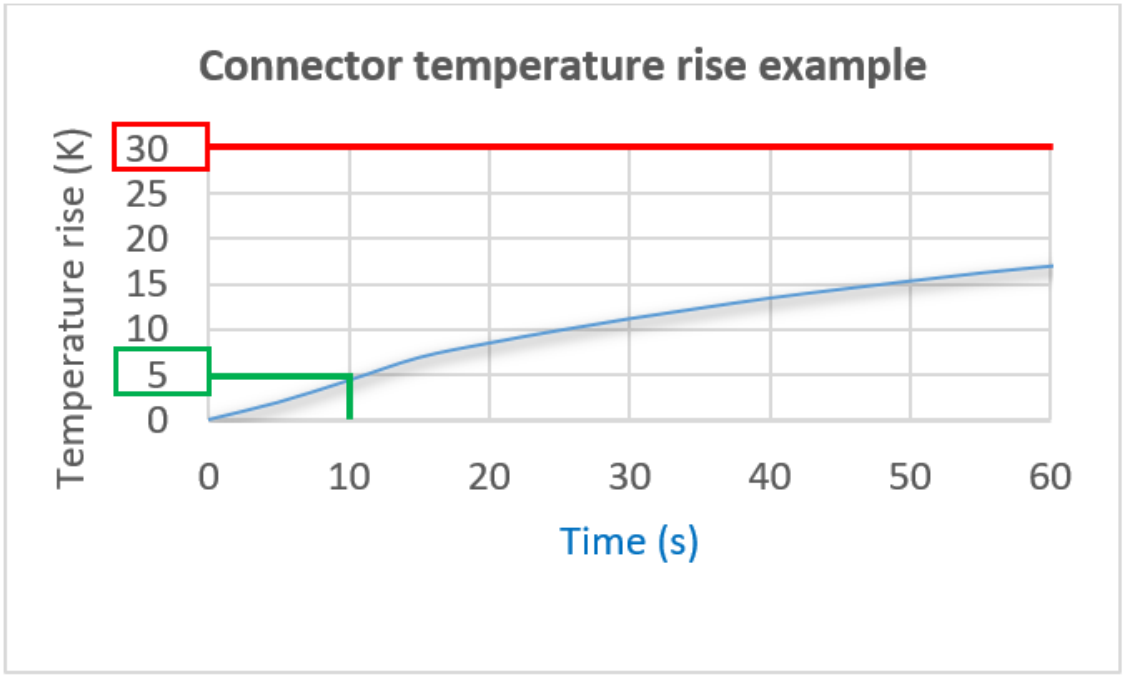
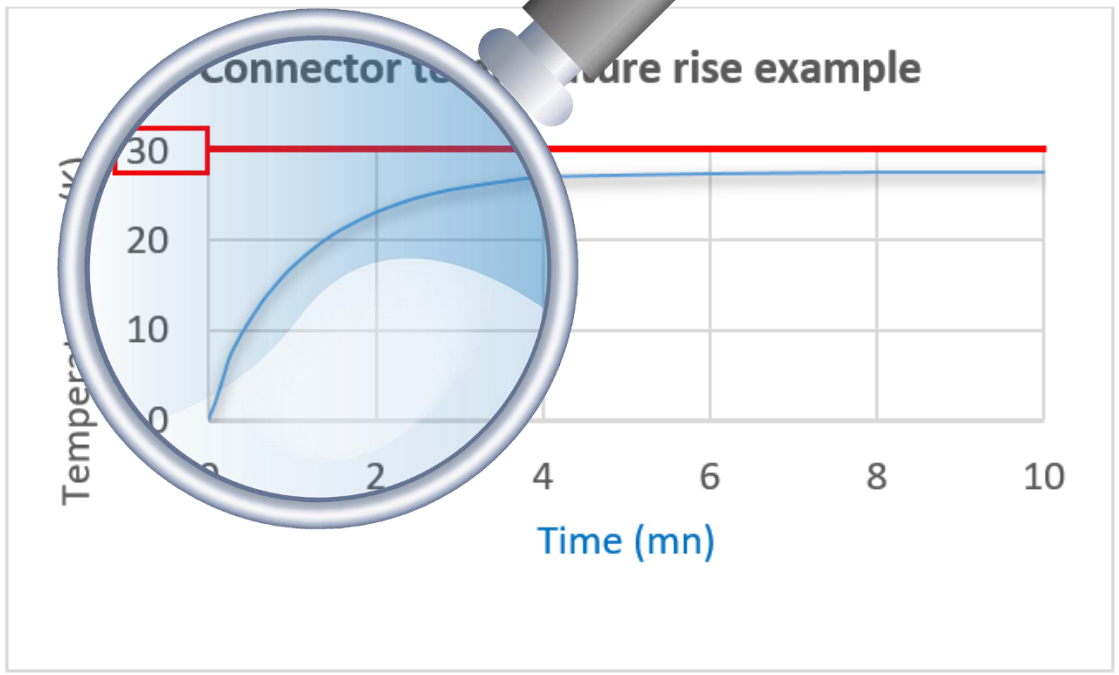
CURRENT RATED TEMPERATURE RISE



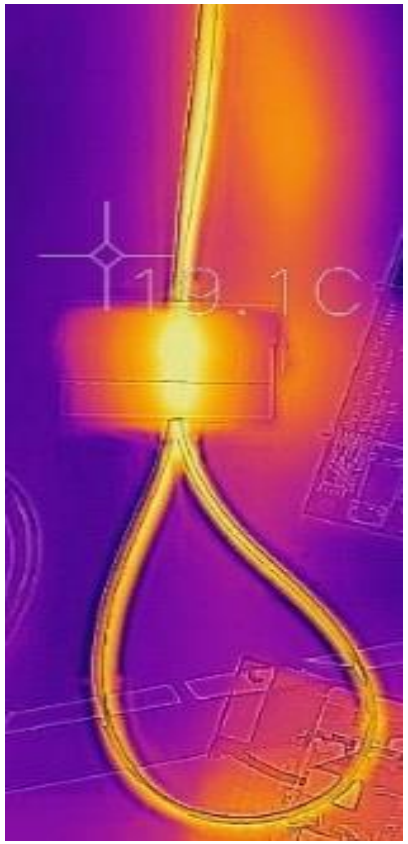
temperatre rise in s

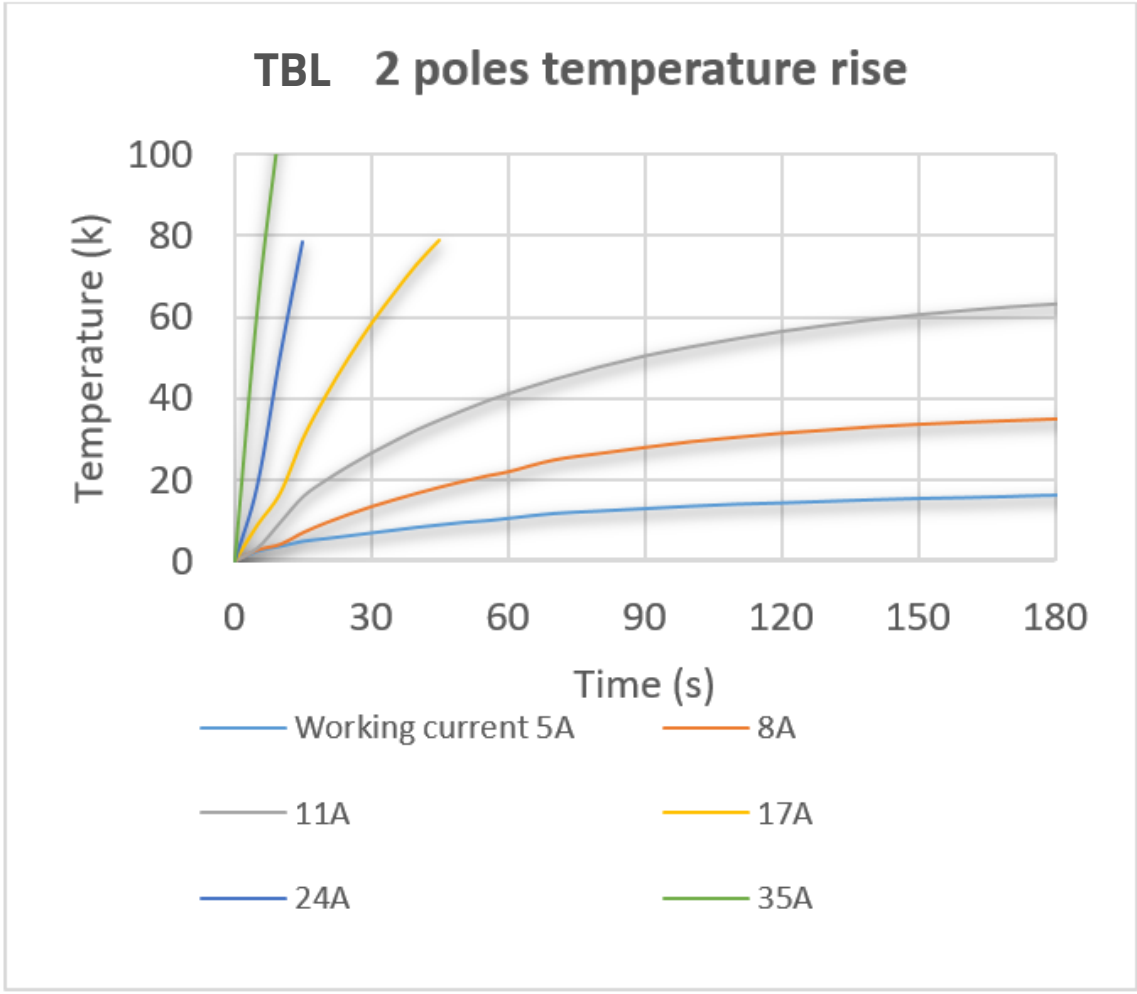


connector temperatre rise in mn

PRE-TEST: INRUSH CURRENT TBL

TBL – 20AWG
wire length 50cm

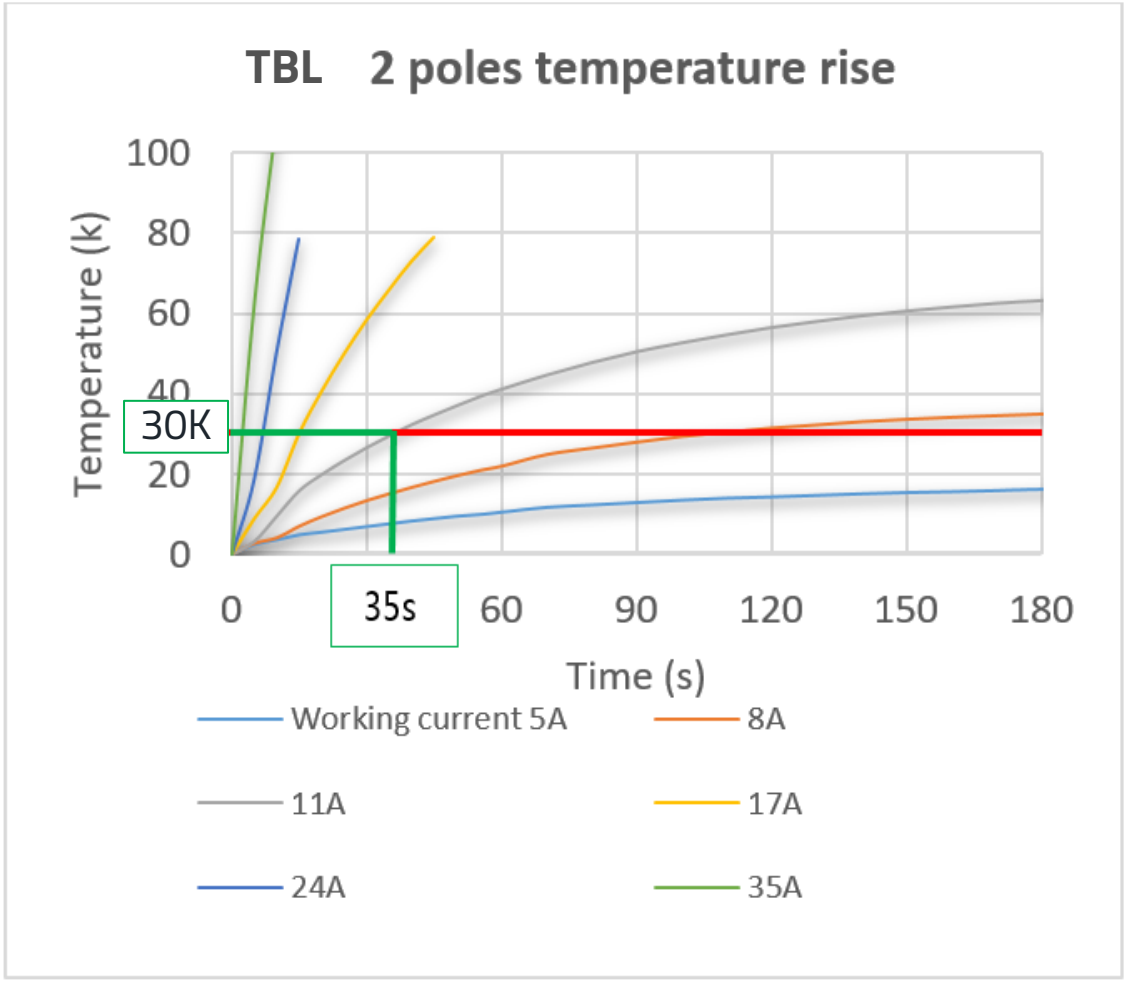




Temperature rise above working current

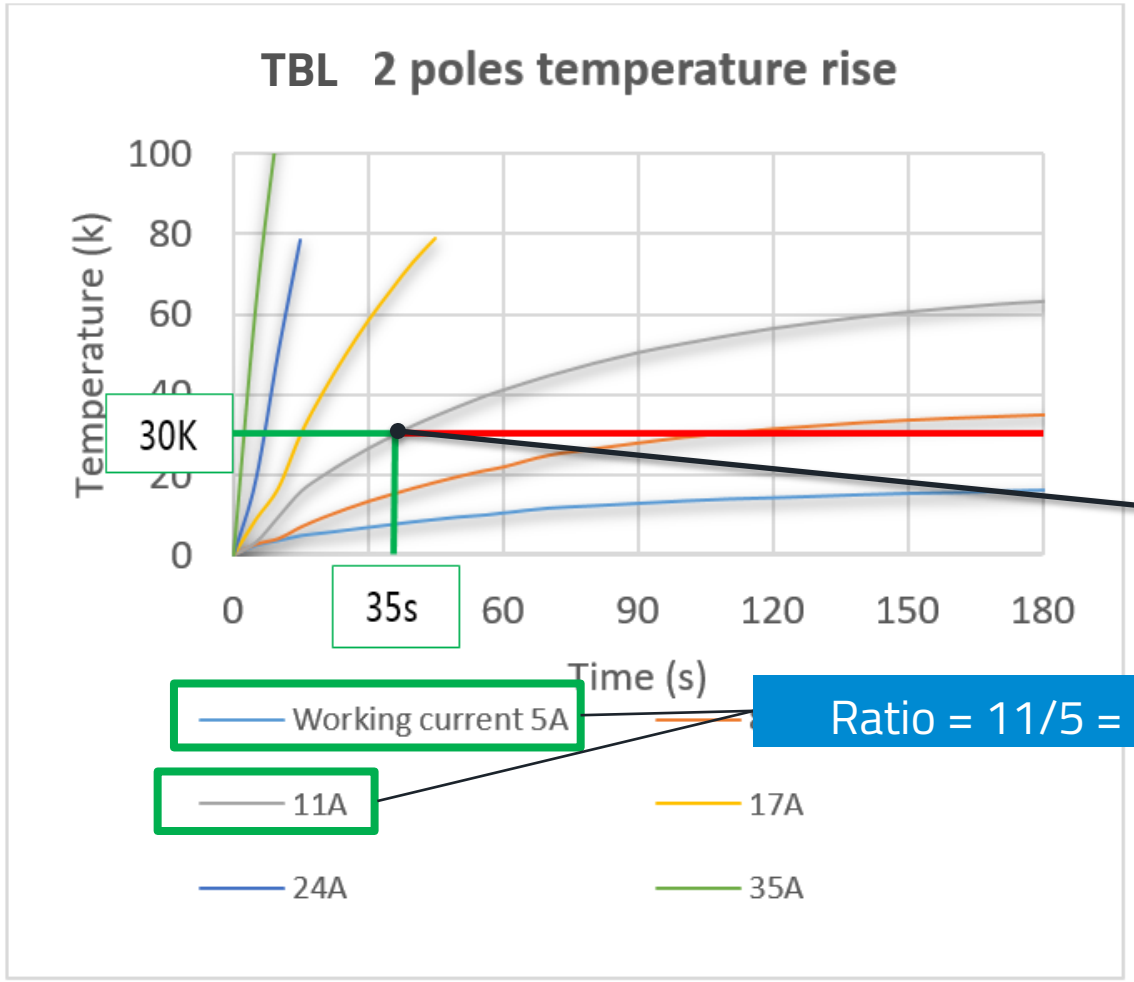
Pictures from WE

PRE-TEST: INRUSH CURRENT DURATION THAT GIVES A ΔT OF 30K



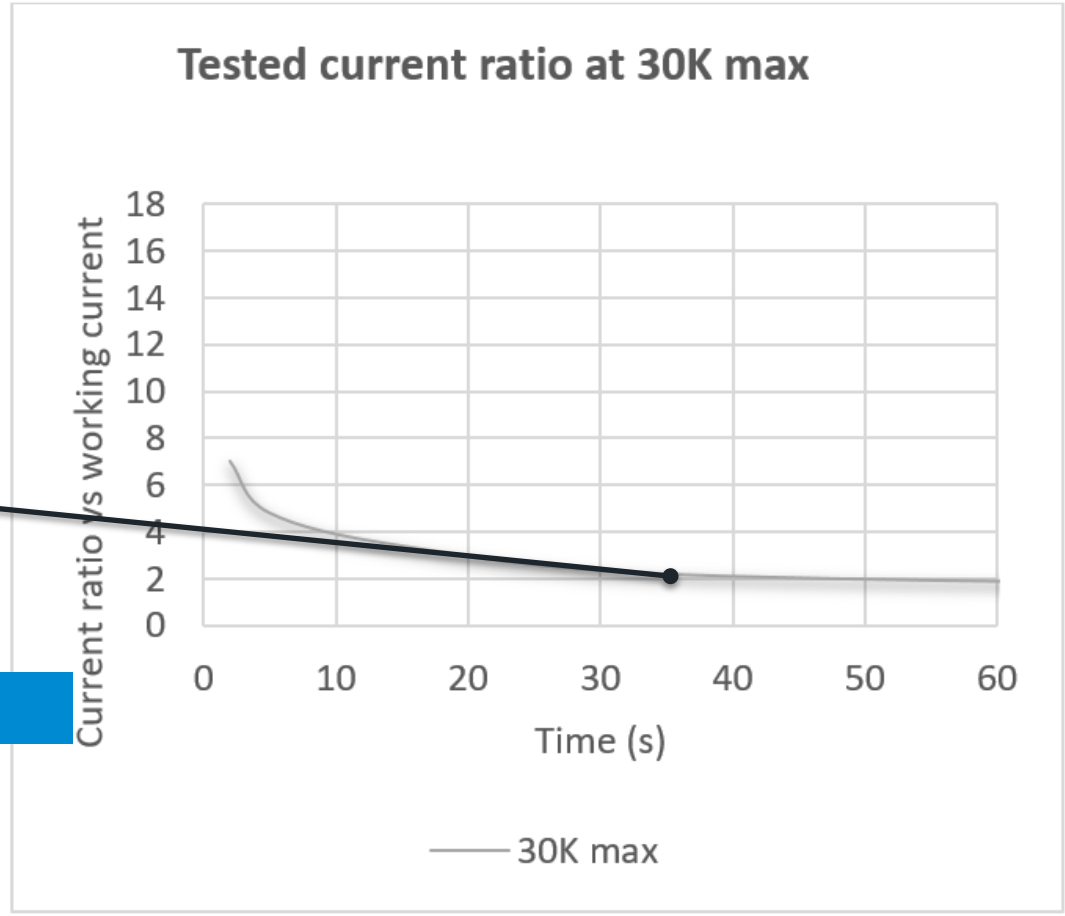
Temperature rise above working current

INRUSH CURRENT 30K CURVE



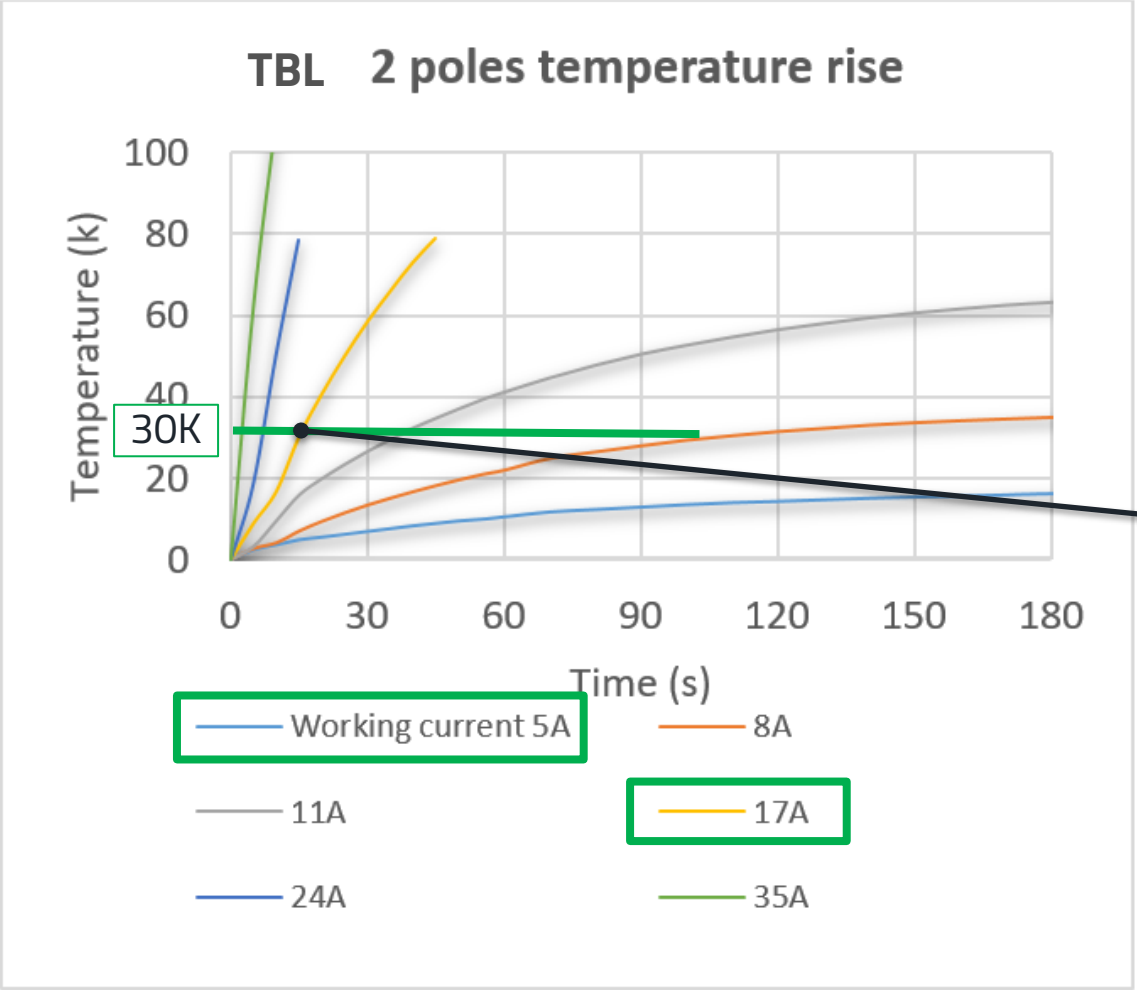
Temperature rise above working current

Ratio = 11/5 = 2,2

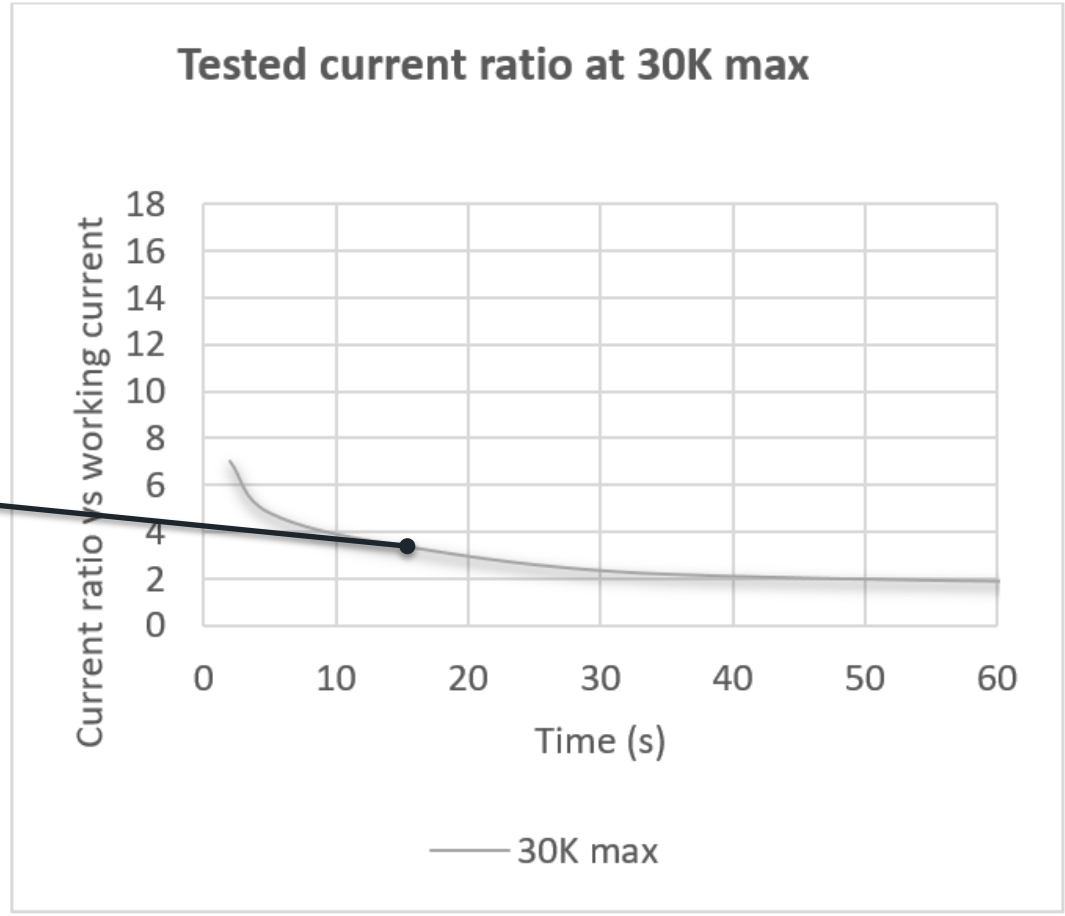


typical 30K temperature rise current

INRUSH CURRENT 30K CURVE

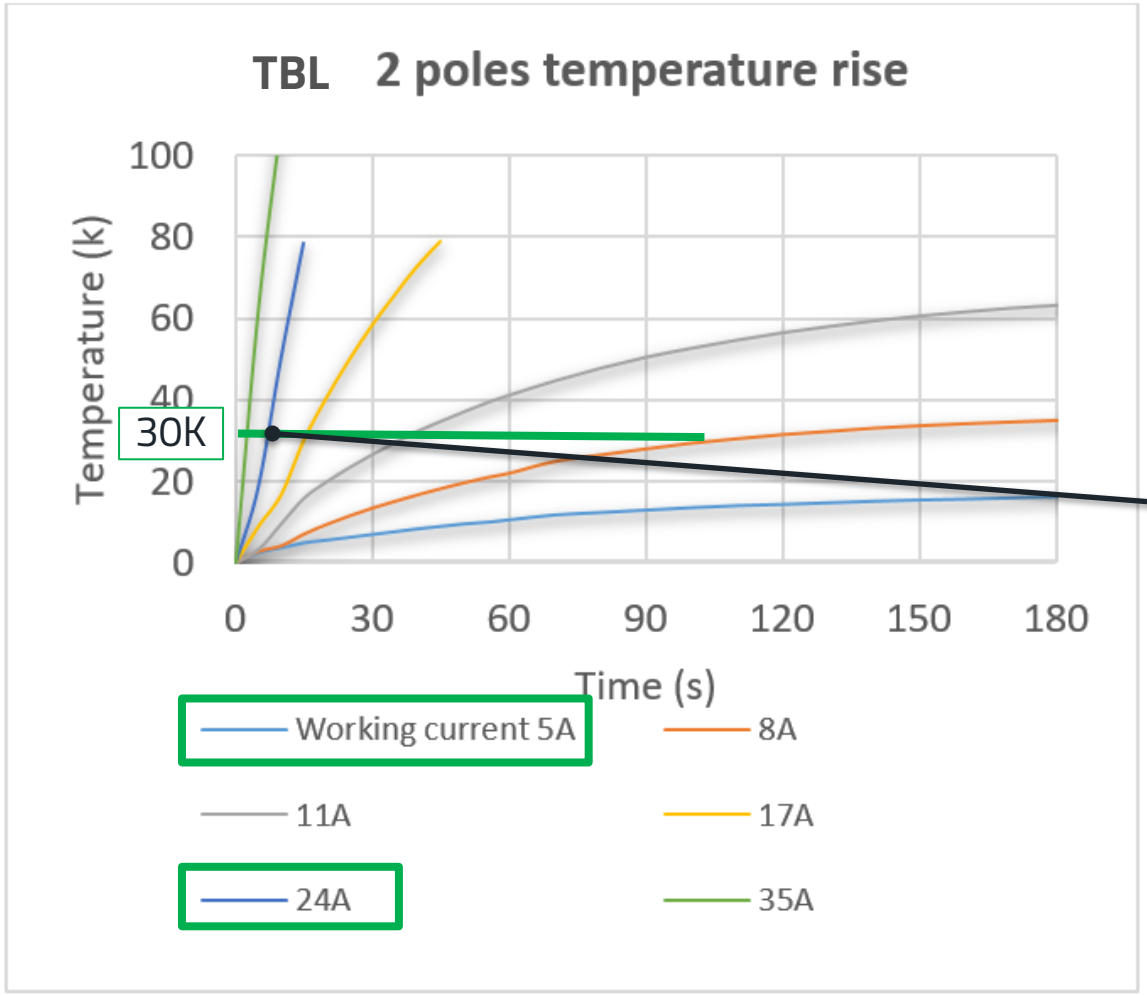


Temperature rise above working current

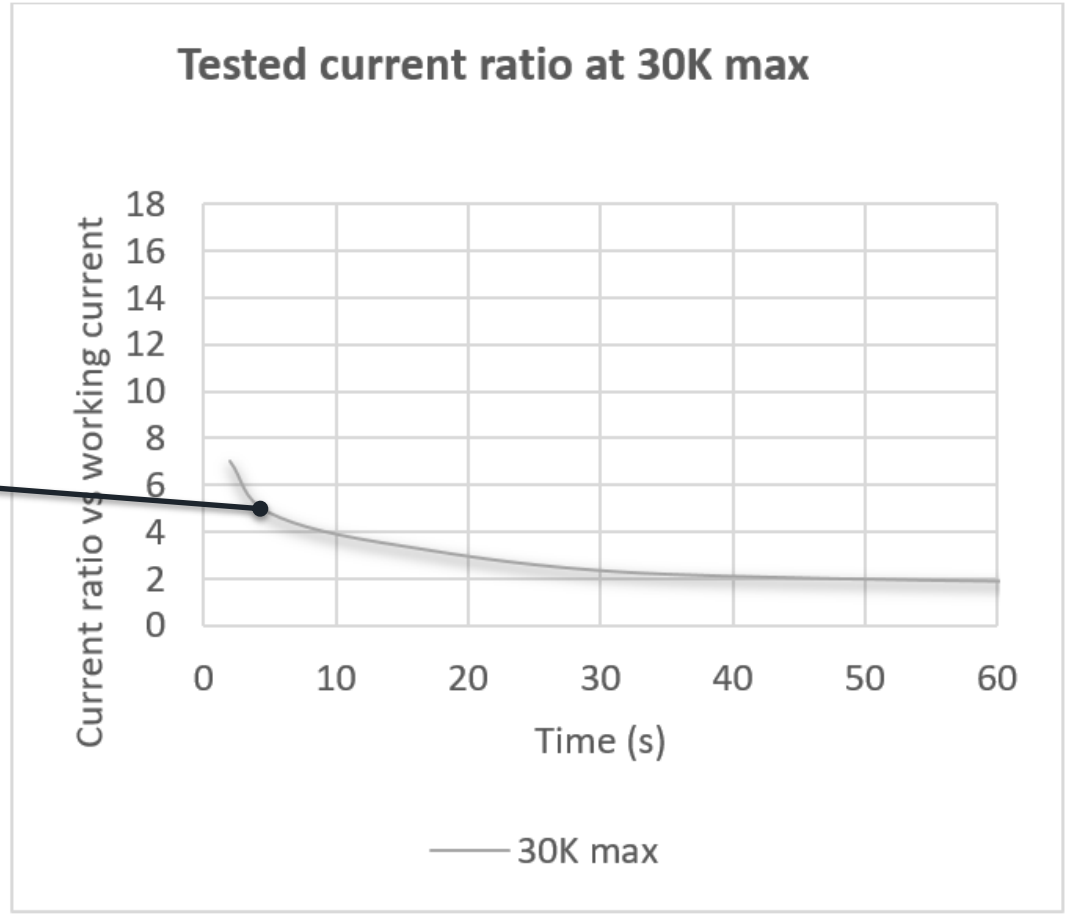


typical 30K temperature rise current

INRUSH CURRENT 30K CURVE

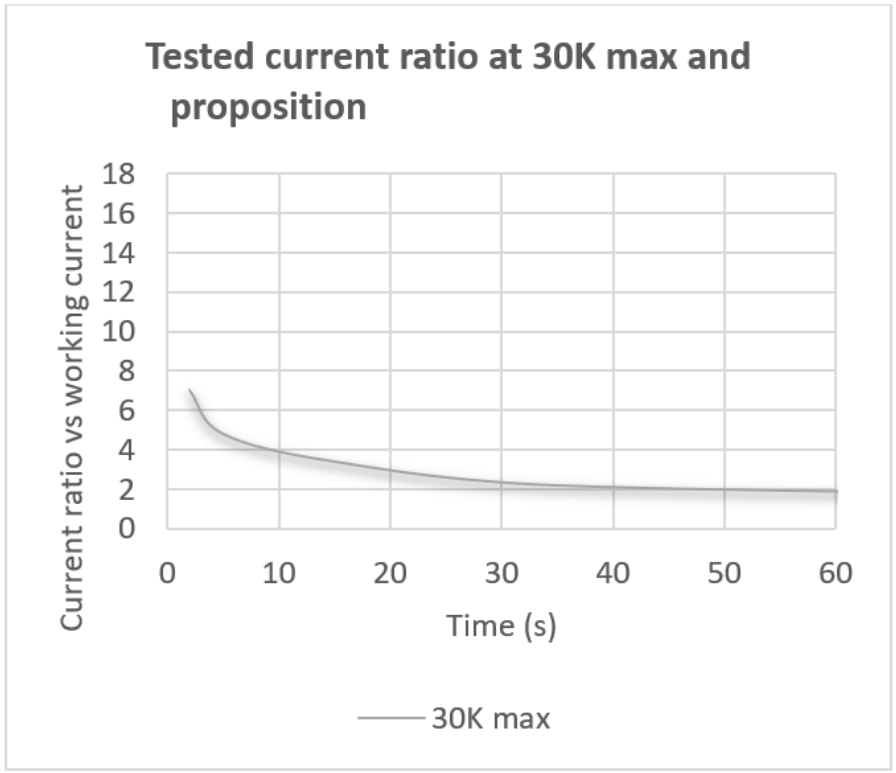


Temperature rise above working current

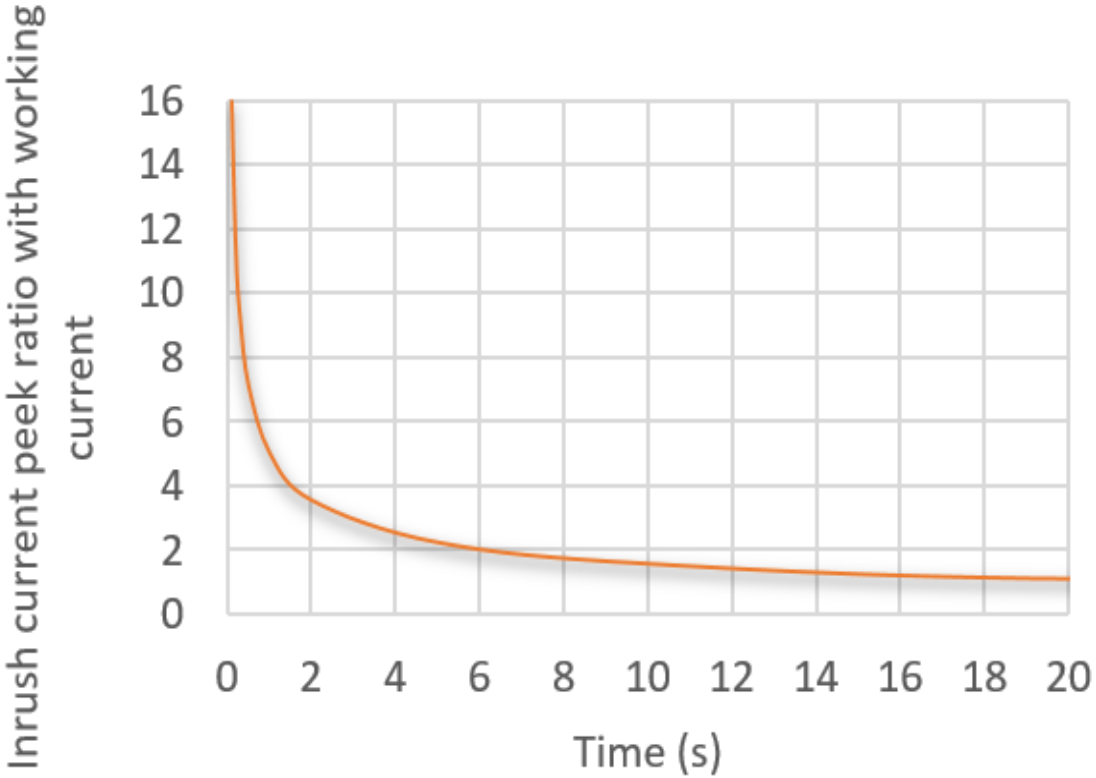


typical 30K temperature rise current

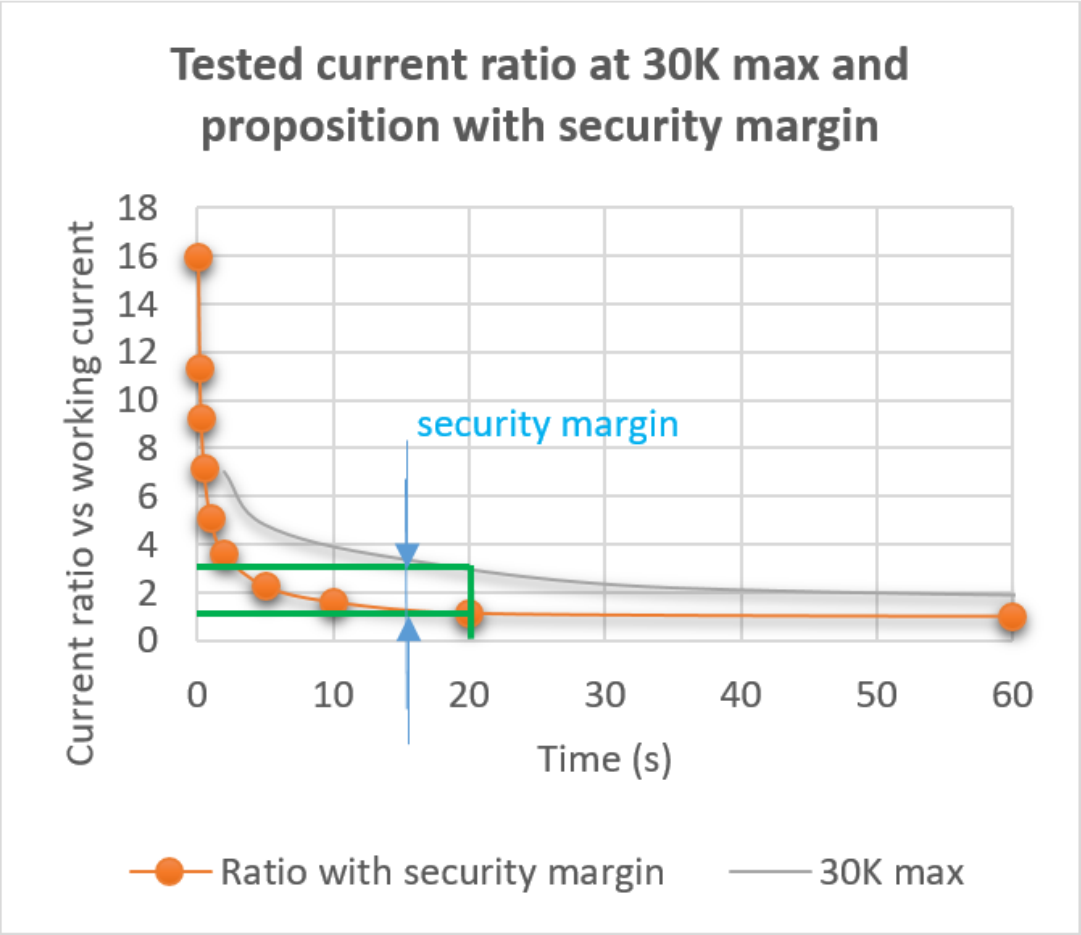
TEST RESULTS VS NEED



typical 30K temperature rise current and proposition



TEST RESULTS VS NEED



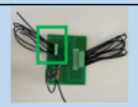
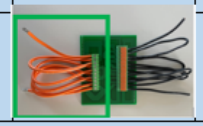
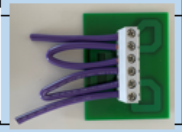
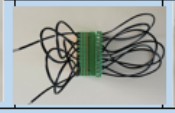
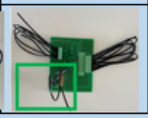
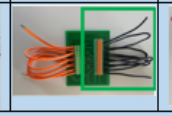
typical 30K temperature rise current and proposition with security margin

$$\frac{I_{measured}}{I_{need}} \approx 3$$

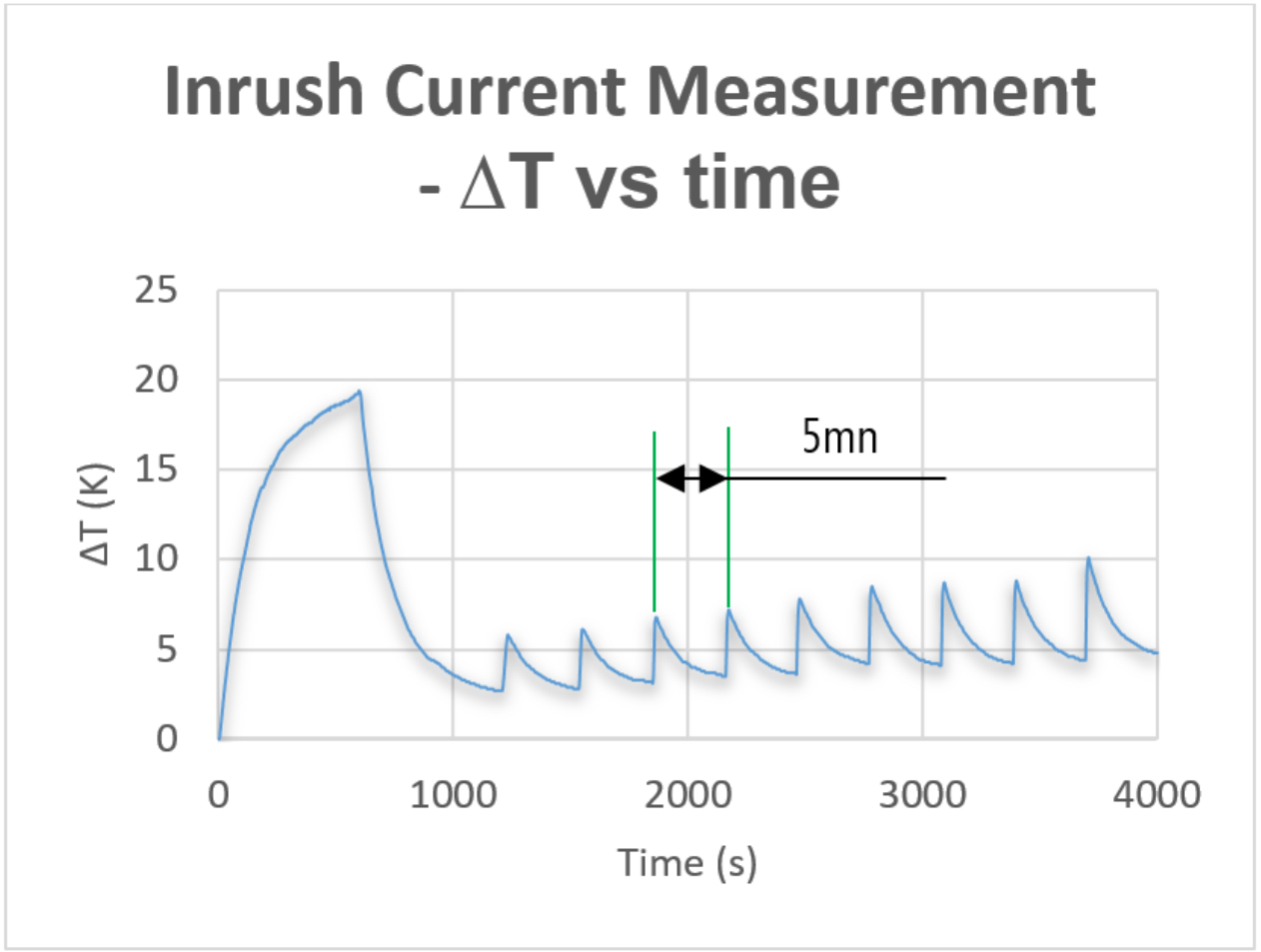
INRUSH CURRENT FULL TESTS

Tests hypothesis:

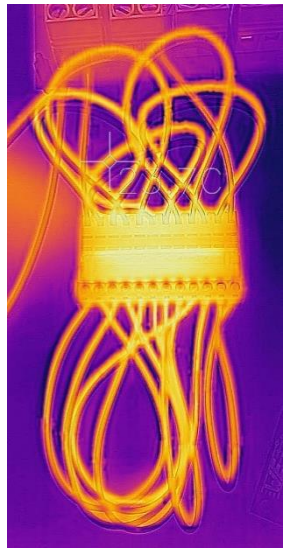
- Mini and maxi number of poles
- Smallest and biggest pitch and current
- Representative technologies for TBL

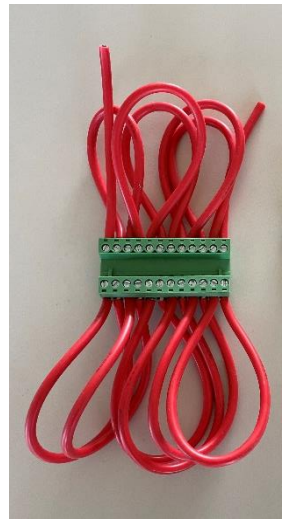
					Terminal block rising cage			Plug spring /PCB	Plug / rising cage	Pug / IDC	Spring		
		x	x	x	x			x			x		
	Product	MPC4 24 poles	MPC4 2 poles	MPC3 24 poles	Pitch 2,54mm 8 poles	Pitch 5mm 10 poles	Pitch 10,16mm 12 poles	Pitch 2,5mm - 12 poles	Pitch 5,08 - 12 poles	Pitch 5,08 - 12 poles	Pitch 2,54 - 8 poles	Pitch 5mm - 24poles	Pitch 7,5 - 5poles
	Working current (A)	6	9	5	6	24	57	12	12	7	6	16	30
													
Current ratio	Time	Test current (A)											
1	10mn	6	9	5	6	24	57	12	12	7	6	16	30
1,1	20s	6,6	9,9	5,5	6,6	26,4	62,7	13,2	13,2	7,7	6,6	17,6	33
1,6	10s	9,6	14,4	8	9,6	38,4	91,2	19,2	19,2	11,2	9,6	25,6	48
2,3	5s	13,8	20,7	11,5	13,8	55,2	131,1	27,6	27,6	16,1	13,8	36,8	69
3,6	2s	21,6	32,4	18	21,6	86,4	205,2	43,2	43,2	25,2	21,6	57,6	108
5,1	1s	30,6	45,9	25,5	30,6	122,4	290,7	61,2	61,2	35,7	30,6	81,6	153
7,1	0,5s	42,6	63,9	35,5	42,6	170,4	404,7	85,2	85,2	49,7	42,6	113,6	213
9,2	0,3s	55,2	82,8	46	55,2	220,8	524,4	110,4	110,4	64,4	55,2	147,2	276
11,3	0,2s	67,8	101,7	56,5	67,8	271,2	644,1	135,6	135,6	79,1	67,8	180,8	339
16	0,1s	96	144	80	96	384	912	192	192	112	96	256	480

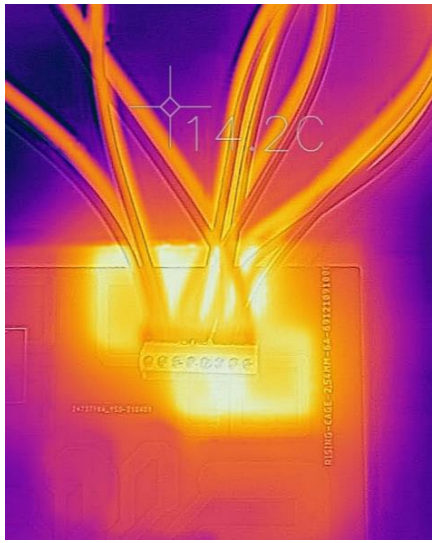
REAL TEST

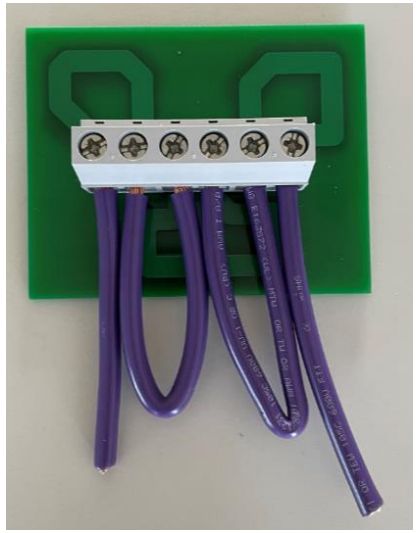


final inrush current test results



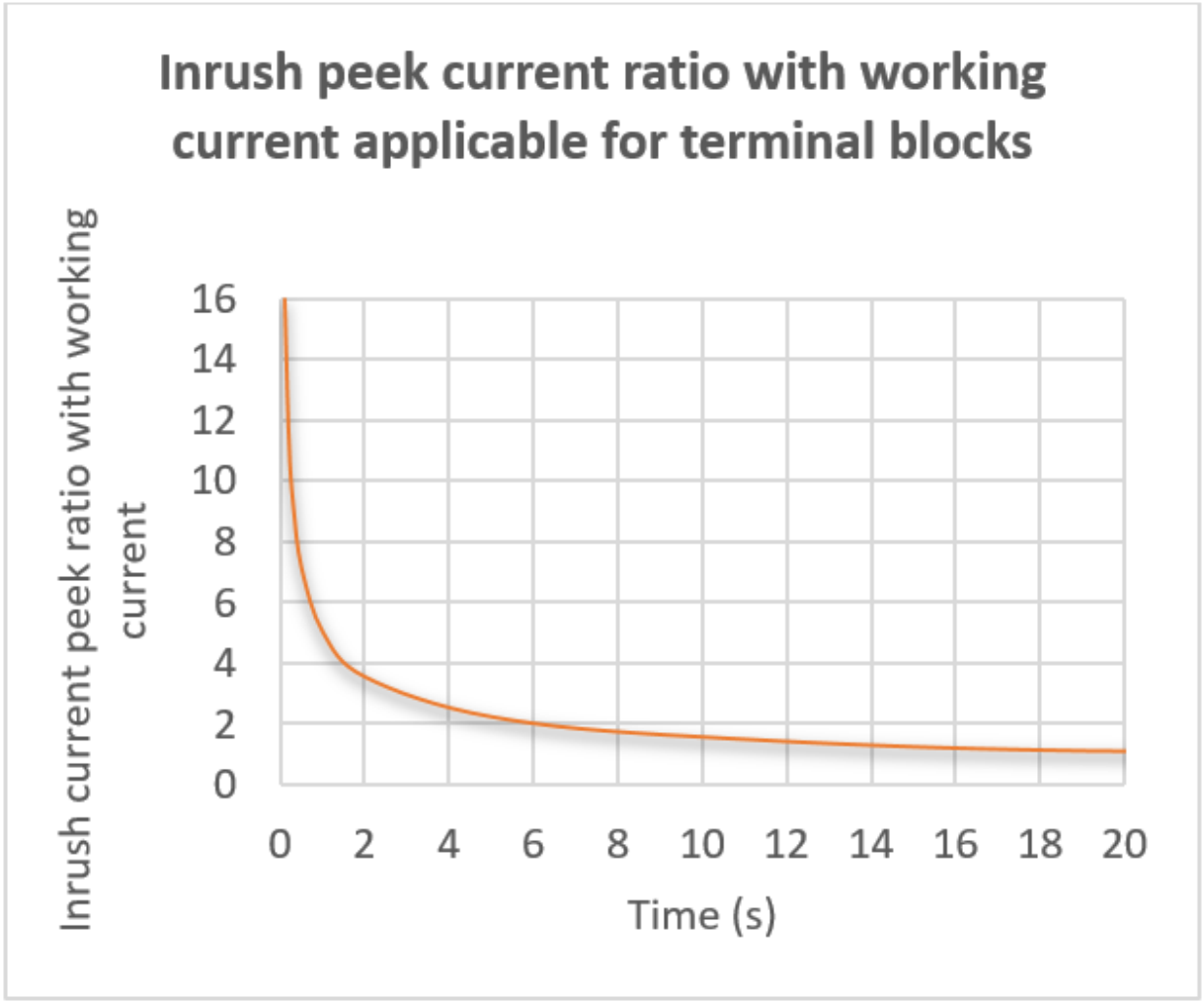


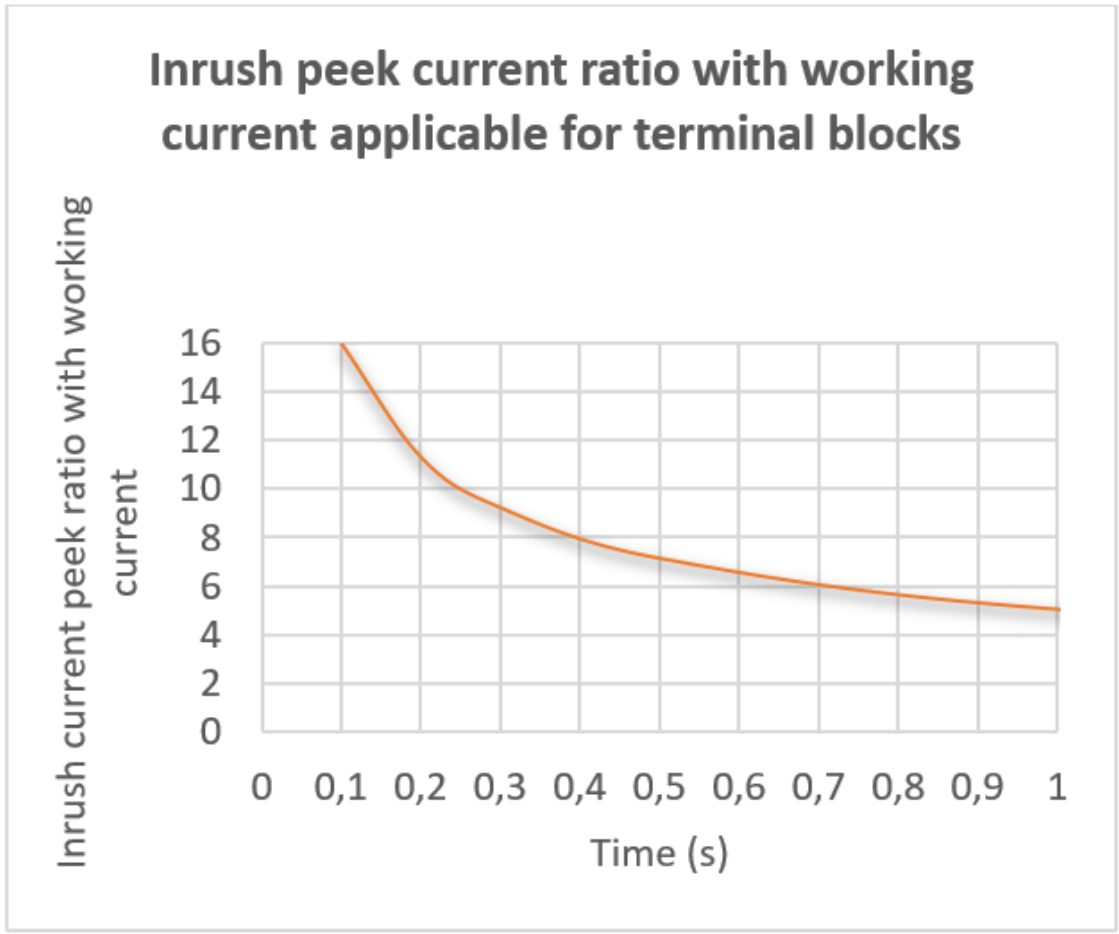




Pictures from WE

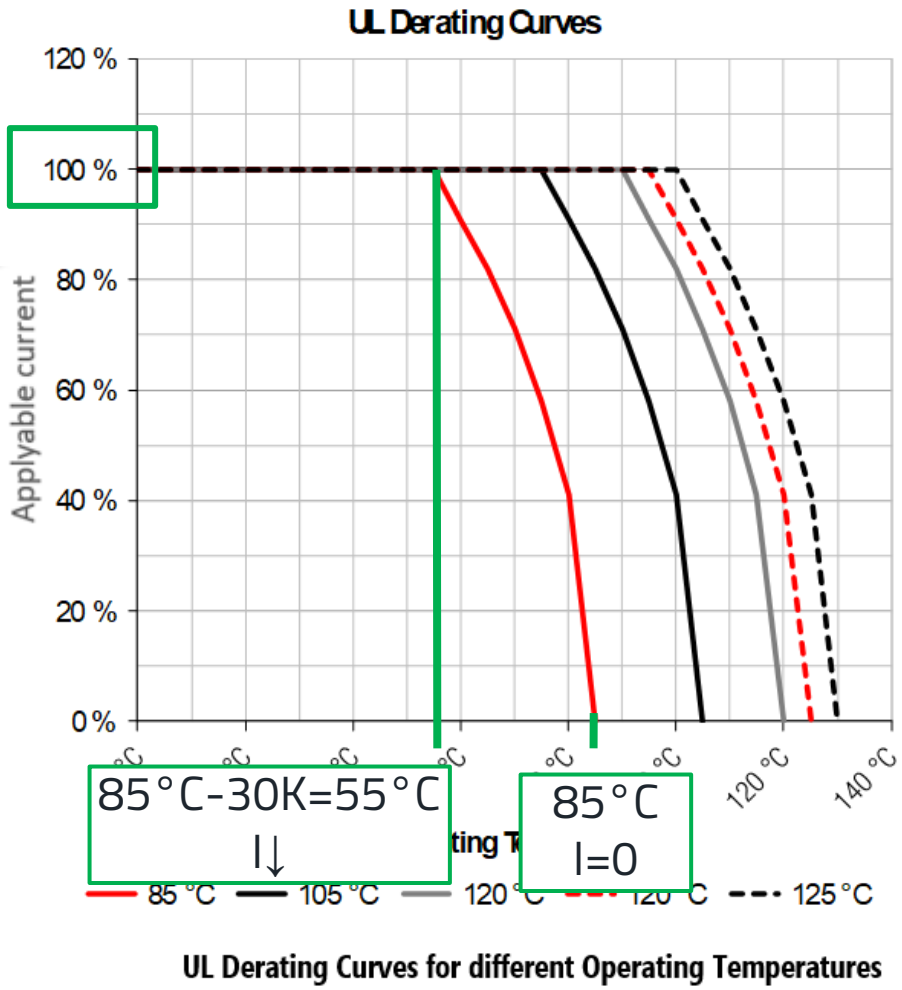
INRUSH CURRENT CURVES





applicable inrush current for eiCan connectors. Different scales

DERATING CURVE WITHOUT INRUSH CURRENT



UL Derating Curves for different Operating Temperatures

Base principle: always $\Delta T \leq 30K$

Connector internal temperature < operating temperature

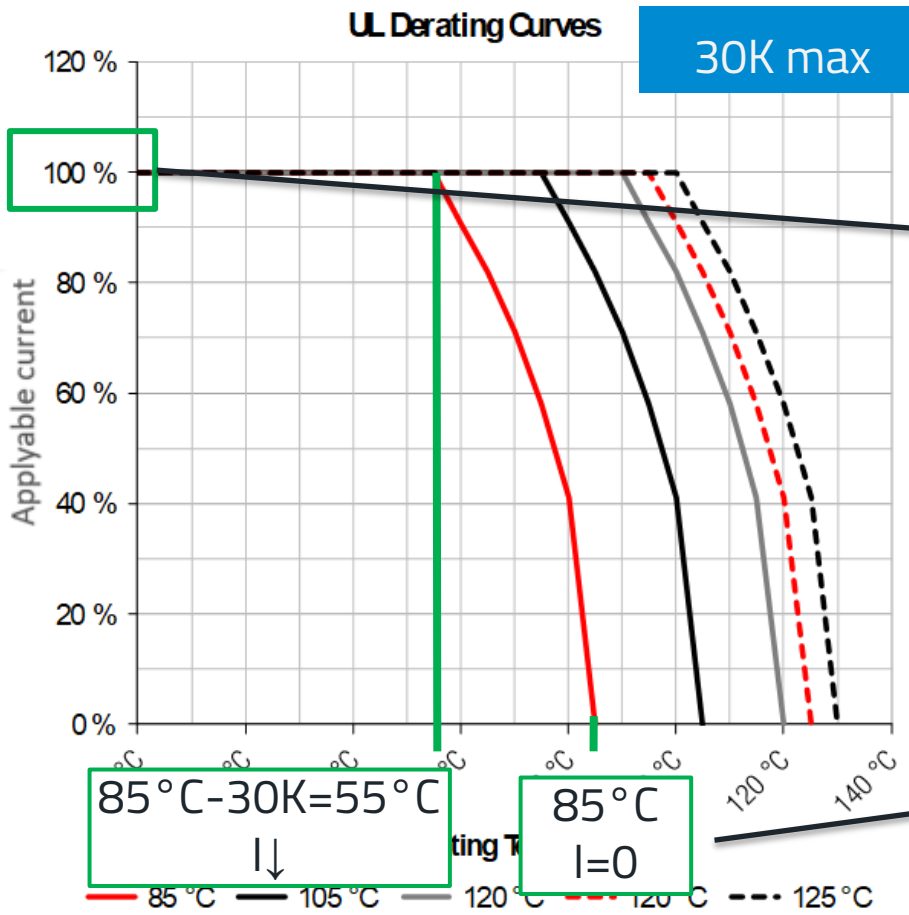
Security margin

Stable current ≤ 15K

and

Inrush current ≤ 15K

DERATING CURVE WITH INRUSH CURRENT



30K max

85 °C-30K=55 °C
I↓

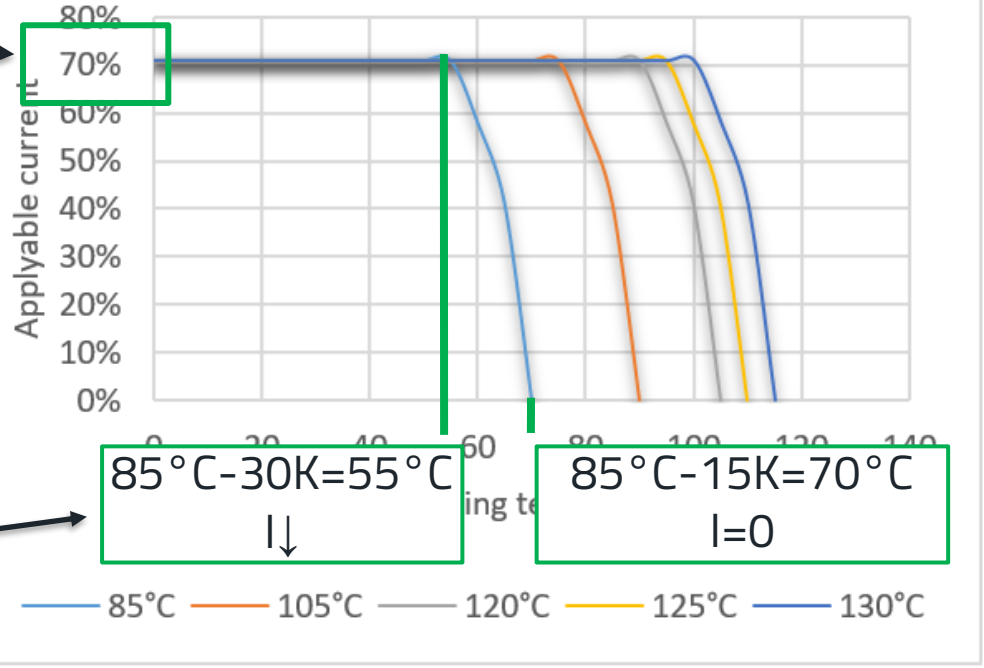
85 °C
I=0

UL Derating Curves for different Operating Temperatures

Stable current
≤ 15K

15K max

$$I_{max15K} = \sqrt{\frac{15K}{30K}} I_{max30K}$$



85 °C-30K=55 °C
I↓

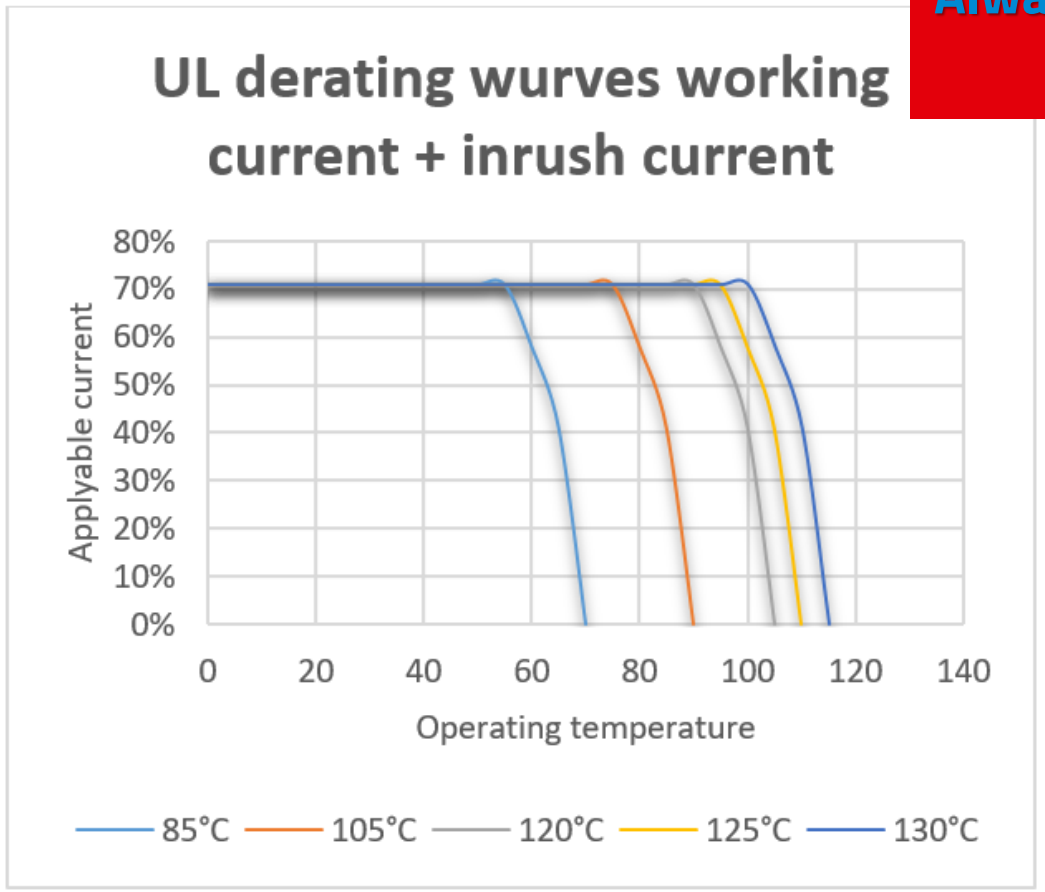
85 °C-15K=70 °C
I=0

UL Derating Curves for stabe and inrush current different Operating Temperatures

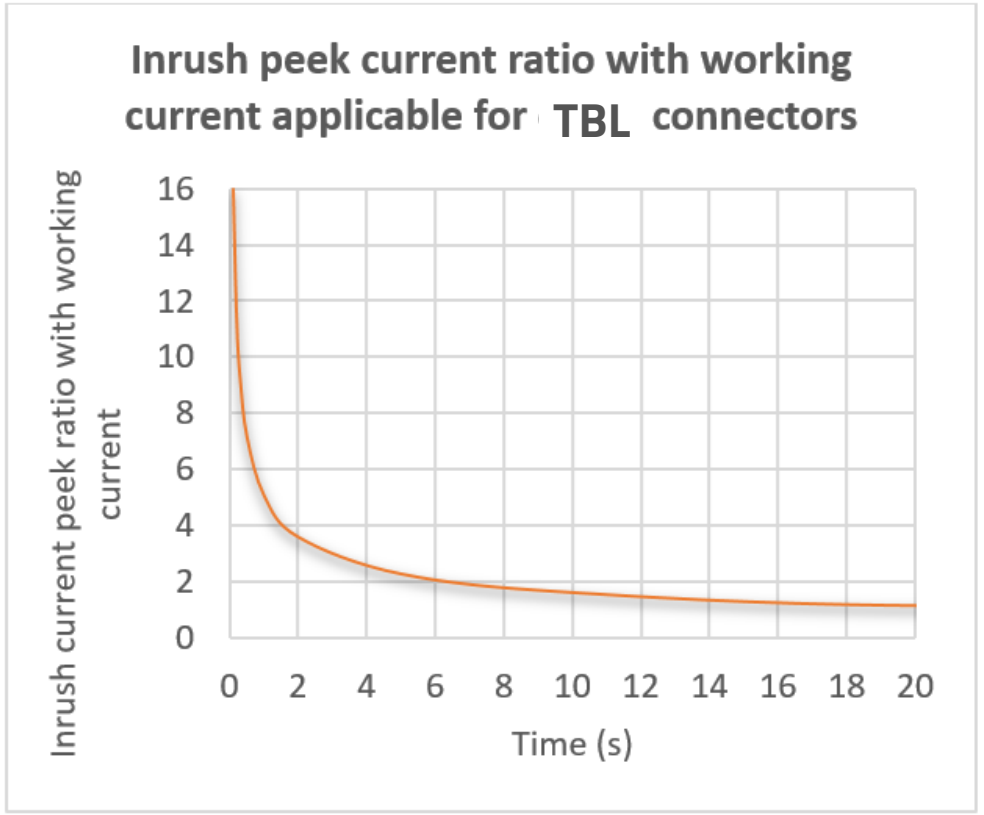
FINAL CURVES

Datasheet is guaranted by WE

Always do a test to check temperature of your system

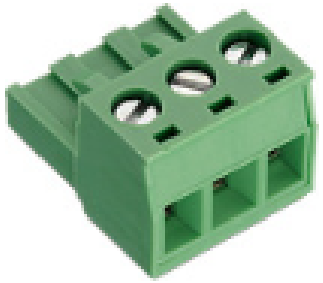


UL Derating Curves for stabe and inrush current different Operating Temperatures

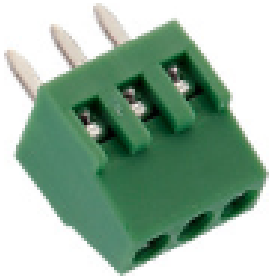


: applicable inrush current for eiCan connectors

RELATED PRODUCTS



Terminal Blocks



Possible to test other products in customer conditions in the application lab