



Qualification of M-type cathode up to 4 A/cm² for space applications

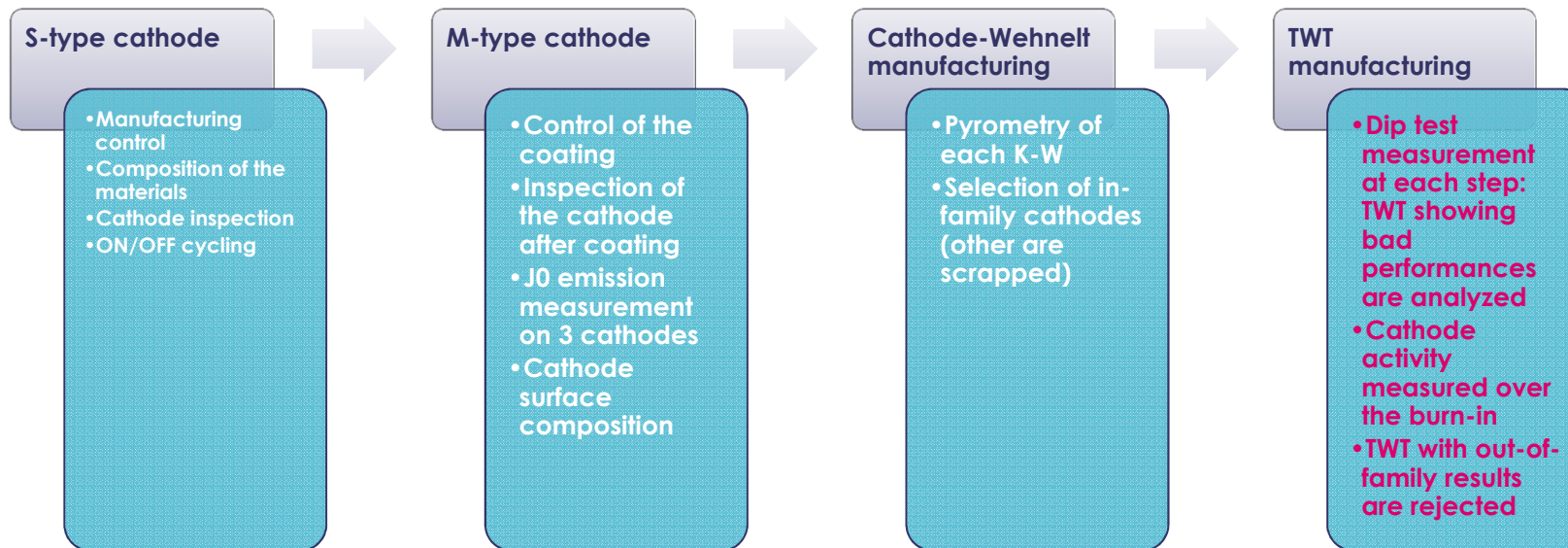
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Qualification of M-type cathode up to 4 A/cm²



Same technology used for M-type cathode at 4 A/cm²
To increase the current density up to 4 A/cm² → New cathode temperature adjustment method

What are the cathode requirements for space applications ?

Objectives

- Use the M-type cathode at $4\text{A}/\text{cm}^2$
- Guarantee lifetime of 15 years:
 - Anode voltage variation has to be lower than the threshold
 - Avoid cathode poisoning
 - Good focusing stability

These parameters depend on the operating temperature and J_0 (zero-field temperature-limited current density)

M-type cathodes at 4 A/cm² : experimental demonstration

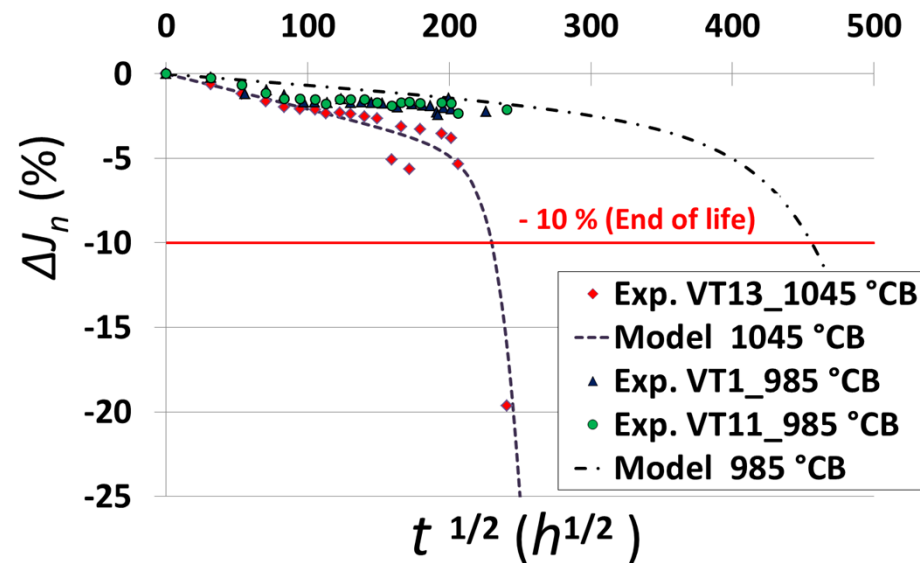
Test vehicles (VT=gun+collector) vs. time at 985 °CB and 1045 °CB: comparison of emission measurement with model

All test vehicles at 4 A/cm²

End of life is reached after 50 khours at 1045°C_B as predicted by the model

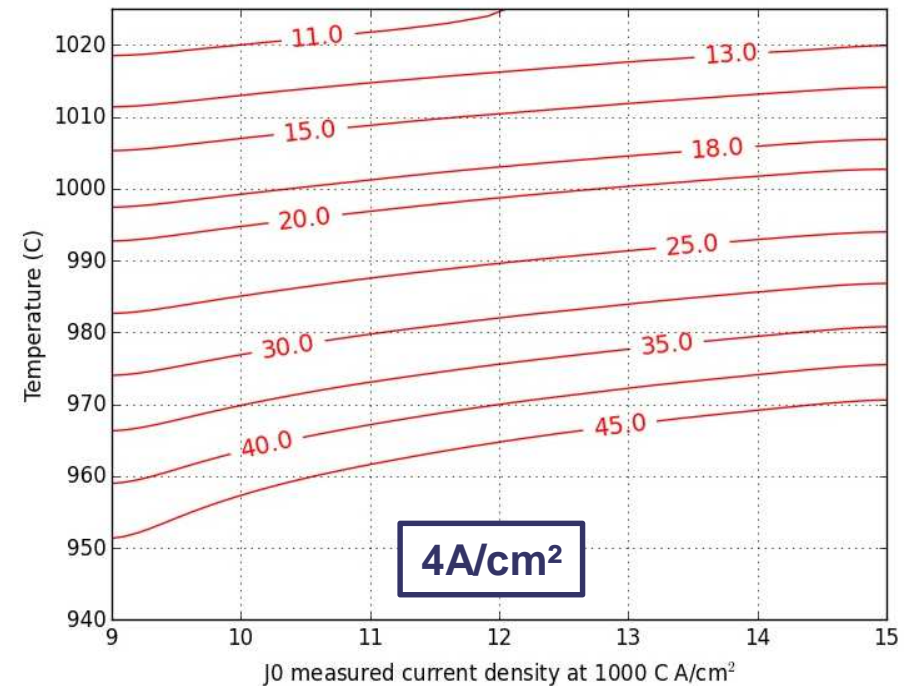
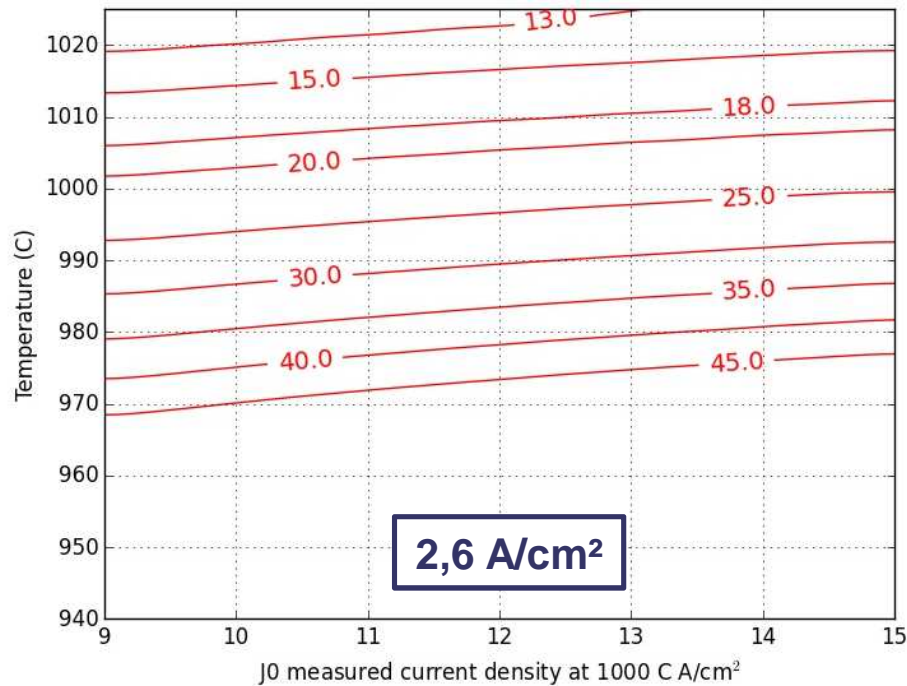
Predicted life-time at 985°C_B is 200 khours (23 years)

But there is a spread on cathode parameters



M-type Cathode life-time

Iso- lifetime lines

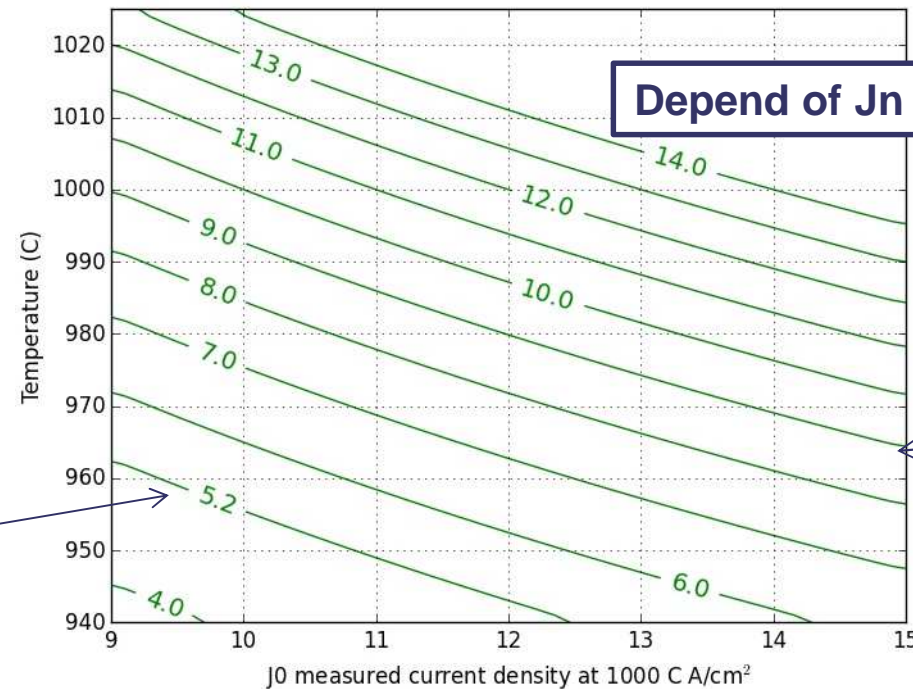


Goal: life-time > 15 years

M-type Cathode emission

Iso-J0 lines at operating temperature

J_0 (TK) : Saturation current density

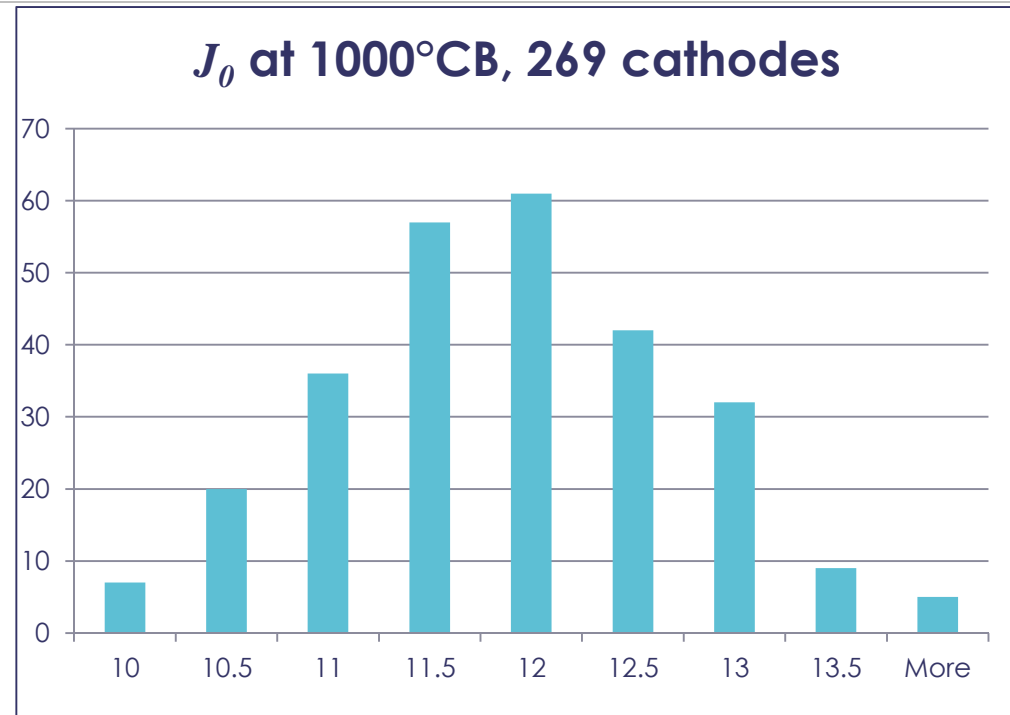


To avoid cathode poisoning and defocusing, $J_0 > 2 J_n$ at the beginning of life.

How to fulfill the cathode requirements?

1. By characterizing the average J_0 and the spread

J_0 (TK) : Saturation current density



At 1000 °C, average : 11.6 A/cm²

→ Spread = ± 1.4 A/cm²

How to fulfill the cathode requirements?

2. By characterizing the average thermal parameters and its spreads

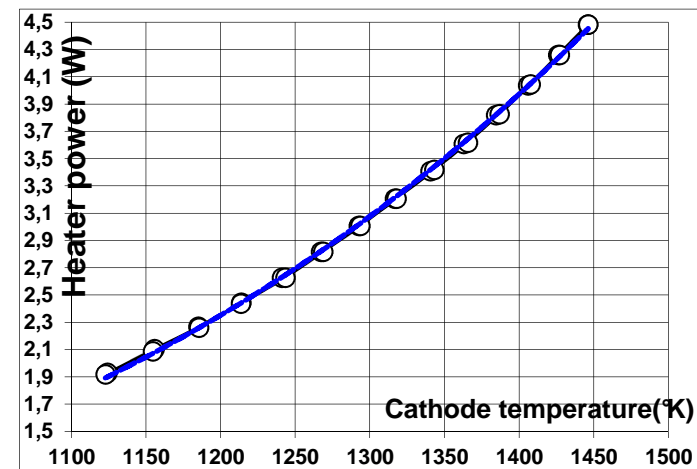
Cathode temperature \rightarrow

Heat sink temperature \rightarrow

$$P_C = \sigma(T_K^4 - T_O^4) + \frac{T_K - T_O}{R_{th}}$$

Cathode heater power \rightarrow

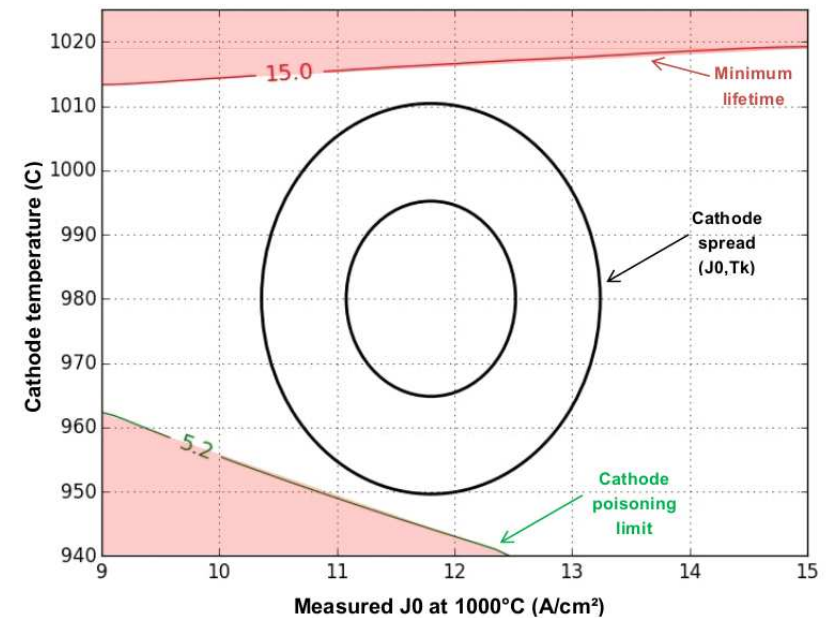
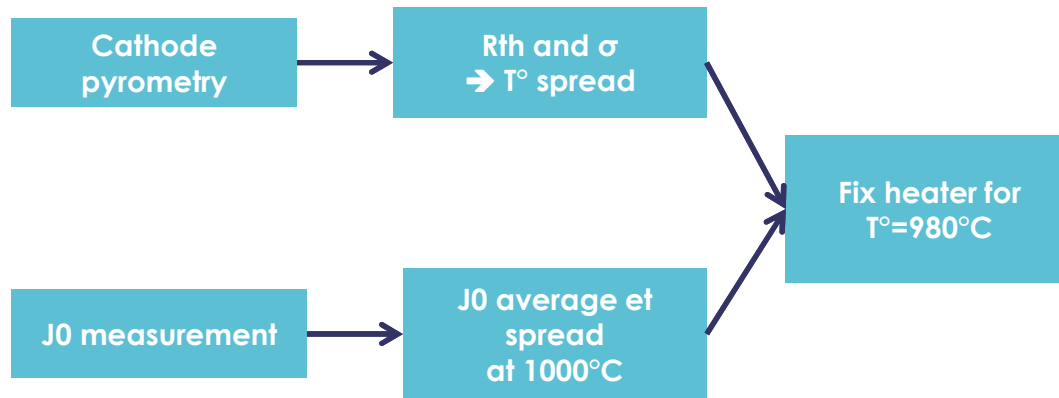
Thermal parameters with spread
Statistics known from gun pyrometry



$\rightarrow T_K$ spread ± 30 deg ($\pm 2\sigma$) at constant heater power

How to fulfill the cathode requirements?

3. By fixing the appropriate heater

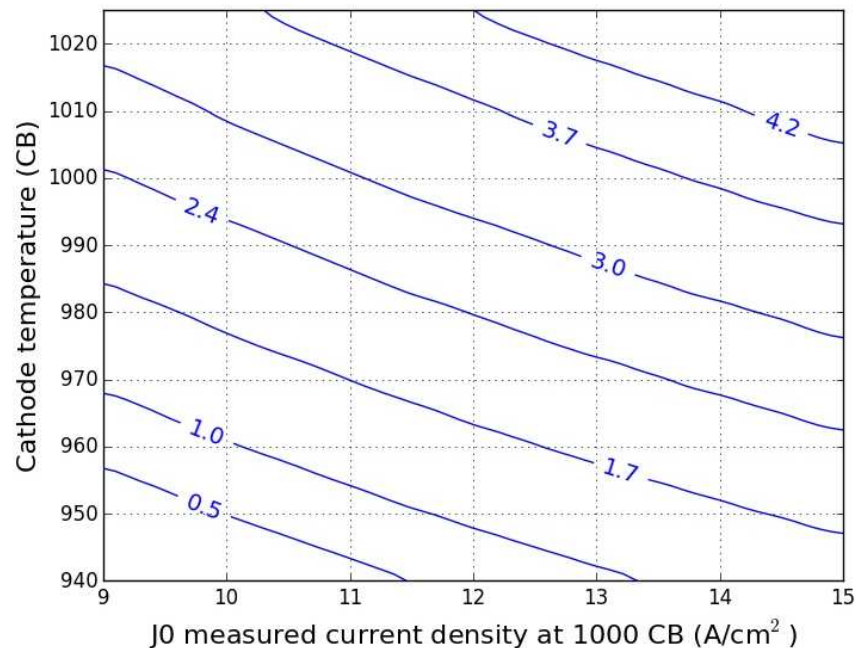


Requiereements are fulfilled, the cathode can be used for space applications

How to check experimentally the cathode temperature?

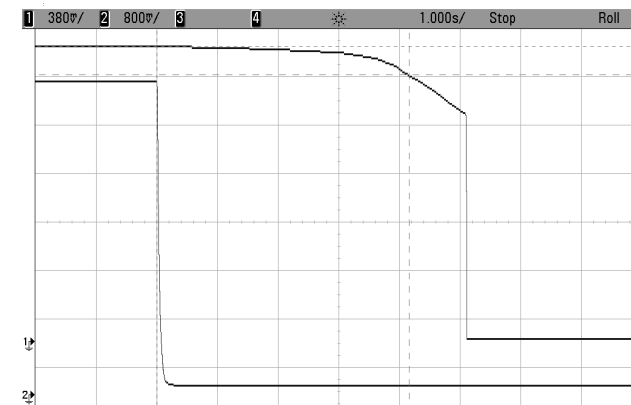
Cathode emission quality can be measured on each TWT:

- Time-to-knee is the time of 10% current drop after heater power is turned off
- It is similar to the well-known temperature-to-knee measurement



For nominal thermal parameters

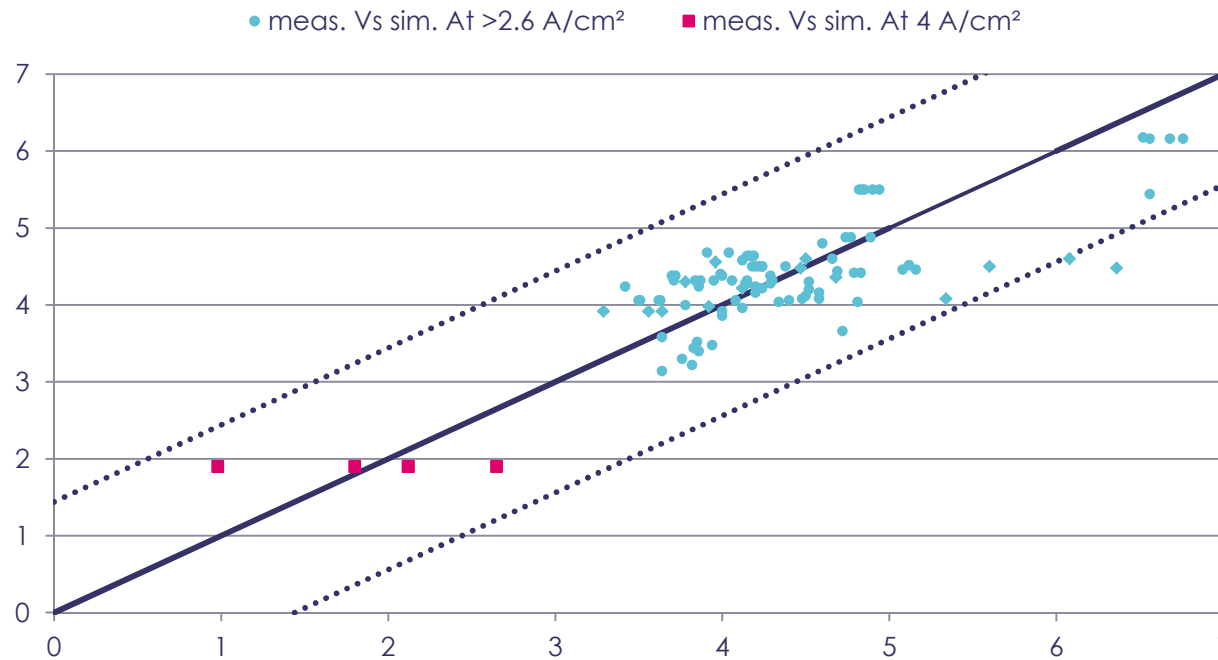
$$R_{th}, \sigma$$



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How to check experimentally the cathode temperature?

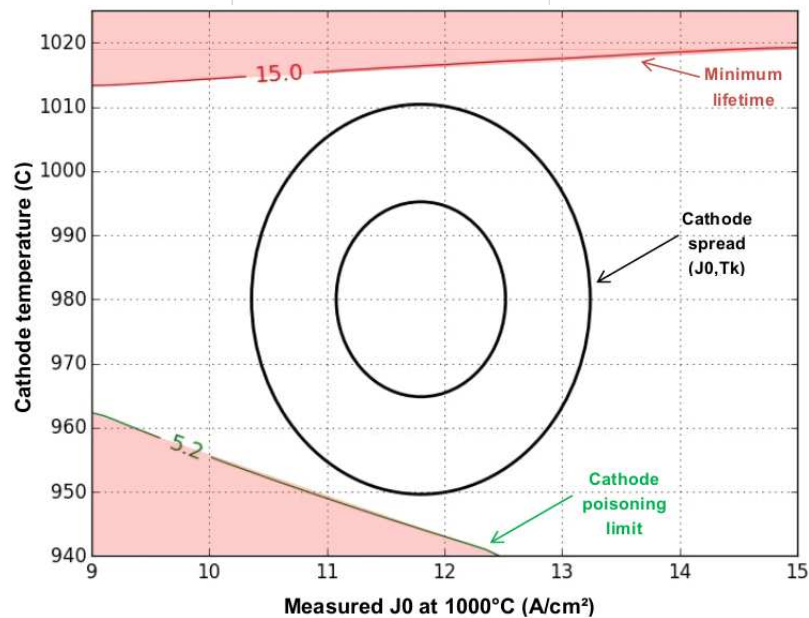
Results:



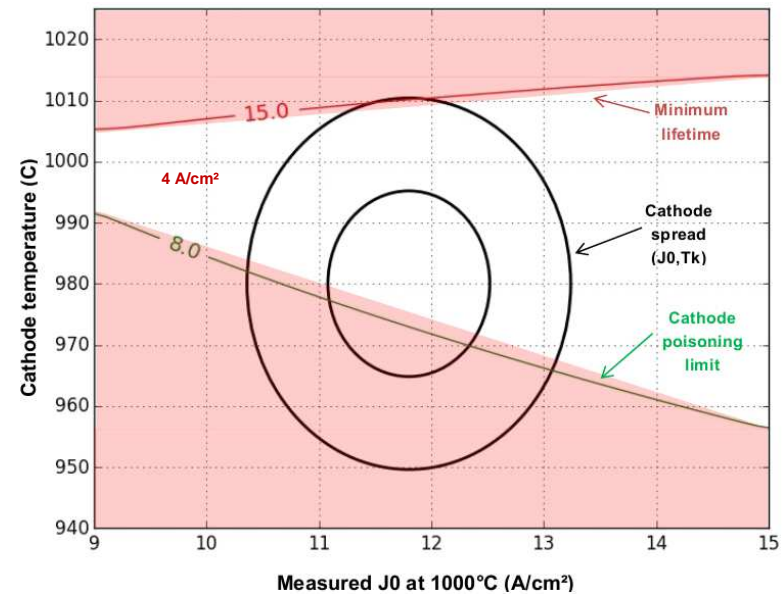
The diptest measurements are compliant with the theoretical diptest spread.

Limitation of the fixed heater method

At 2.6 A/cm²



At 4 A/cm²

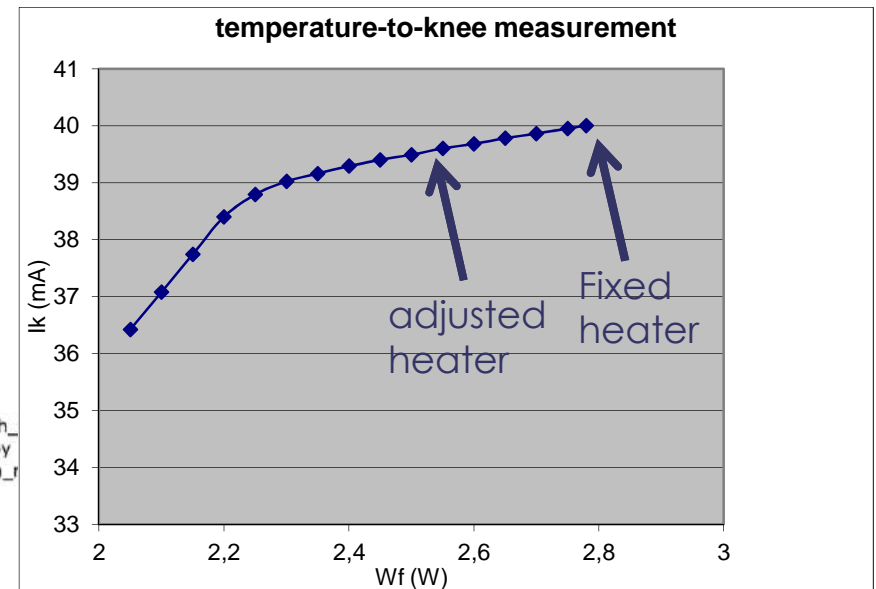
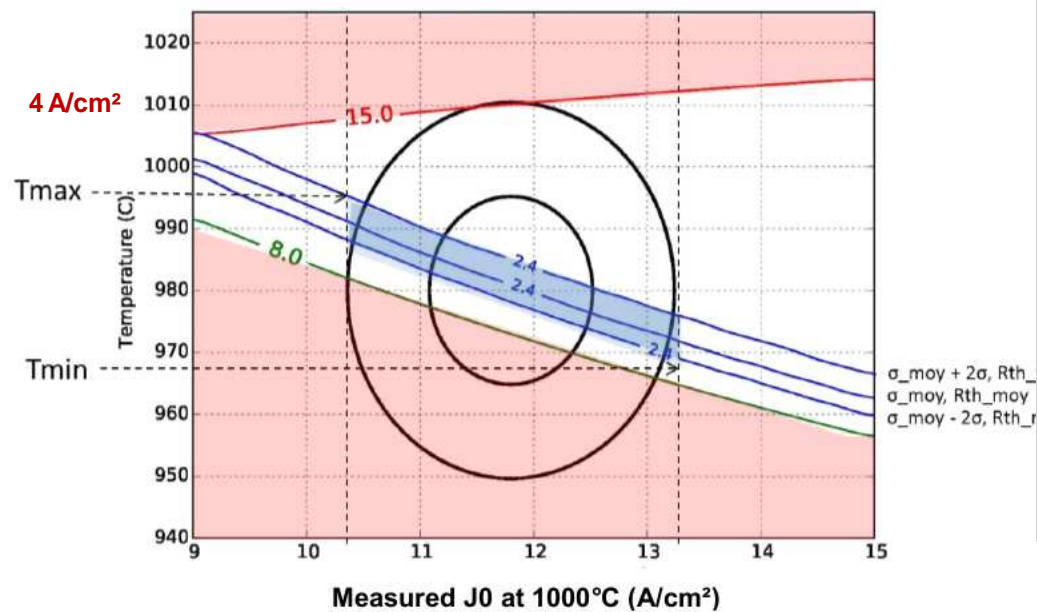


Live tests at 4 A/cm² are positive
→ M-type cathode can operate at 4 A/cm² provided the temperature spread reduction

New method to adjust the cathod temperature.

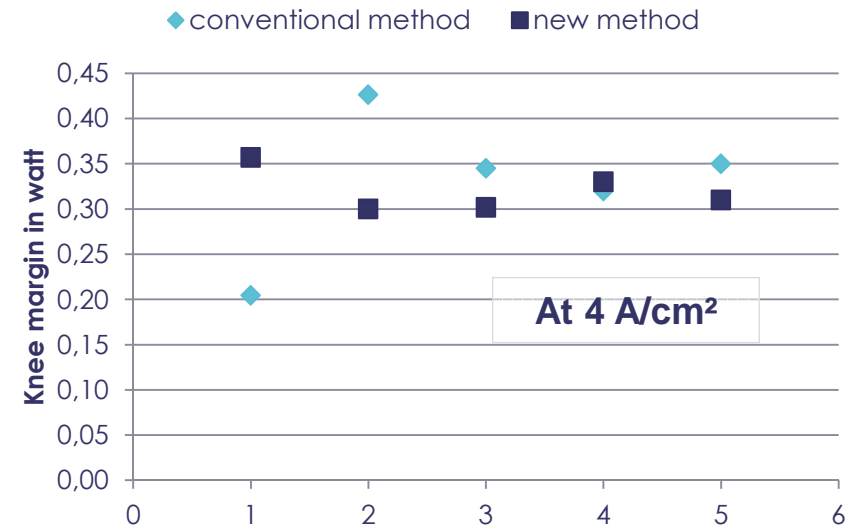
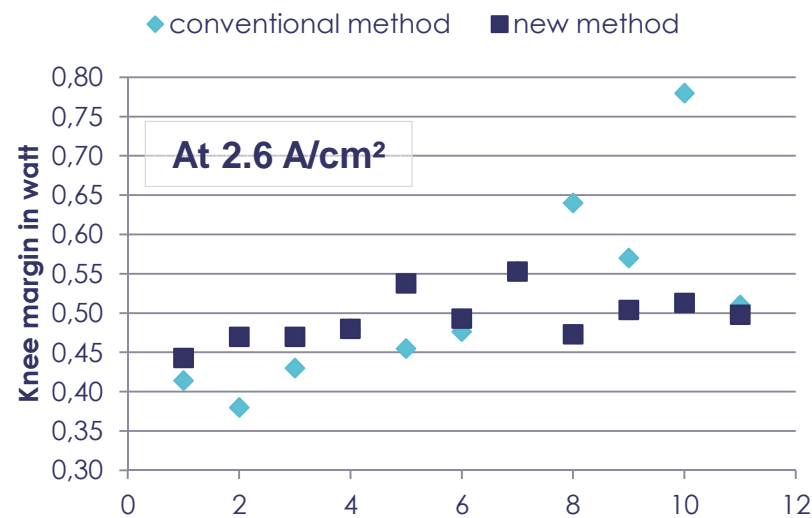
M-type Cathode heater setting for constant time-to-knee

99.8% cathodes



New method to adjust the cathode temperature.

Results:



The knee margin standard deviation is 3.3 times lower with the new method than the current method.

→ Cathode temperature spread is reduced by factor 3.3

Conclusion

- The M-type cathode fulfills space missions of 15 years at 4 A/cm²
 - Provided that each cathode heater power is adjusted for a fixed time-to-knee
- Life-time at 4 A/cm² is demonstrated experimentally on test vehicles
- It is also demonstrated by well-established Thales cathode life-time model
- All spreads impacting life-time are known and taken into account:
 - Cathode emission quality J_0
 - Cathode temperature spread