



11T QH connection Endurance, discharge, destructive On several types of connection

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Summary

- Test protocols
 - Sample label: E(N)(S or GB)-(A or S)E-(DP)
 - E: Echantillon, N: Neither cleaning nor pickling, S: pin connector, GB: Assembly jig so flat connector, A: pre-tinning, S: No pre-tinning, DP partial pickling
 - Polyimide on both sides
- Endurance test – Discharge test
 - Connection with pin connector
 - Cleaning, pickling, pre-tinning (ES-AE)
 - Connection with flat connector
 - No Cleaning, No pickling, pre-tinning *only the connector*,
 - Samples done with assembly jig (ENGB-AE)
 - Samples done with upgraded assembly jig (ENGB2-AE) – Connector pressed on trace during soldering.
 - Direct wire connected to trace
 - Cleaning, pickling, pre-tinning (EF-AE)
 - Connection on end spacer
 - Pin connector, Cleaning, pickling, pre-tinning (ES-AE)
 - Direct Wire, Cleaning, pickling, pre-tinning (EF-AE)
- Destructive test
 - High current : Pin connector, Cleaning, pickling, pre-tinning (ES-AE)
 - Pull test: Connection on end spacer, filled by Eccobond
 - Pin connector, Cleaning, pickling, pre-tinning (ES-AE)
 - Direct Wire, Cleaning, pickling, pre-tinning (EF-AE)

Endurance test – Discharge test

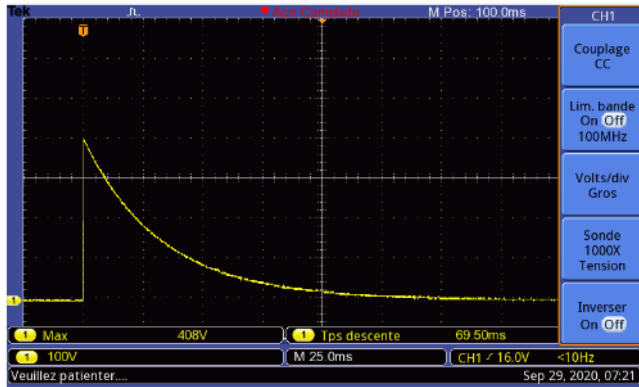
- Discharge like during 11T assembly
- At warm
- Endurance test: 15 discharges (50 for (1&2) -ES-AE)
 - 4 in 180 during assembly per quench heater
- 80 A (150 at cold)
- Discharge tester EFFACEC EP000183
- Power resistor of 5 ohms in order to simulate the QH resistance
- $\tau = 40$ ms
- Thermic picture to analyse weak point

Endurance test (ES-AE)

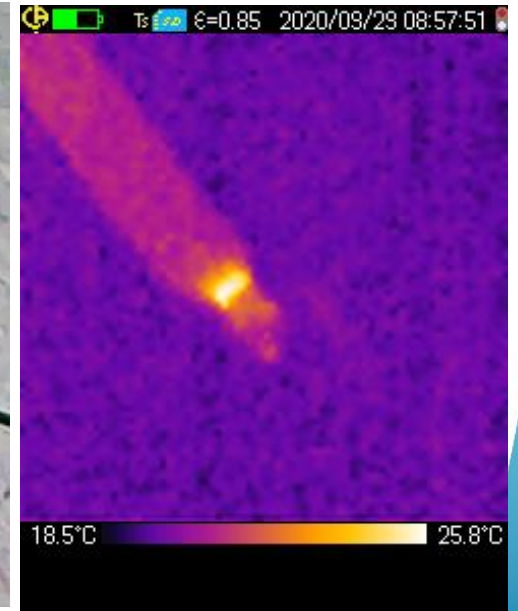
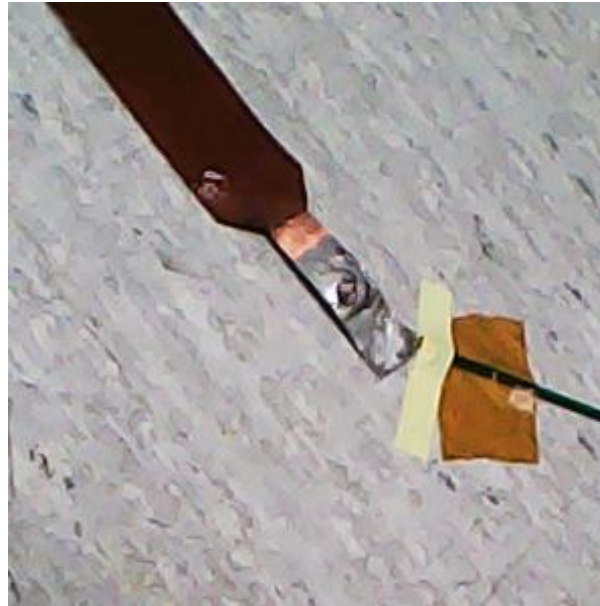
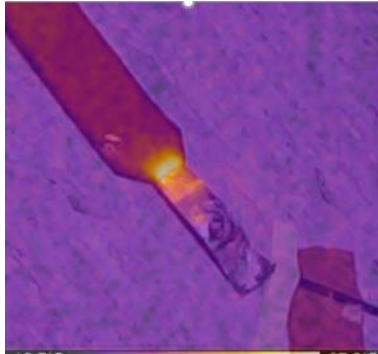
Pin connector

- Trace is cleaned, pickled and pre-tinned
- Bent pin connector crimped on the wire
- 50 cm long wire
- Pin connector soldered on 30 cm of trace
- 4 samples set up by General Electric
- 1-ES-AE
- 2-ES-AE
- 3-ES-AE
- 7-ES-AE

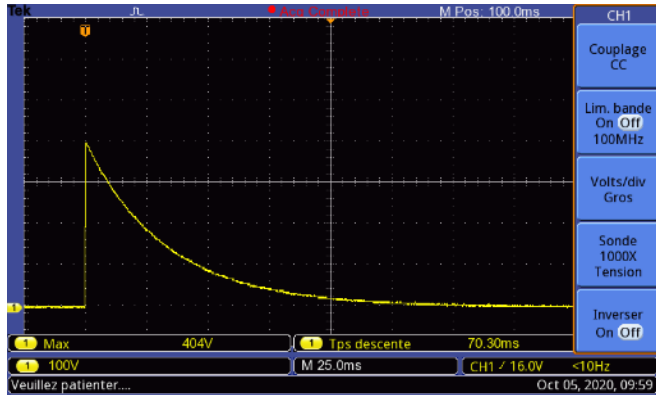
1-ES-AE / 15th discharge



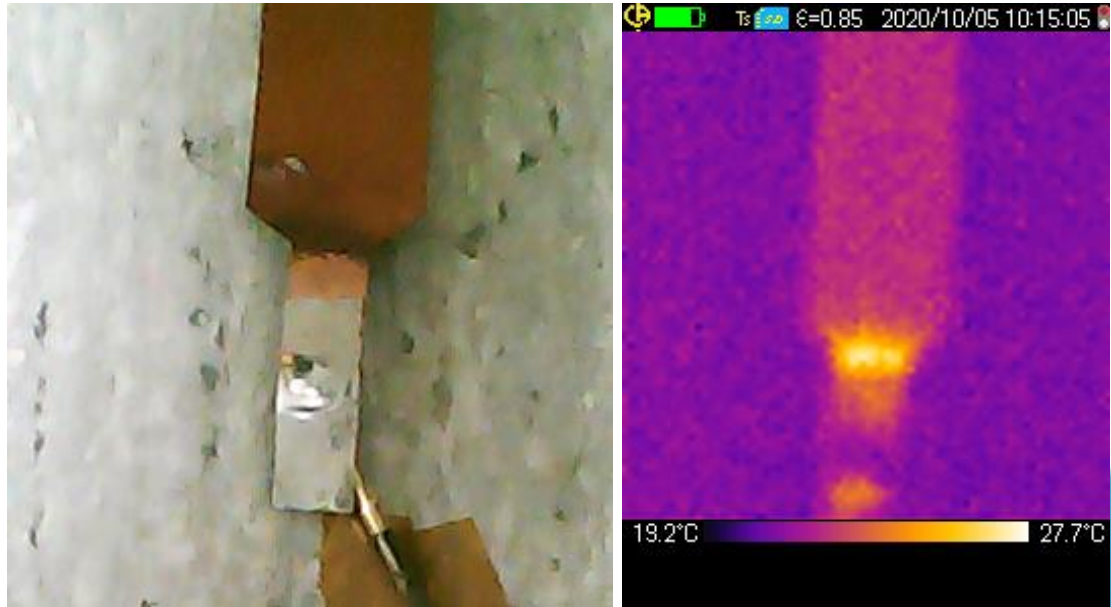
No degradation
Warm spot in the insulated area
 $T < 27^\circ\text{C}$



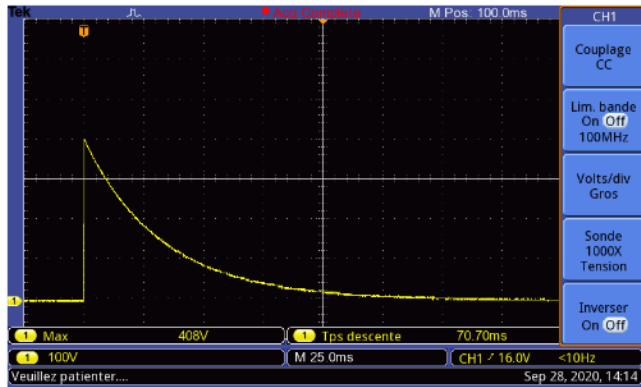
1-ES-AE / 50th discharge



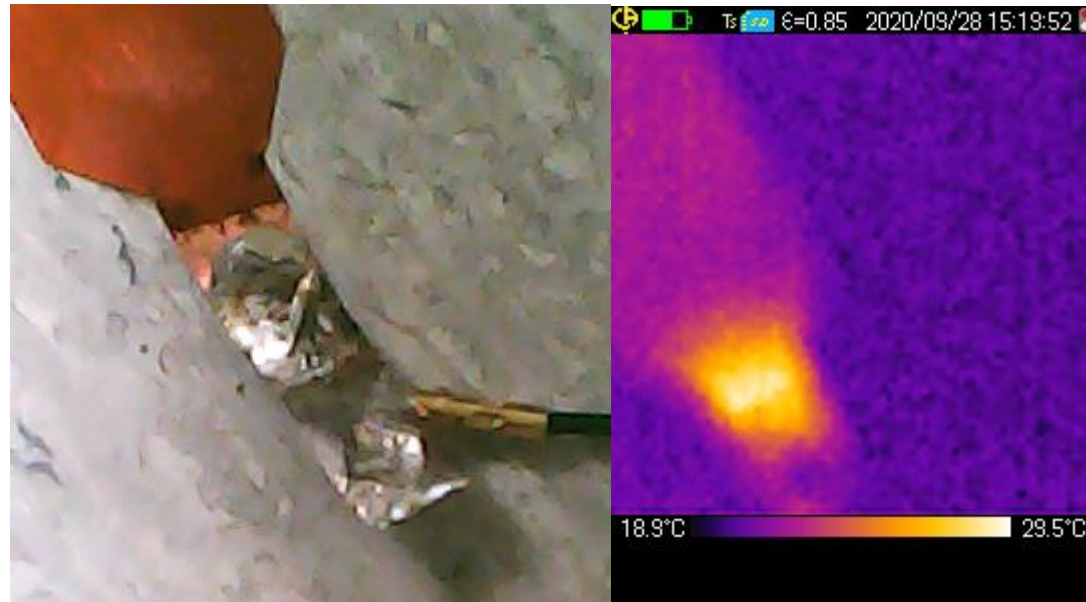
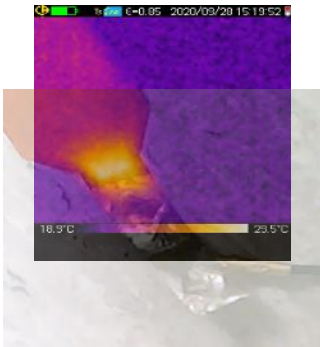
No degradation
Warm spot in the insulated area
 $T < 29^\circ\text{C}$



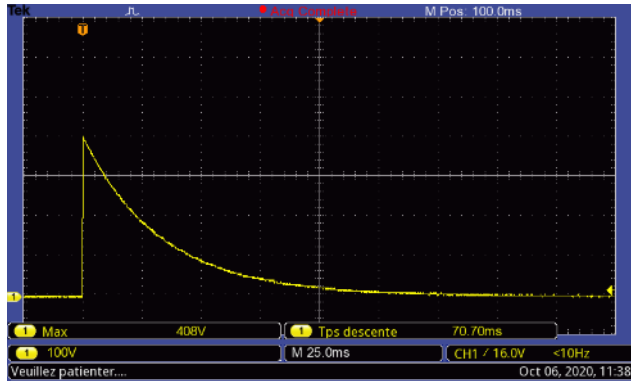
2-ES-AE / 15th discharge



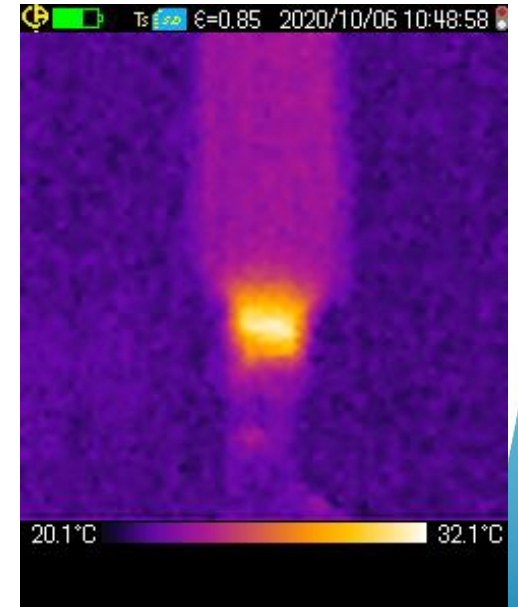
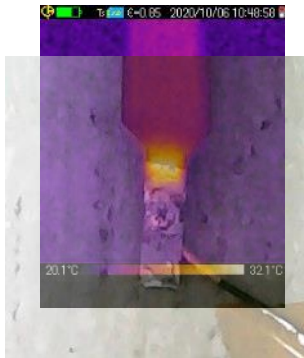
No degradation
Warm spot in the insulated area
 $T < 31^\circ\text{C}$



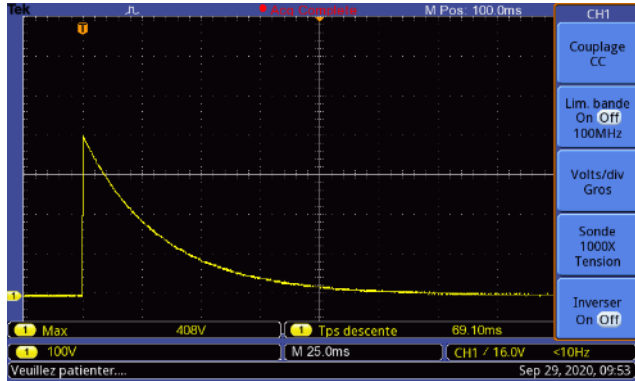
2-ES-AE / 50th discharge



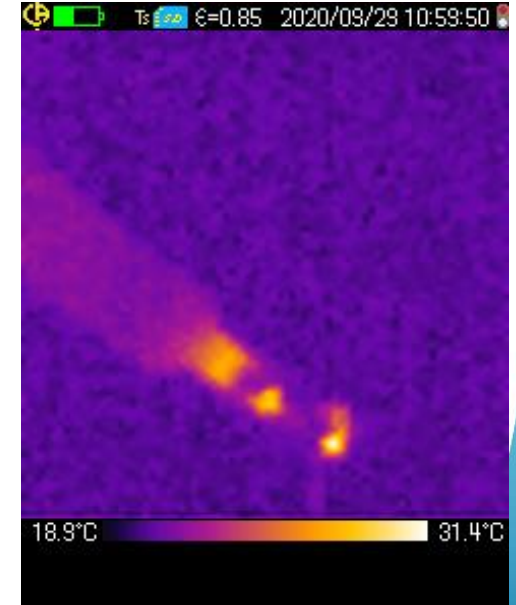
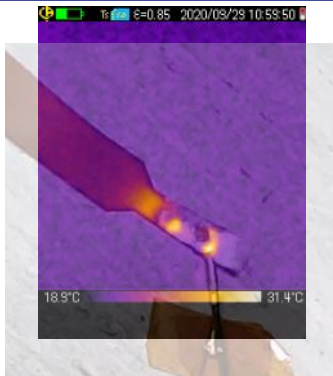
No degradation
Warm spot in the insulated area
 $T < 33\text{ }^{\circ}\text{C}$



3-ES-AE / 15th Discharge



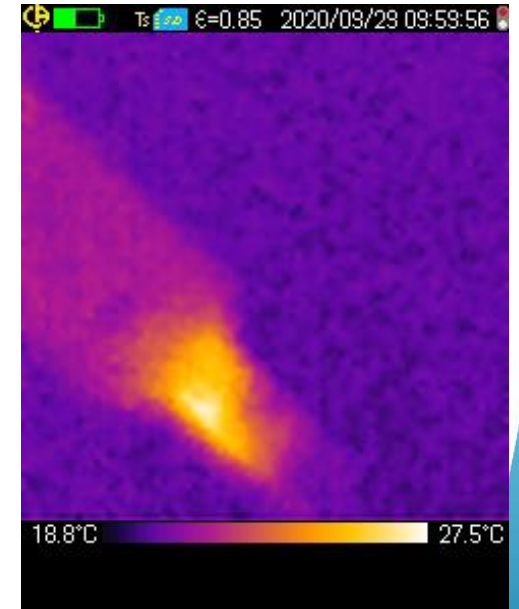
No degradation
Warm spot in the insulated area
Light effect in tin area
 $T < 33\text{ }^{\circ}\text{C}$



7-ES-AE / 15th Discharge



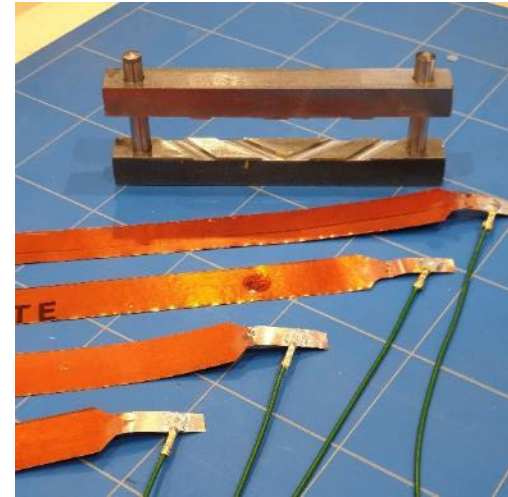
No degradation
Warm spot in the narrow area
 $T < 28^\circ\text{C}$



Endurance test (ENGB-AE)

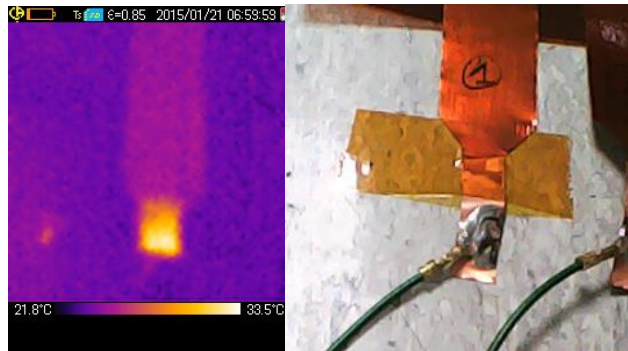
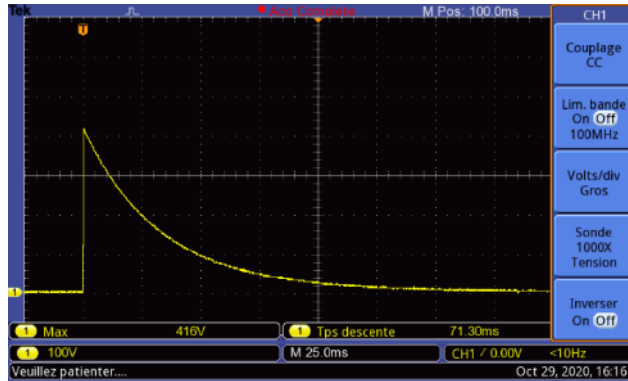
Flat Connector

- Trace is neither cleaned, nor pickled
- Only the flat connector is pre-tinned, not the trace
- Flat connector crimped
- 50 cm long wire
- Flat connector soldered on 30 cm of trace
- 4 samples set up by Ludovic Favier with assembly jig
- 1-ENGB-AE
- 2-ENGB-AE
- 3-ENGB-AE
- 7-ENGB-AE



By courtesy of
Ludovic Favier

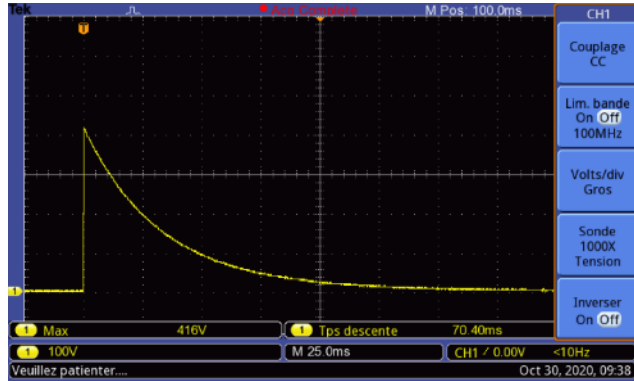
1-ENGB-AE / 15th Discharge



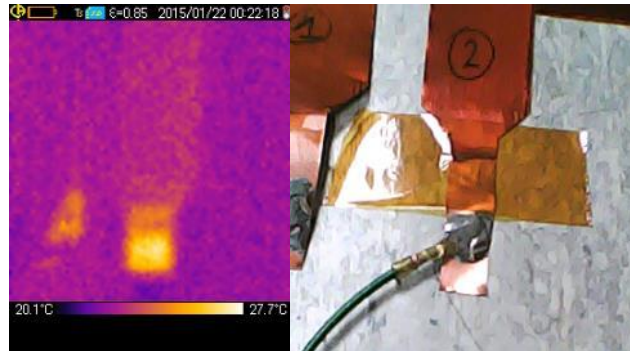
No degradation
Warm spot in the narrow area; Under the polyimide tape
 $T < 34\text{ }^{\circ}\text{C}$



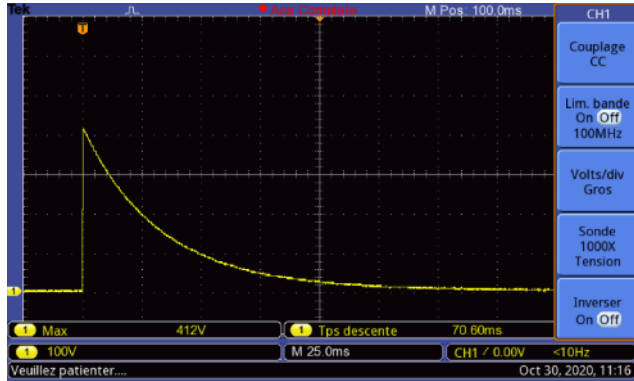
2-ENGB-AE / 15th Discharge



No degradation
Warm spot in the narrow area; Under the polyimide tape
 $T < 28^{\circ}\text{C}$



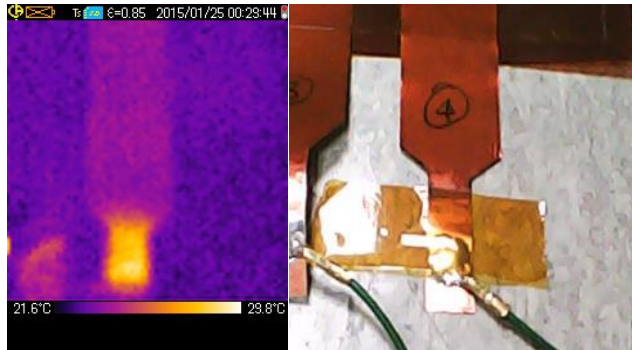
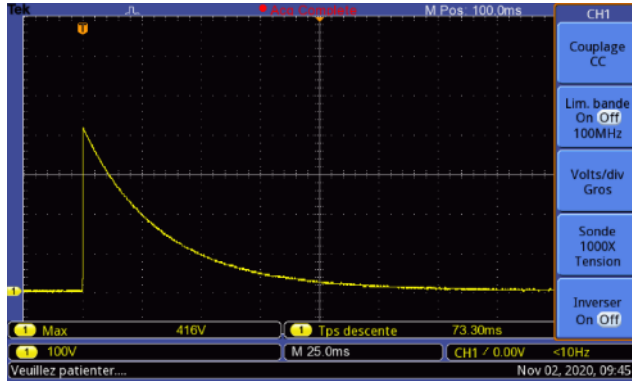
3-ENGB-AE / 15th Discharge



No degradation
Warm spot in the narrow area; Under the polyimide tape
 $T < 32\text{ }^{\circ}\text{C}$



4-ENGB-AE / 15th Discharge



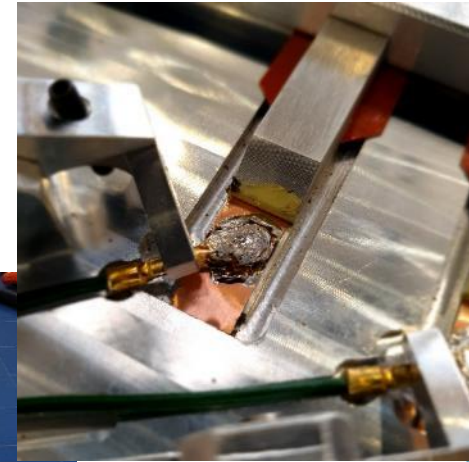
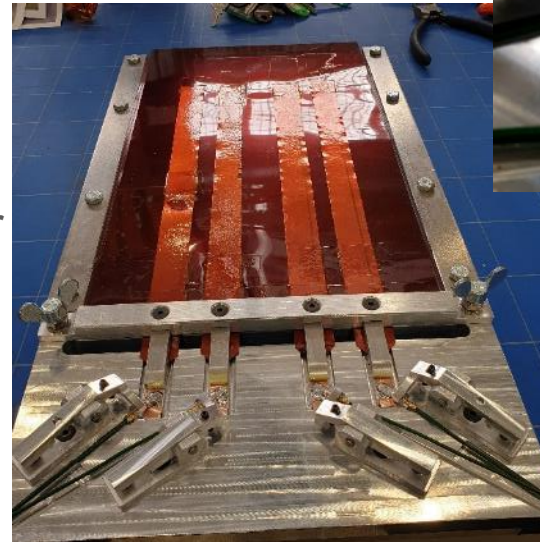
No degradation
Warm spot in the narrow area; Under the polyimide tape
 $T < 30^\circ\text{C}$



Endurance test (ENGB2-AE)

Flat Connector – upgraded assembly jig

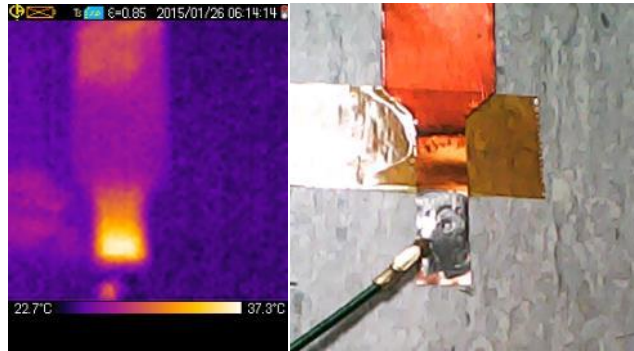
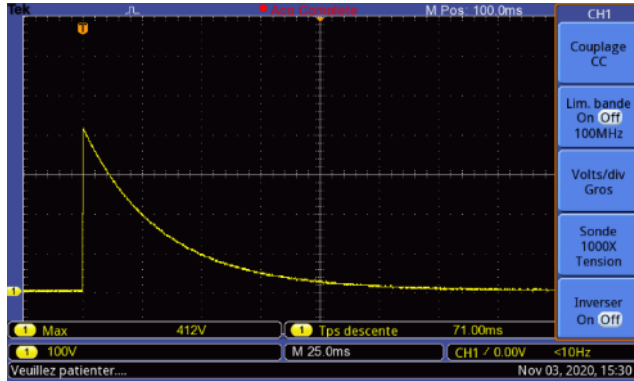
- Trace is neither cleaned, nor pickled
- Only the flat connector is pre-tinned, not the trace
- Flat connector crimped and pressed on trace during soldering
- 50 cm long wire
- Flat connector soldered on 30 cm of trace
- 4 samples set up by Ludovic Favier with assembly jig, only one for endurance test
- 1-ENGB2-AE



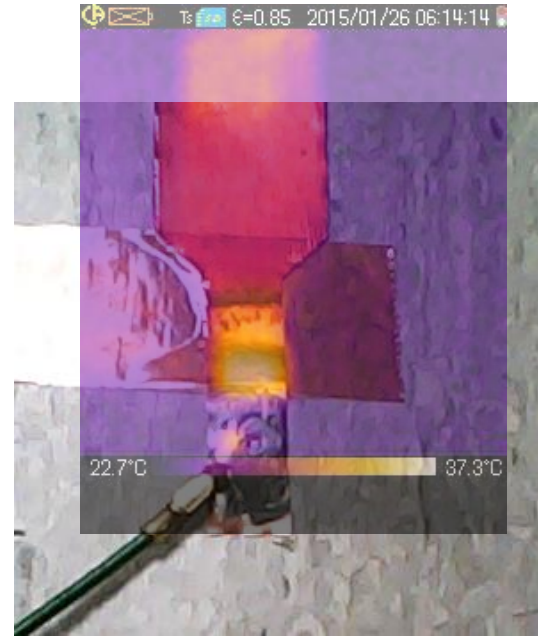
By courtesy of
Ludovic Favier

Upgraded
version

1-ENGB2-AE / 15th Discharge



No degradation
Warm spot in the narrow area; Under the polyimide tape
 $T < 38^\circ\text{C}$

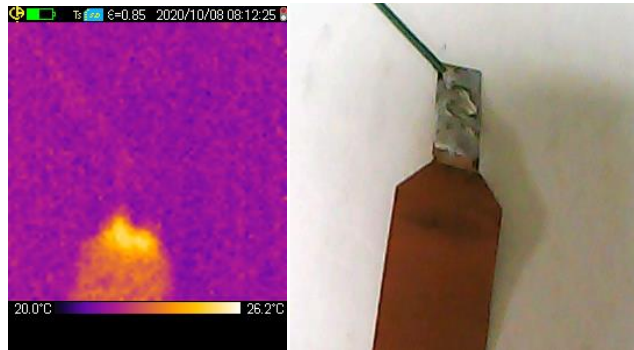
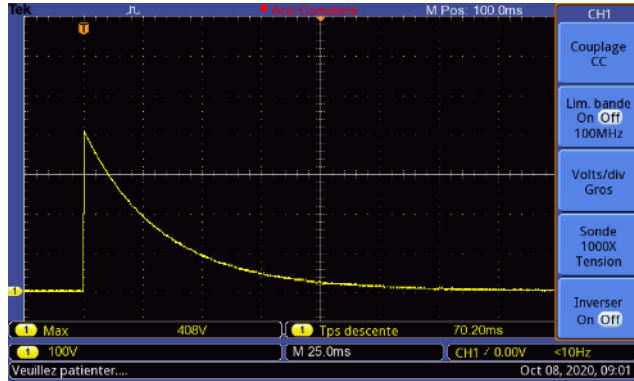


Endurance test (EF-AE)

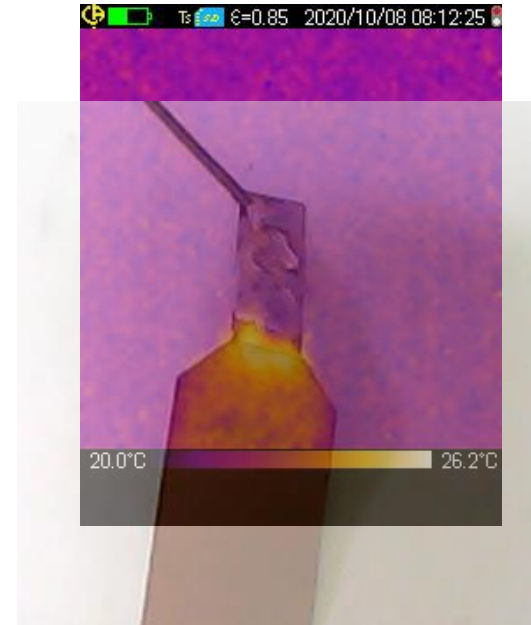
Wire soldered on trace

- Trace is cleaned, pickled and pre-tinned
- Wire directly soldered on the trace
- 50 cm long wire
- 3 samples set up by General Electric
- 1-EF-AE
- 2-EF-AE
- 3-EF-AE

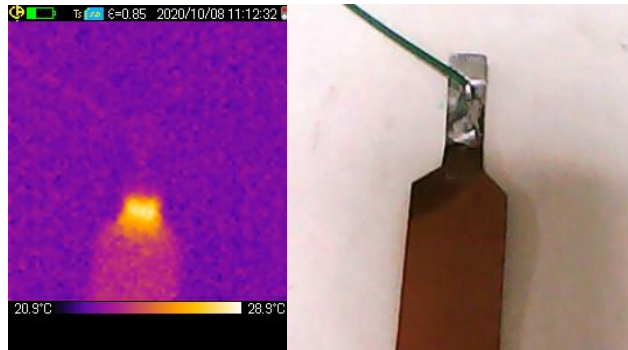
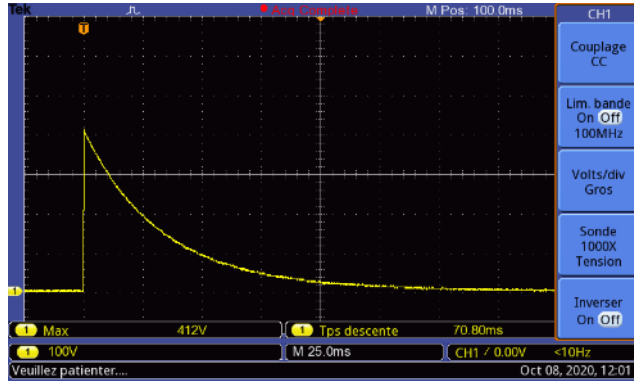
1-EF-AE / 15th Discharge



No degradation
Warm spot in the narrow area
 $T < 27^\circ\text{C}$



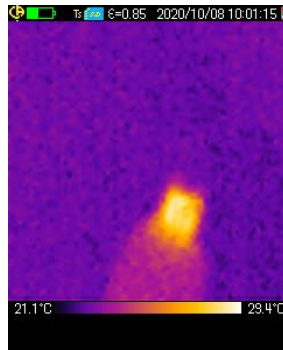
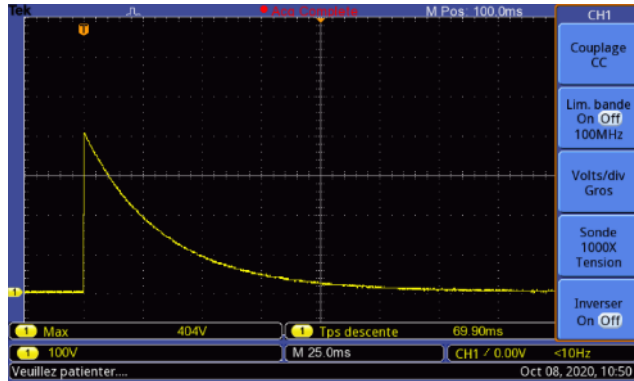
2-EF-AE / 15th Discharge



No degradation
Warm spot in the narrow area
 $T < 30\text{ }^{\circ}\text{C}$



3-EF-AE / 15th Discharge



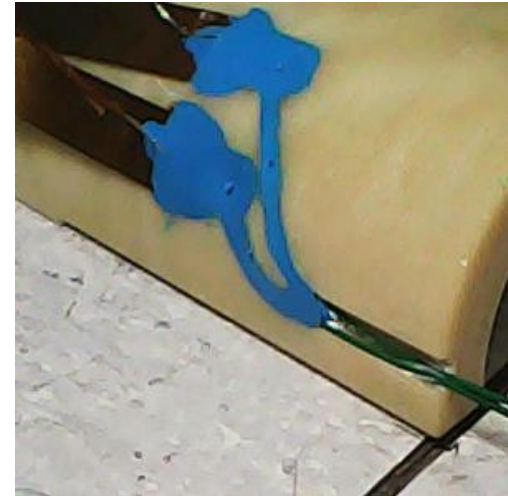
No degradation
Warm spot in the narrow area
 $T < 31\text{ }^{\circ}\text{C}$



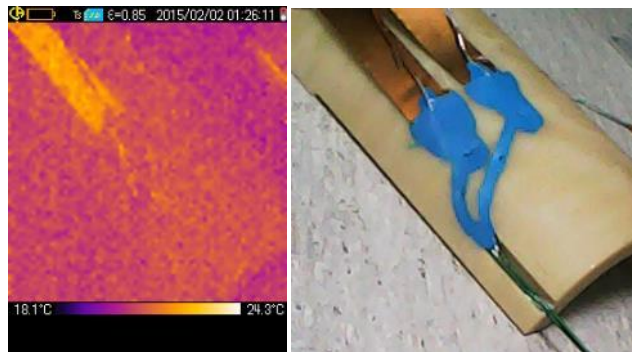
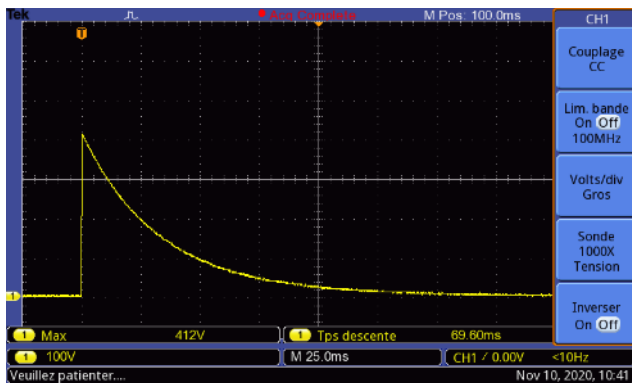
Endurance test (ES-AE) & (EF-AE)

Connection on end spacer

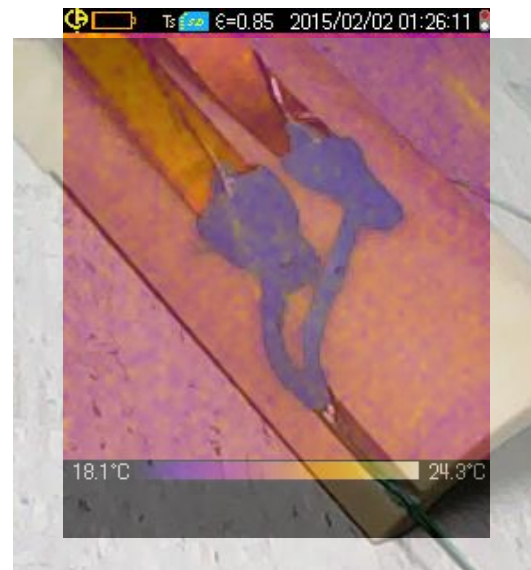
- Trace is cleaned, pickled and pre-tinned
- 50 cm long wire
- Soldered on 30 cm of trace
- The 2 samples had been used for endurance test; Set up by General Electric
 - Wire directly soldered on the trace
 - 2-EF-AE – 15 discharges
 - Pin connector
 - 2-ES-AE – 50 discharges
- Trace set on end spacer
 - Thermocouple near the connection
 - Filled with Eccobond by GE



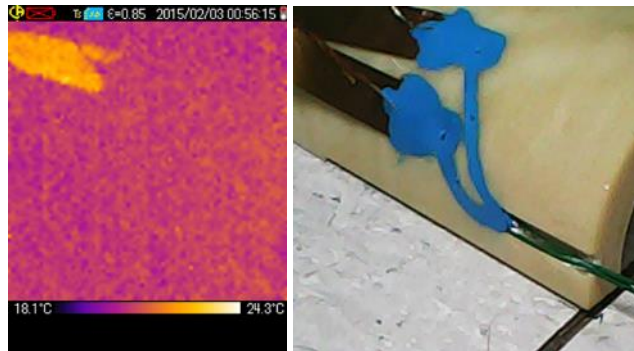
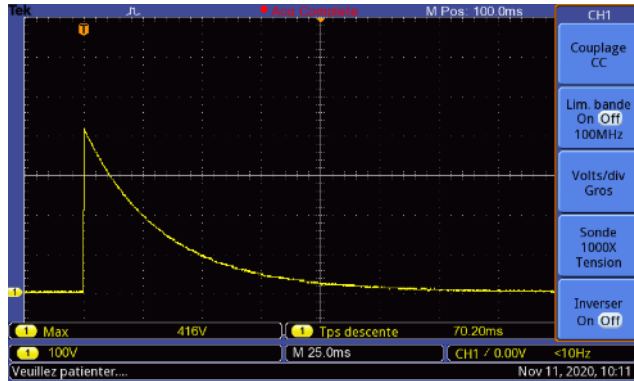
2-EF-AE / 15th Discharge (Total 30)



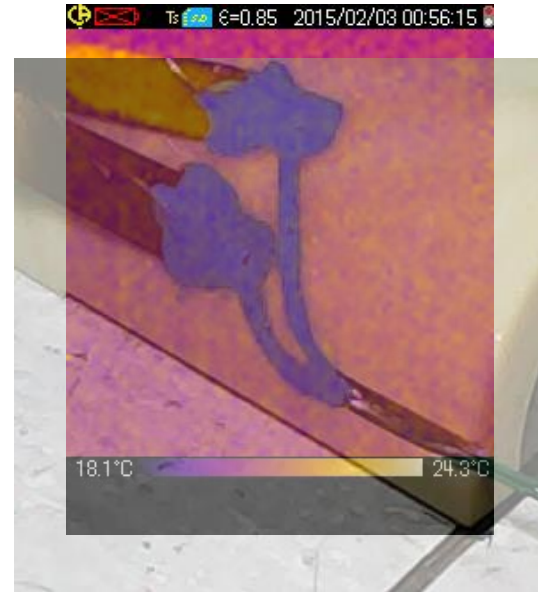
No degradation
Warm spot in the straight area
T < 25 °C by camera – Connection hidéd by Eccobond
No T°C rise saw by thermocouple (latency)



2-ES-AE / 15th Discharge (Total 65)



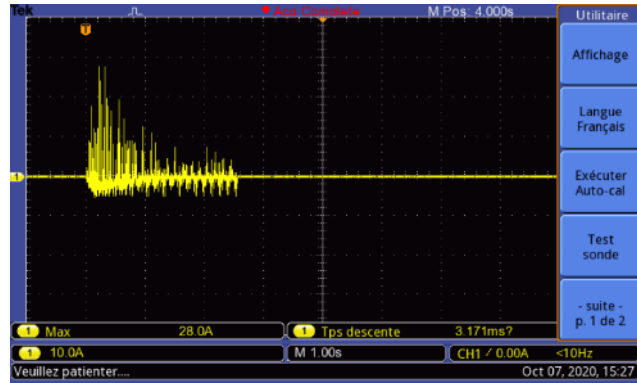
No degradation
Warm spot in the straight area
 $T < 25\text{ }^{\circ}\text{C}$ by camera – Connection hid by Eccobond
No $T^{\circ}\text{C}$ rise saw by thermocouple (latency)



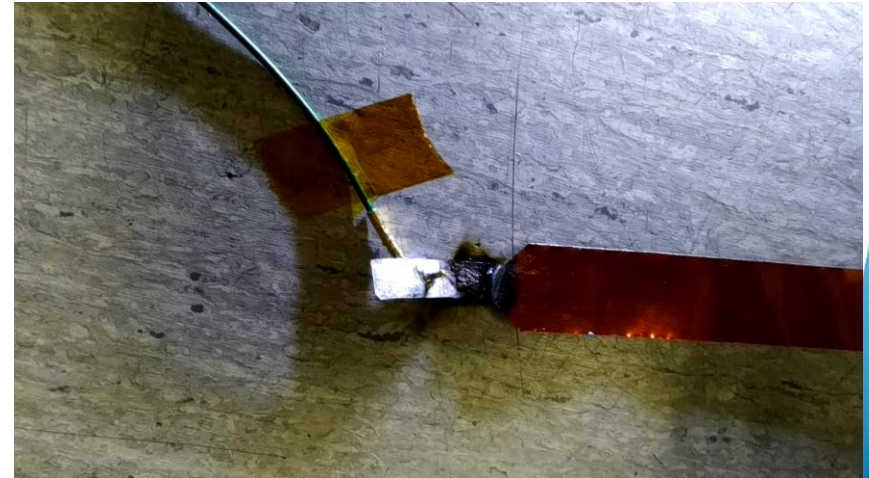
Destructive test (ES-AE)

- DC current
- Start at «low» energy as close as discharge test
- At warm
- Micro-ohm meter Megger DLR0-600
- Per calculation 5 A, but equipment starts at 10 A
 - The impact of the length time is not taken in account, only the quantity of energy.
- 10 A (2.5 s ramp up, 2 s plateau, 2.5 s ramp down)
- Increasing by 5 A up to breakage
- Thermic picture to analyse weak point
- Camera to record the breakage
- The 2 samples had been used for endurance test 15; Set up by General Electric
 - 3-ES-AE
 - 7-ES-AE

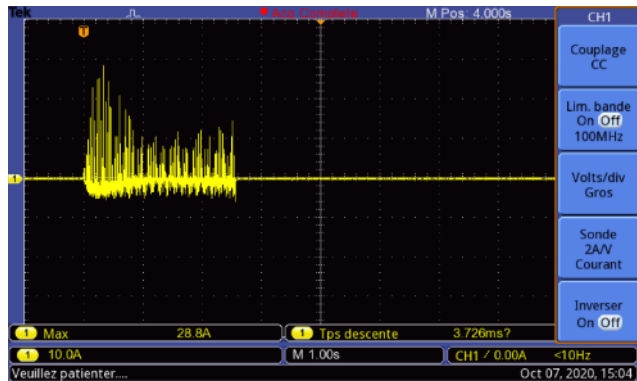
3-ES-AE



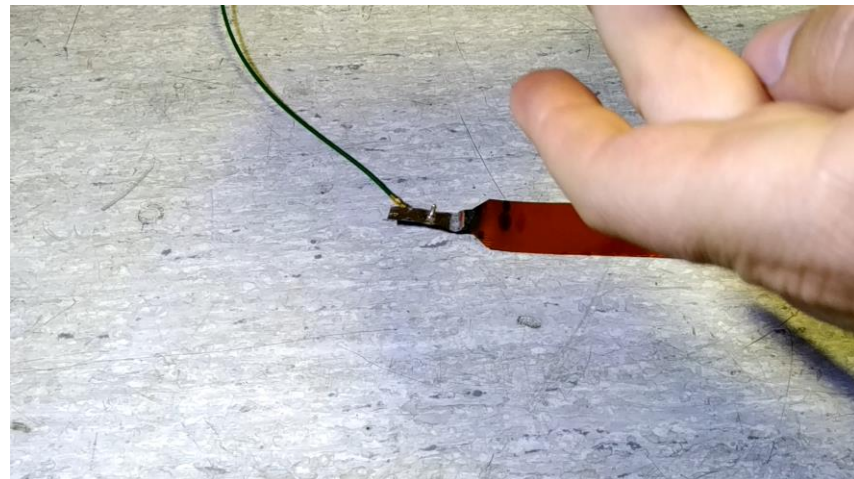
Breakage in the narrow part
50 A -> 56 250 J
Current curve not usable
280°C max temperature (camera limit)



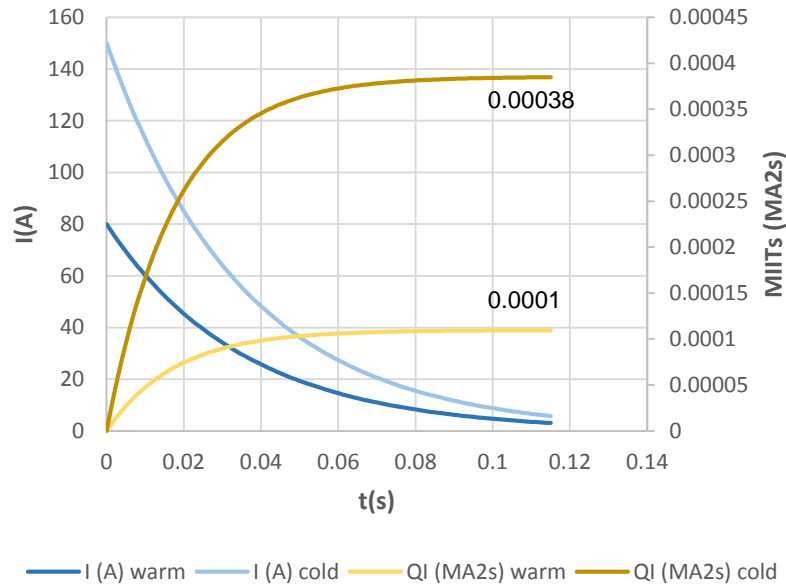
7-ES-AE



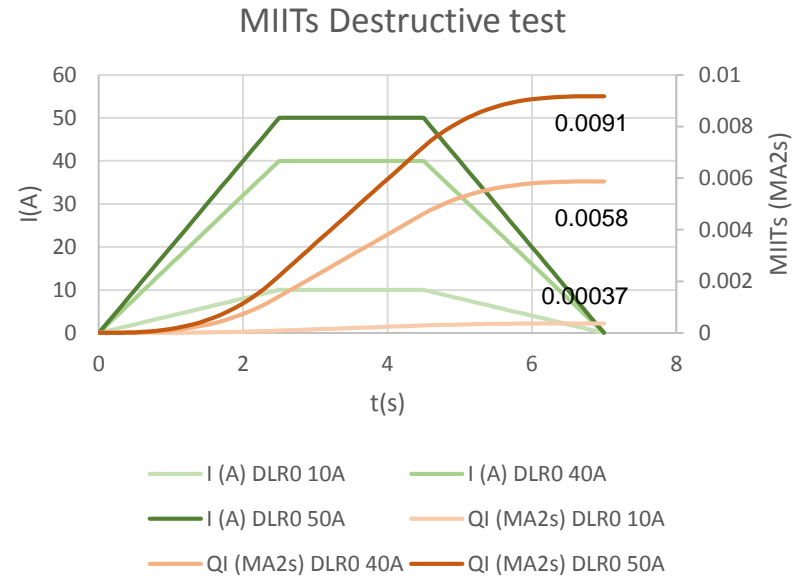
Breakage in the narrow part
40 A -> 36 000 J
Current curve not usable
280°C max temperature (camera limit)

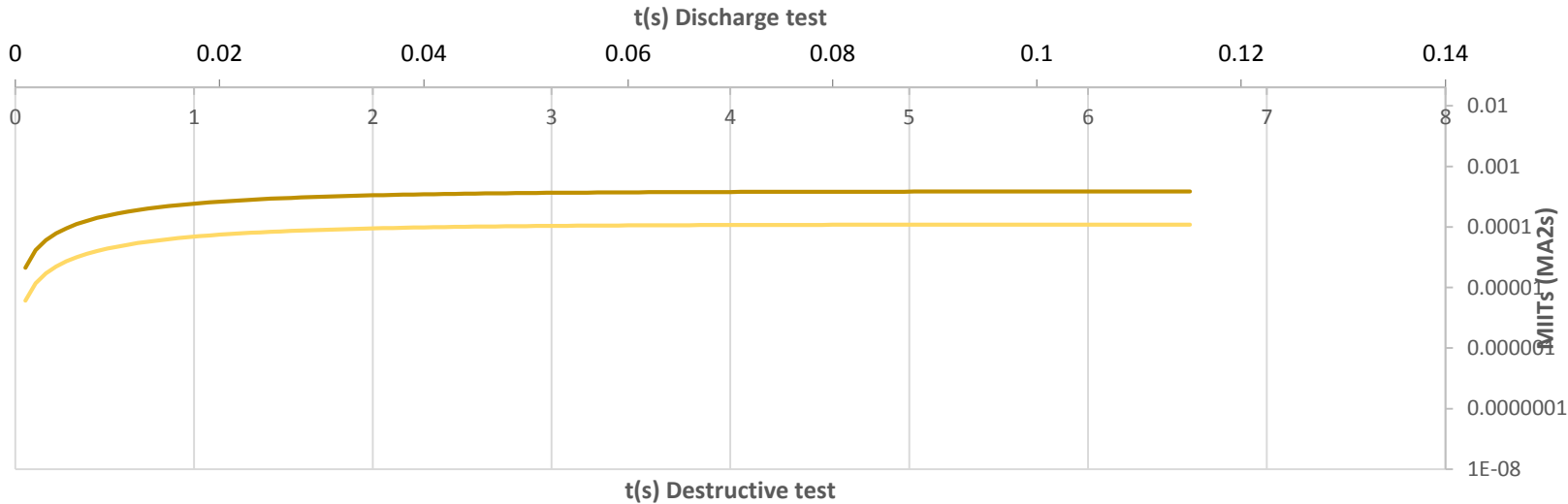


Discharge test



Destructive test





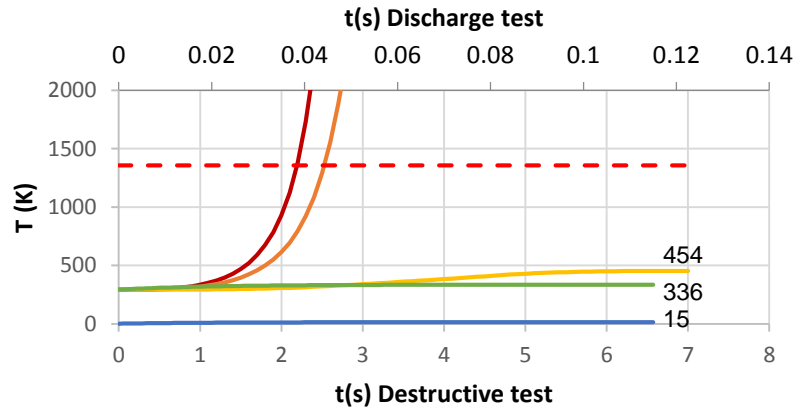
— QI (MA2s) DLRO 10A
 — QI (MA2s) DLRO 40A
 — QI (MA2s) DLRO 50A
 — QI (MA2s) warm
 — QI (MA2s) cold

MIITs discharge and destructive test

Destructive test at 10 A is at the same level of MIITs than discharge test at cold
 Destructive test at 40 & 50 A are more than 10 times higher than cold test

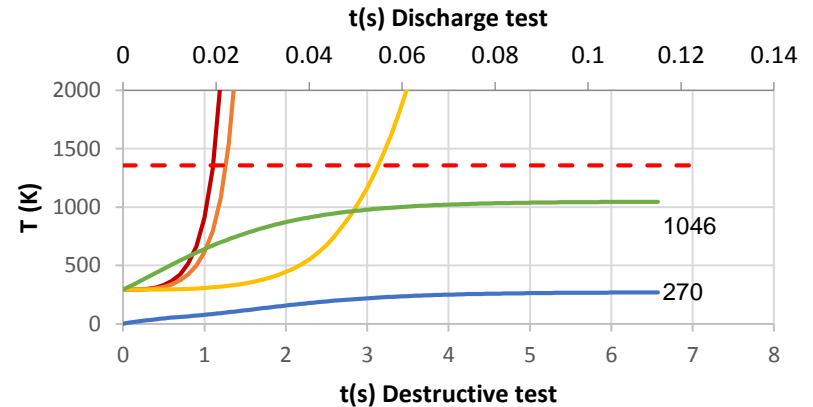
Temperature reached by calculation

Temperature dispersion not taken in account (Either to stainless Steel nor to He)
Copper thickness = 15 μm



— T Destructive 293K 50A — T Destructive 293K 40A
— T Destructive 293K 10A - - - Cu Melts (K)
— T Discharge 1.9K 150A — T Discharge 293K 80A

Temperature dispersion not taken in account (Either to stainless Steel nor to He)
Copper thickness = 5 μm



— T Destructive 293K 50A — T Destructive 293K 40A
— T Destructive 293K 10A - - - Cu Melts (K)
— T Discharge 1.9K 150A — T Discharge 293K 80A

Destructive test (ES-AE & EF-AE)

Pull test

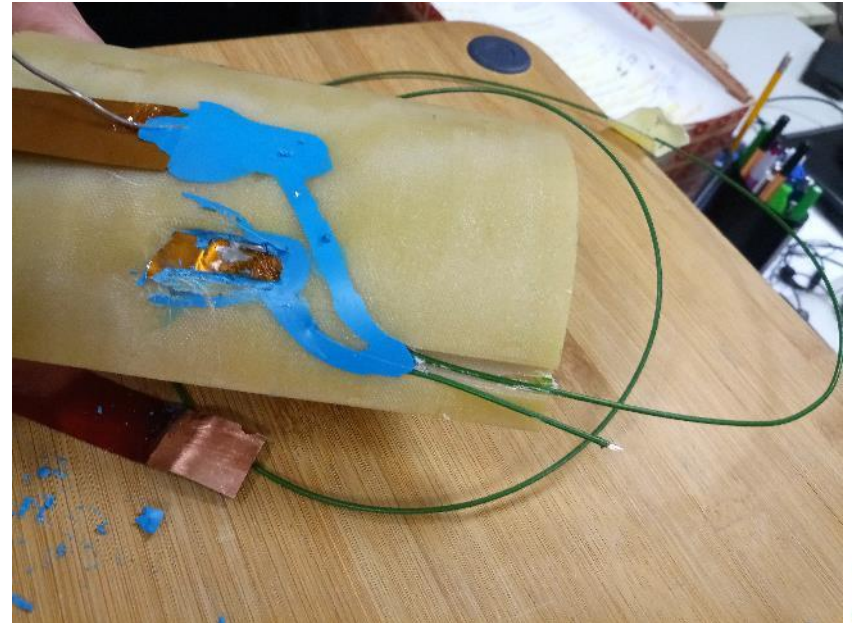
- Connection on end spacer
- Set up by General Electric
- Wire directly soldered on the trace
 - 2-EF-AE, 30 discharges so far
 - Test 1: Wire pulled
 - Test 2: Trace pulled
- Pin connector
 - 2-ES-AE, 65 discharges so far
 - Test 1: Wire pulled
 - Test 2: Trace pulled



2-EF-AE / Pull test



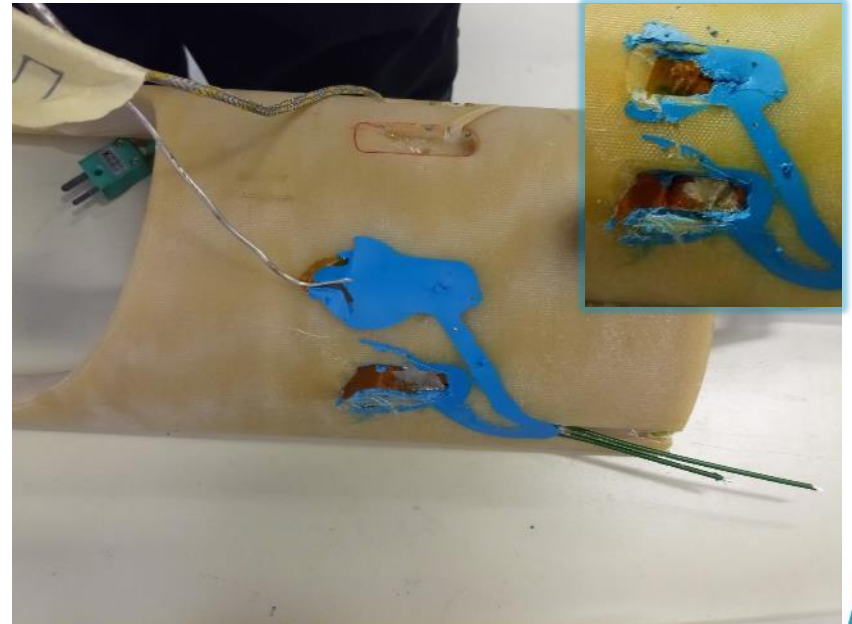
Connection on trace still intact
Wire cut at the plier level, 290.3 Nm
Trace cut at the Eccobond level, 215.8 Nm



2-ES-AE / Pull test



Connection on trace still intact
Wire cut at the plier level, 364.8 Nm
Trace cut at the Eccobond level, 333Nm



Conclusion

- Endurance test 15 or 50 didn't show degradation of the connection (soldering-crimped connector-wire), but a warm spot in the narrow part of the trace. The hot point is around 30 °C. That location strongly depends of the presence of insulation material on the trace. No significative difference between connection (pin & flat connector, direct wire).
- Endurance test on end spacer, the Eccobond hides the temperature in the narrow part, and the thermocouple time response is too slow. Nevertheless no degradation has been seen.
- Destructive test are in the same way, no degradation of the connection. The narrow part burnt at 40 and 50 A, 7 s test. Reported to 40 ms: Meaning 8 or 10 times more current than in cold condition during a quench, obviously the length time is not taken in account (fuse effect).
- With MIITs calculation, the result is in the same order. To add, MIITs result of destructive test at 10 A is like discharge test at cold at 150 A.
- Calculation of temperature reached in the narrow copper part shows the high impact of the copper coating thickness. With severe condition, no temperature dispersion, no stainless-steel layer, minimal thickness of 5 μm , the reached temperature (calculated) during a quench is less than 300 K; That is very conservative.
- Pull test showed that the Eccobond adds more strength to the assembly,
- To conclude:
 - In normal condition, the weak point is not the solder between connector and trace
 - The soldering has to be extremely bad to be burnt during a discharge
 - We can be confident against the narrow trace and the soldering

Result summary

Sample	Endurance test 15 Discharges	Endurance test 50 Discharges	Endurance test 15 Discharges End spacer	Pull test	Breakage current	Energy (breakage)	Matching Discharge Current (R = 5 Ω)
1-ES-AE	Ok	Ok	-		-	-	-
2-ES-AE	Ok	Ok	Ok	Wire 364.8 Nm Trace 333 Nm	-	-	-
3-ES-AE	Ok	-	-		50 A	56 250 J	800 A
7-ES-AE	Ok	-	-		40 A	36 000 J	640 A
1-ENGB-AE	Ok	-	-		-	-	-
2-ENGB-AE	Ok	-	-		-	-	-
3-ENGB-AE	Ok	-	-		-	-	-
4-ENGB-AE	Ok	-	-		-	-	-
1-ENGB2-AE	Ok						
1-EF-AE	Ok	-	-		-	-	-
2-EF-AE	Ok	-	Ok	Wire 290.3 Nm Trace 215.8 Nm	-	-	-
3-EF-AE	Ok	-	-		-	-	-



Thanks for your attention



Annexe



Energy

Discharge test at warm

- $U = 400 \text{ V}$
- $C = 7.05 \text{ mH}$
- $E = \frac{1}{2} \times C \times U^2$
- $E = 564 \text{ J}$

DLRO600

- Ramp up: 2.5 s
- Plateau: 2 s
- Ramp down: 2.5 s
 - $I = 10 \text{ A}$
 - $R = 5 \Omega$
 - $E = R \cdot I^2 \cdot dt$
- $E = R \times I^2 \times \Delta t$
- $E = 2250 \text{ J}$