NEPP Evaluation of Automotive Grade Tantalum Chip Capacitors

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List of Acronyms

AEC	Automotive Electronics Council
AS & D	Aerospace & Defense
C	Capacitance
DCL	Direct Current Leakage
DF	Dissipation Factor
EDS	Energy Dispersive X-ray Spectroscopy
ESR	Equivalent Series Resistance
NASA	National Aeronautics and Space Administration
NEPP	NASA Electronic Parts & Packaging
PWB	Printed Wiring Board
SE	Secondary Electron (scanning electron microscopy mode)

Abstract

Automotive grade tantalum (Ta) chip capacitors are available at lower cost with smaller physical size and higher volumetric efficiency compared to military/space grade capacitors. Designers of high reliability aerospace and military systems would like to take advantage of these attributes while maintaining the high standards for long-term reliable operation they are accustomed to when selecting military-qualified established reliability tantalum chip capacitors (e.g., MIL-PRF-55365).

The objective for this evaluation was to assess the long-term performance of off-the-shelf automotive grade Ta chip capacitors (i.e., manufacturer self-qualified per AEC Q-200). Two (2) lots of case size D manganese dioxide (MnO_2) cathode Ta chip capacitors from 1 manufacturer were evaluated. The evaluation consisted of construction analysis, basic electrical parameter characterization, extended long-term (2000 hours) life testing and some accelerated stress testing. Tests and acceptance criteria were based upon manufacturer datasheets and the Automotive Electronics Council's AEC Q-200 qualification specification for passive electronic components.

As-received a few capacitors were marginally above the specified tolerance for capacitance and ESR. X-ray inspection found that the anodes for some devices may not be properly aligned within the molded encapsulation leaving less than 1 mil thickness of the encapsulation. This evaluation found that the long-term life performance of automotive grade Ta chip capacitors is generally within specification limits suggesting these capacitors may be suitable for some space applications.

Outline

- ☐ Device selection
- ☐ Construction Analysis
- ☐ Initial Parametric Characterization
- ☐ Extended Life Test Performance
- ☐ Accelerated Stress Testing – Data Analysis in Progress
- ☐ Conclusions

Basic Evaluation

Test	Description	Qty
Construction Analysis	External visual; Xray; Cross section; Materials analysis	5
Initial Electricals	C, DF, ESR, DCL	100
PWB Mounting	Solder reflow oven using Sn63Pb37	80
Life Test	$V = 0.67 \times V_R$; $T = 125°C$; $t = 1000$ hrs then extended to 2000 hrs	80
Accelerated & Step Stress Testing	150°C bake; $V = 1xV_R$ to $1.1xV_R$ $T = 105°C$ to $145°C$ $t = 100$ hrs to 1000 hrs depending on stress	40 per Group

Device Selection

Automotive Grade (AEC Q-200)
Capacitors were purchased through authorized distribution

Mfr	C Value / Voltage	ESR rating	Case Size
“A”	22 uF (10%) / 35V	200 mohm	D
“A”	220 uF (10%) / 10V	125 mohm	D

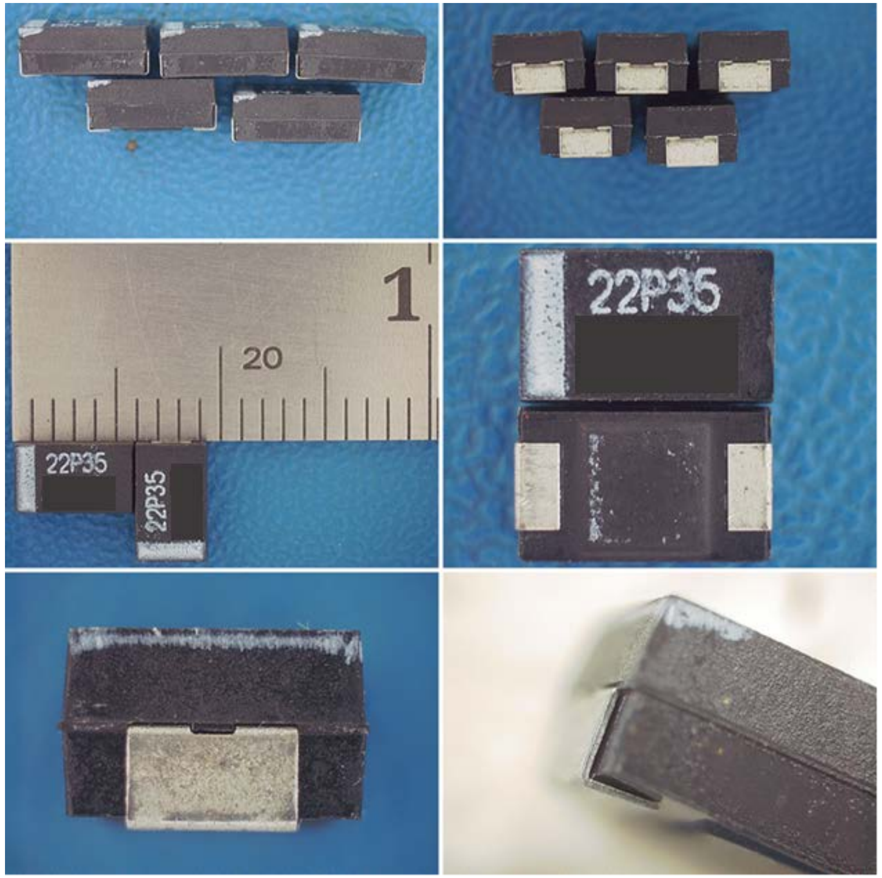
[redacted]

[redacted]

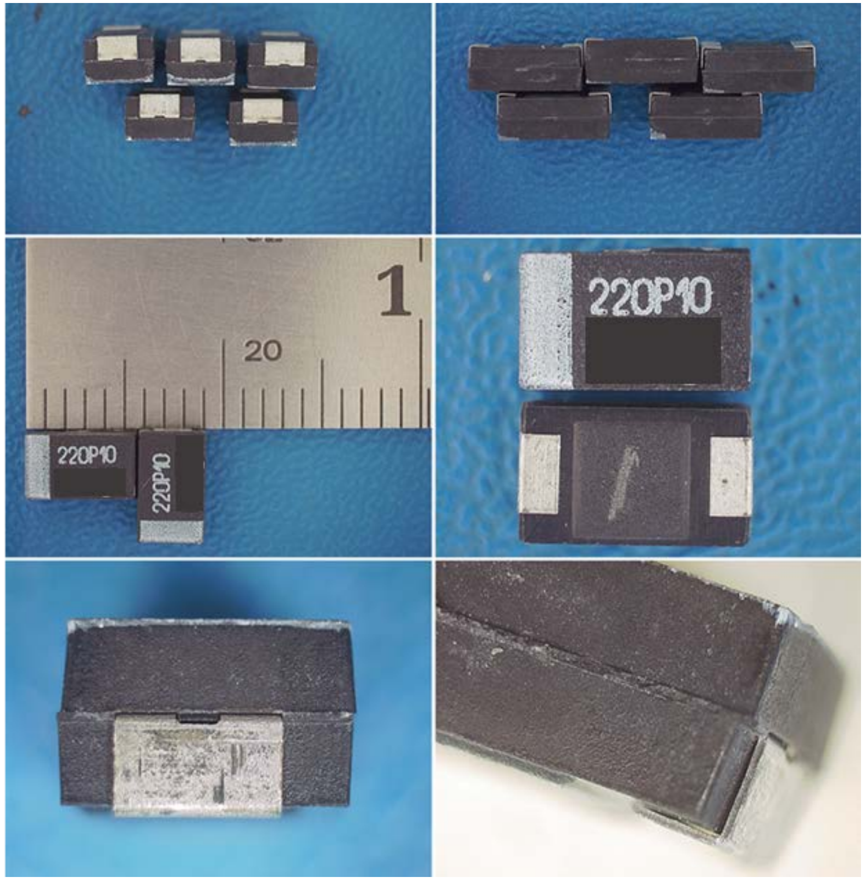
External Visual – low power optical microscopy

✓ No External Visual Anomalies Detected

22 uF / 35 V

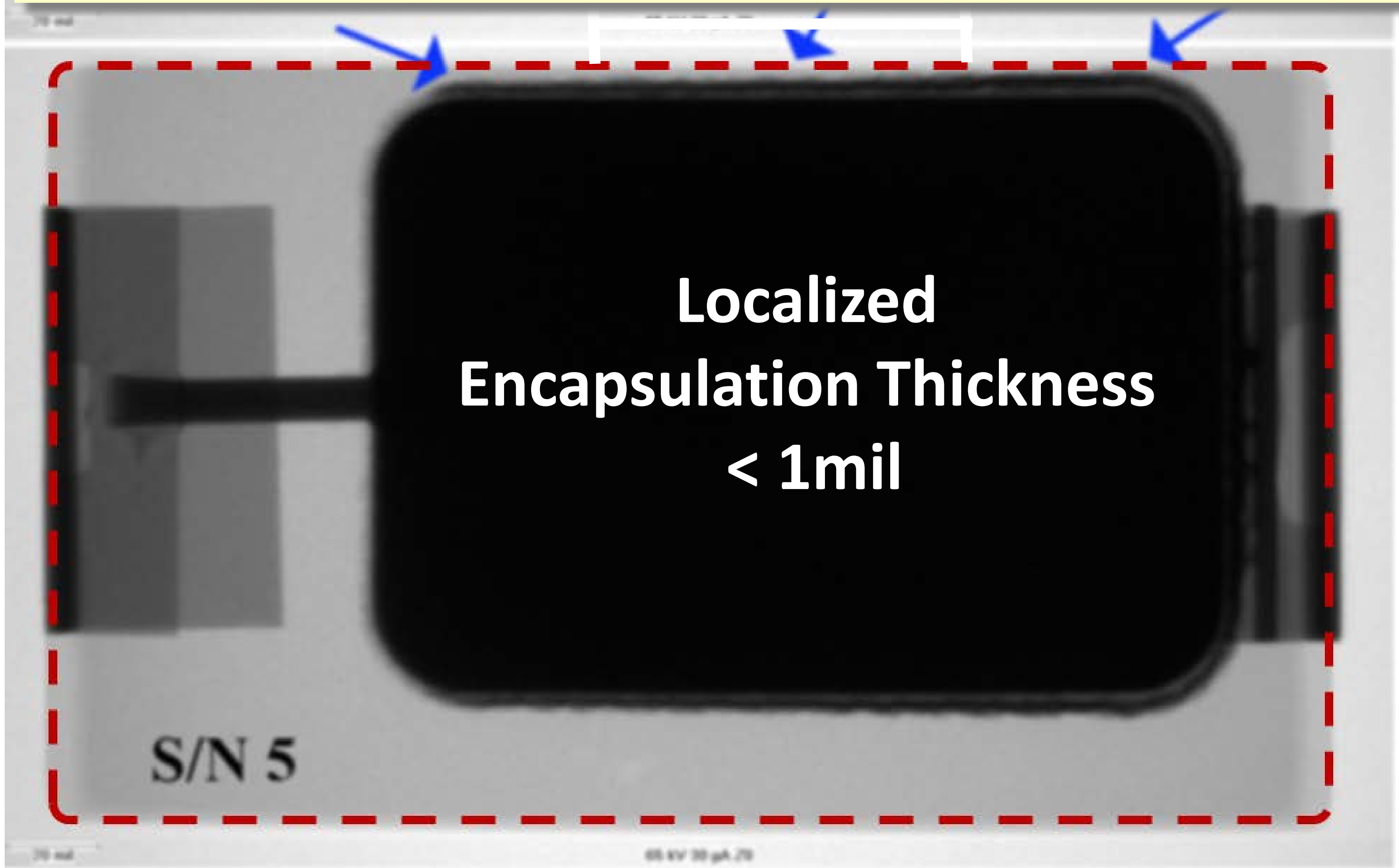


220 uF / 10V

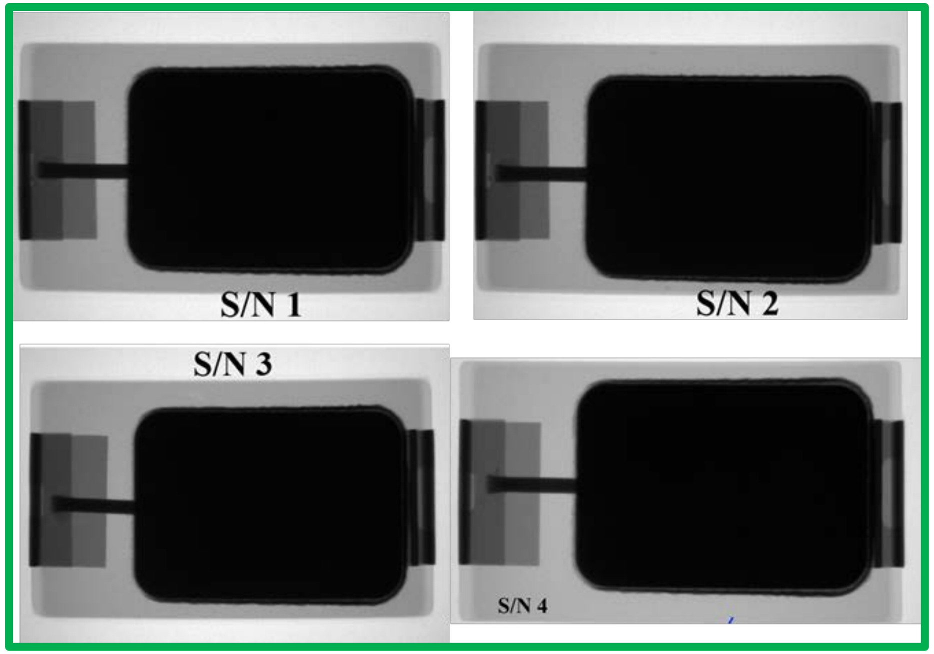


X-ray Inspection – 220uF/10V

✓**Concern** -- *Anode misaligned within molded case (1 of 5 devices) results in localized < 1 mil package thickness. Increased risk of handling and/or moisture-related degradation*

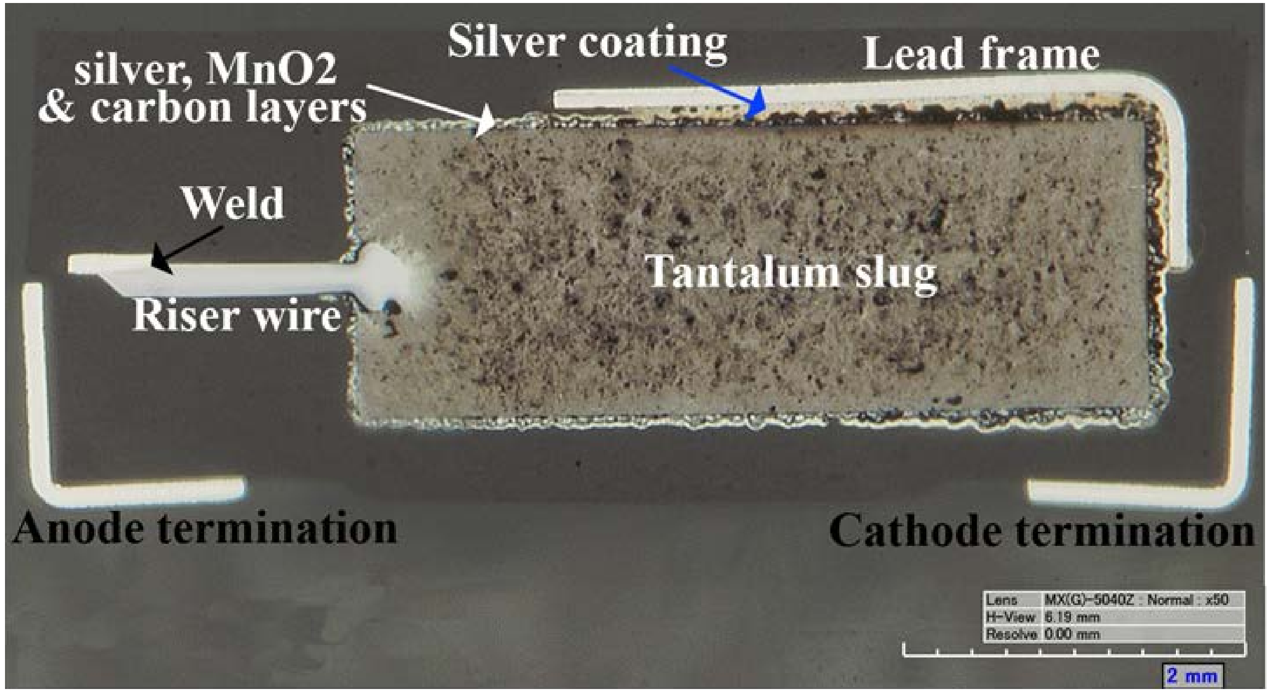


Localized
Encapsulation Thickness
< 1mil



Construction Analysis

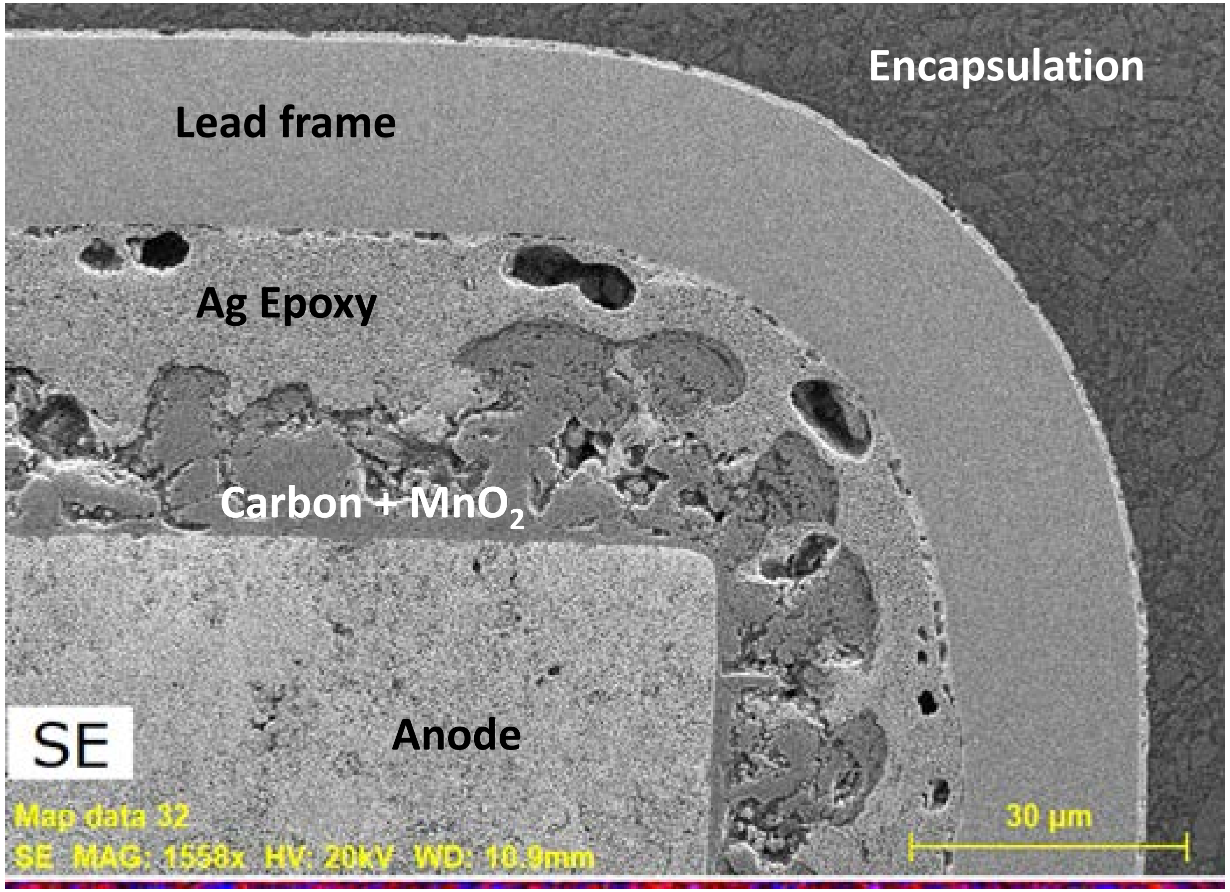
- ✓ ***Standard MnO_2 Cathode Construction***
- ✓ ***Materials & Design Similar to MIL-PRF-55365***

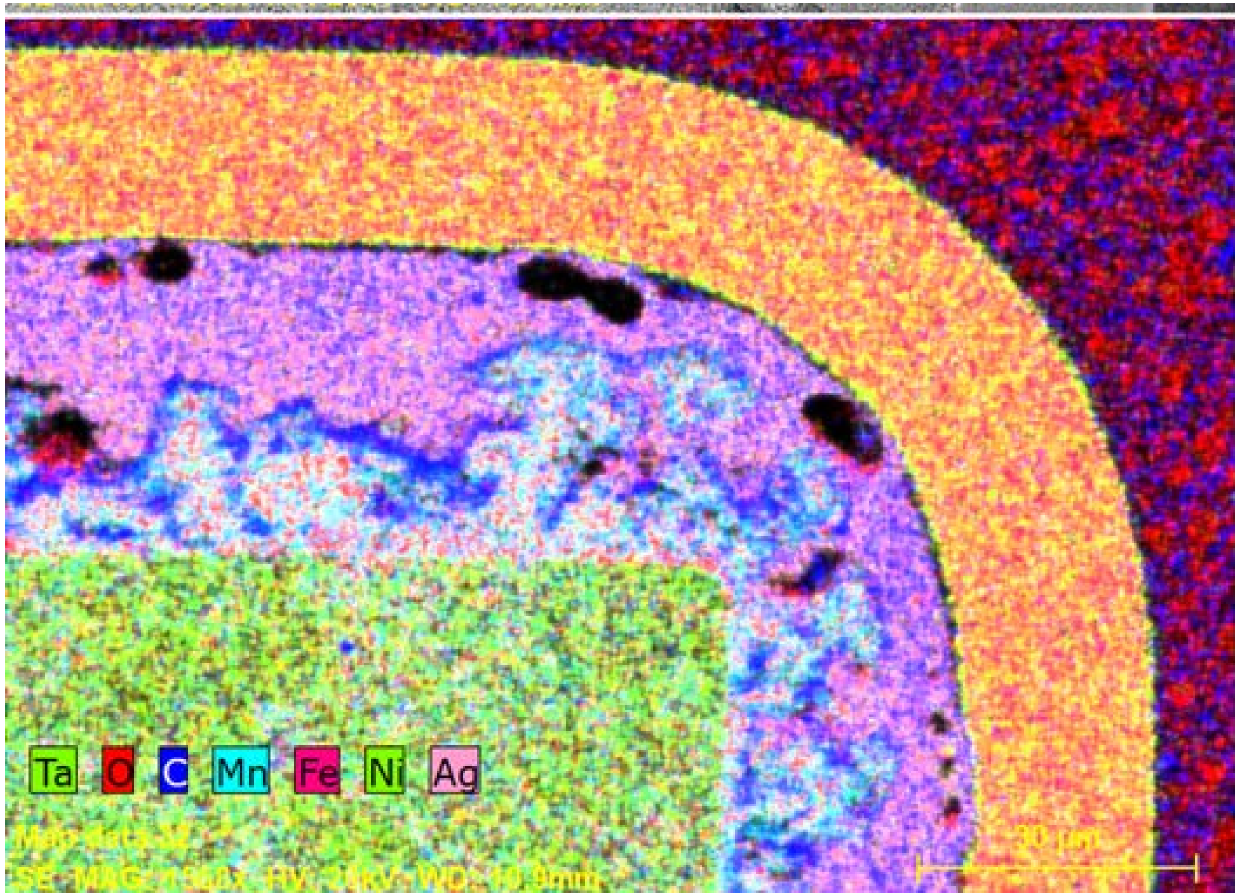


Structure	Composition
Anode	Sintered Ta
Riser wire	Ta wire welded to anode
Dielectric	Ta_2O_5
Cathode layers	MnO_2 + Carbon + Ag
Cathode attach	Ag epoxy
Lead frame	Sn-plated Fe-Ni alloy
Encapsulation	Epoxy molded

Construction Analysis

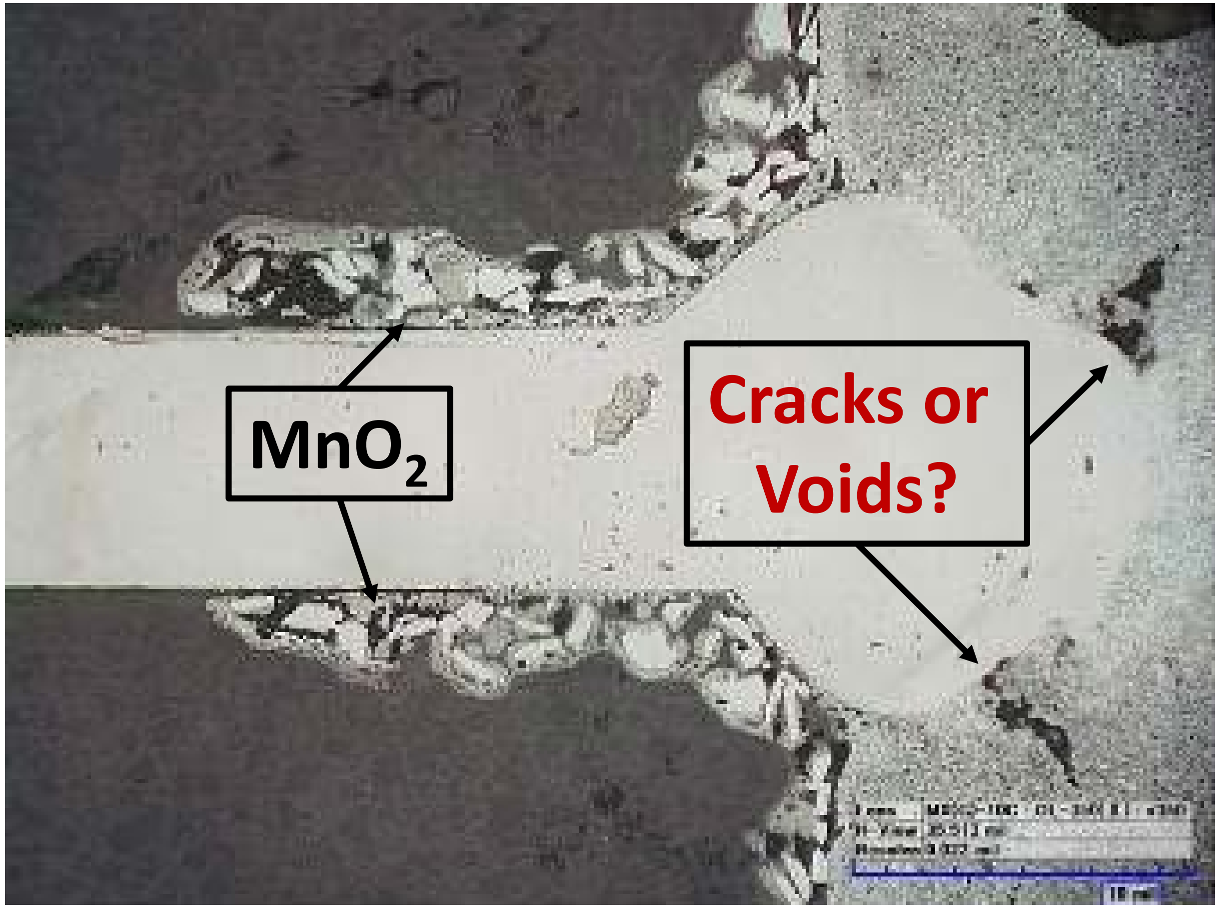
✓ *EDS Shows Standard MnO_2 Cathode Construction*





Construction Analysis

Observations - Further Review Suggested



MnO_2

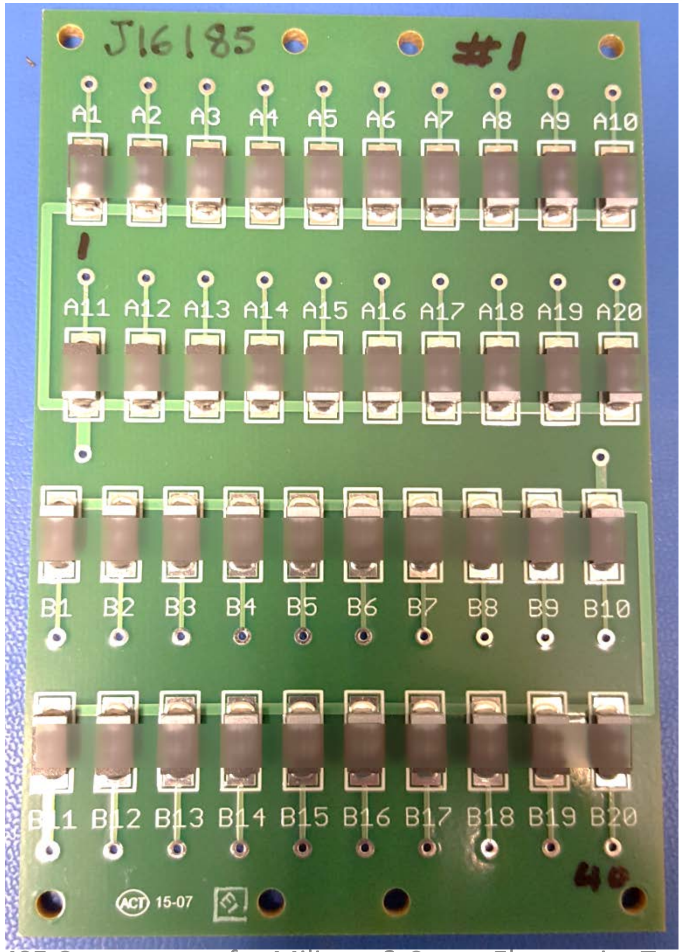
Cracks or Voids?

- ✓ Possible voids or cracks in anode at the weld between Ta riser wire and the anode
  - ✓ *Potential for propagation leading to dielectric damage?*
- ✓ MnO_2 extending along the Ta riser wire
  - ✓ *Dielectric thickness on riser wire may not be as thick as within the anode?*
  - ✓ *If so, then this may have reduced dielectric breakdown strength?*

PWB Mounting for Life Tests

✓ *Sn63Pb37 Reflow Oven (Peak T = 230°C)*

✓ *Per J-STD-020 and Manufacturer Recommended Profile*



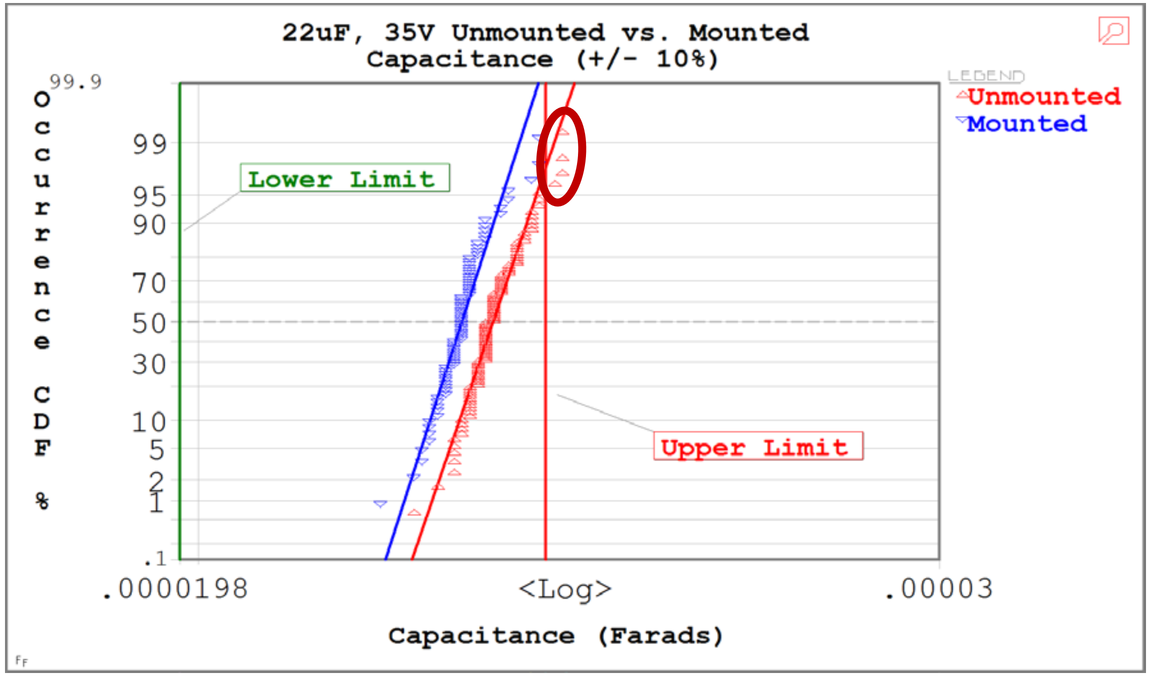
Setpoints (Celsius)

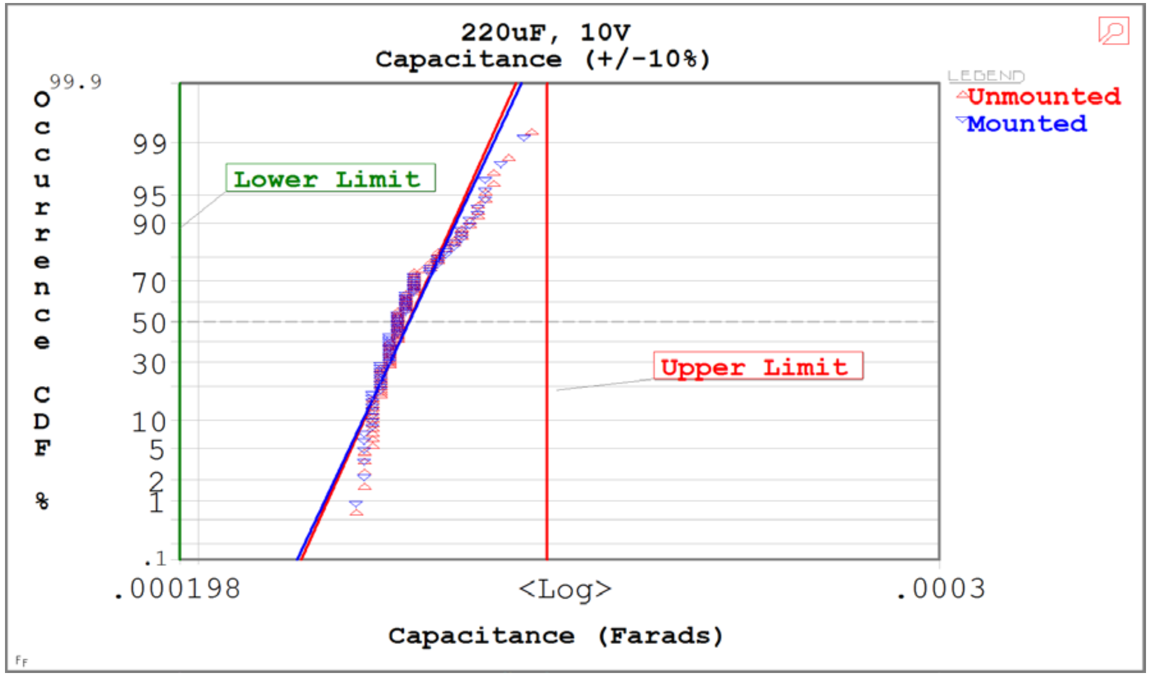
Zone	1	2	3	4	5	6	7	8	9	10
Top	120.0	115.0	123.0	147.0	173.0	173.0	176.0	207.0	230.0	260.0
Bottom	120.0	115.0	123.0	147.0	173.0	173.0	176.0	207.0	230.0	260.0

Conveyor Speed (inch/min): 26.50

Initial Parametric Characterization
Capacitance

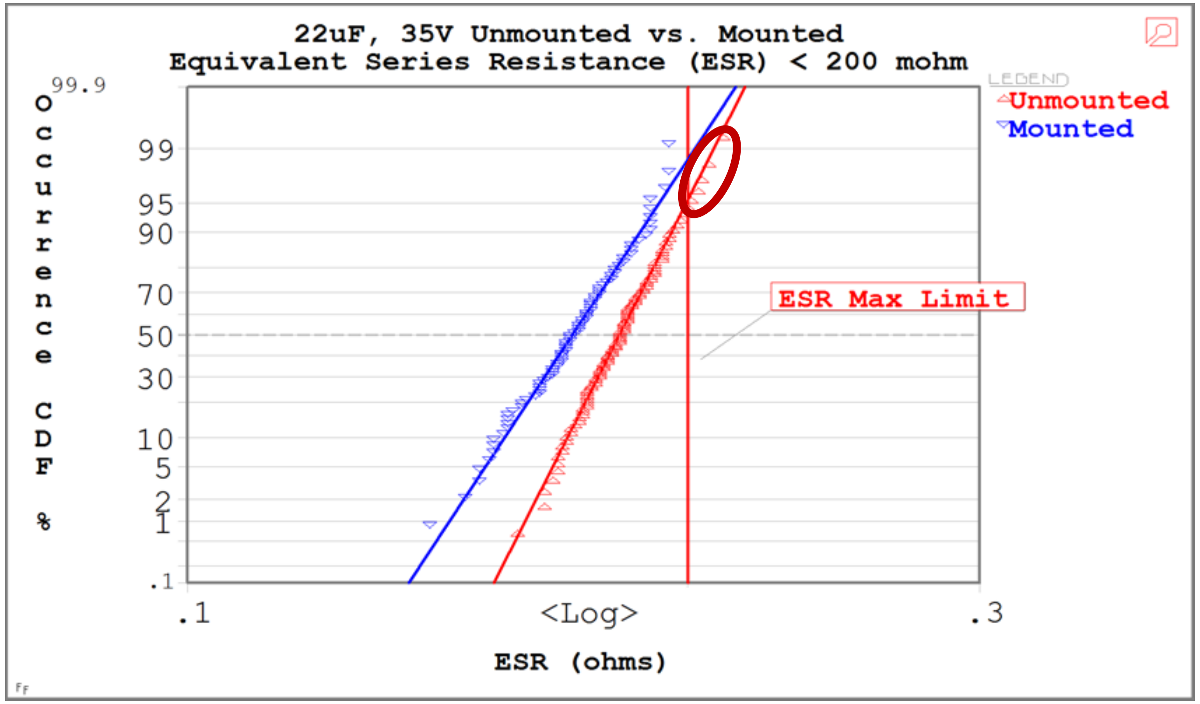
- ✓ *As-received a few devices **marginally exceed upper capacitance tolerance***
- ✓ *Capacitance **recovers within specification after PWB assembly** most likely as a result of moisture release*

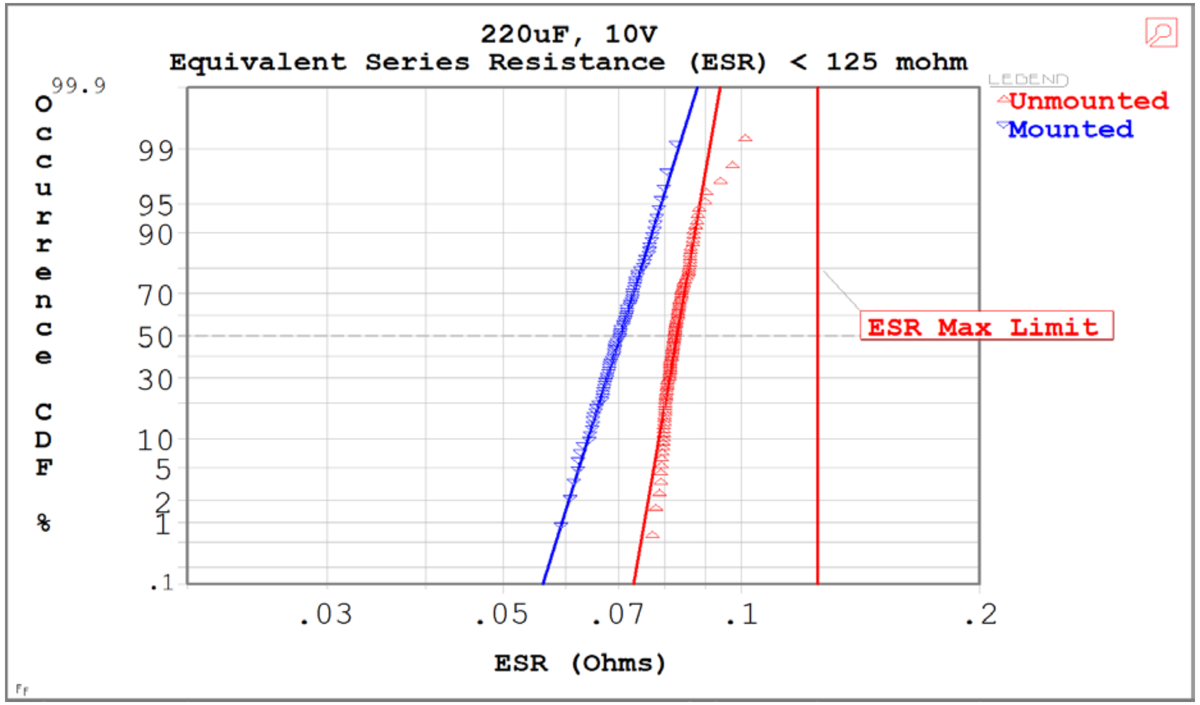




Initial Parametric Characterization
ESR

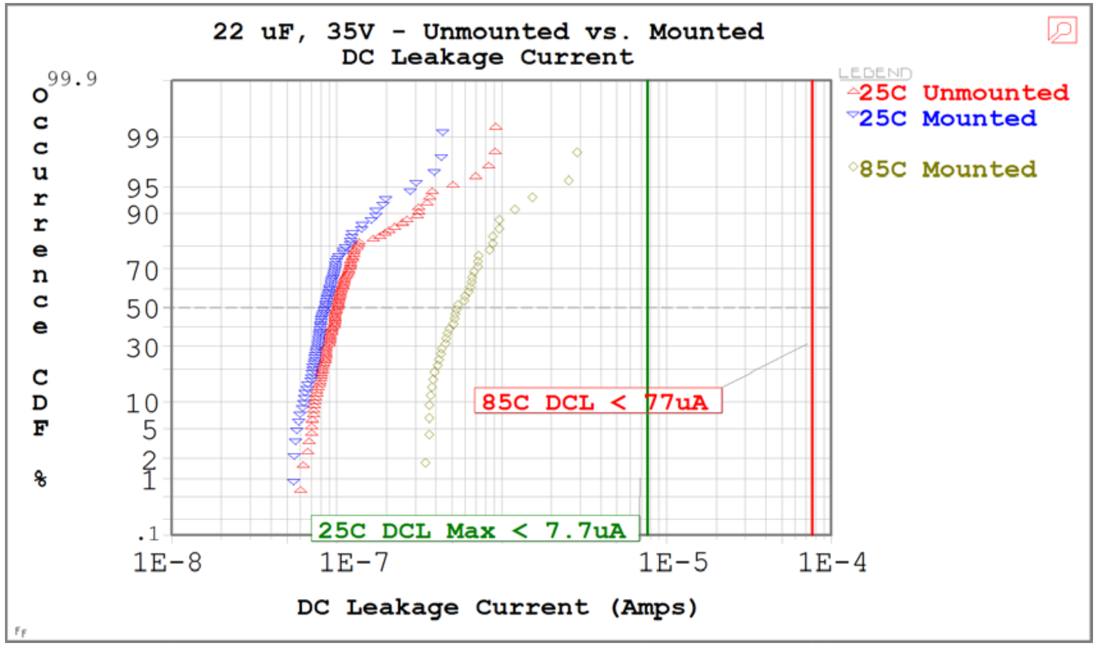
- ✓ *As-received a few devices* ***marginally exceed ESR limit by up to 5%***
- ✓ ***ESR recovers within specification after PWB assembly*** *most likely as a result of moisture release*

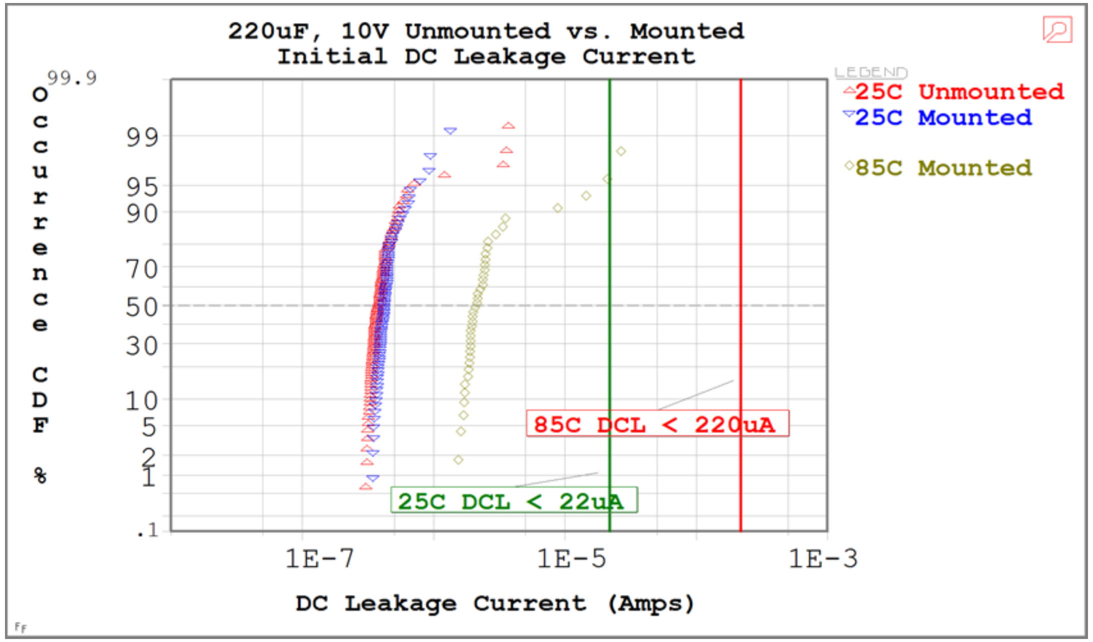




Initial Parametric Characterization
DCL

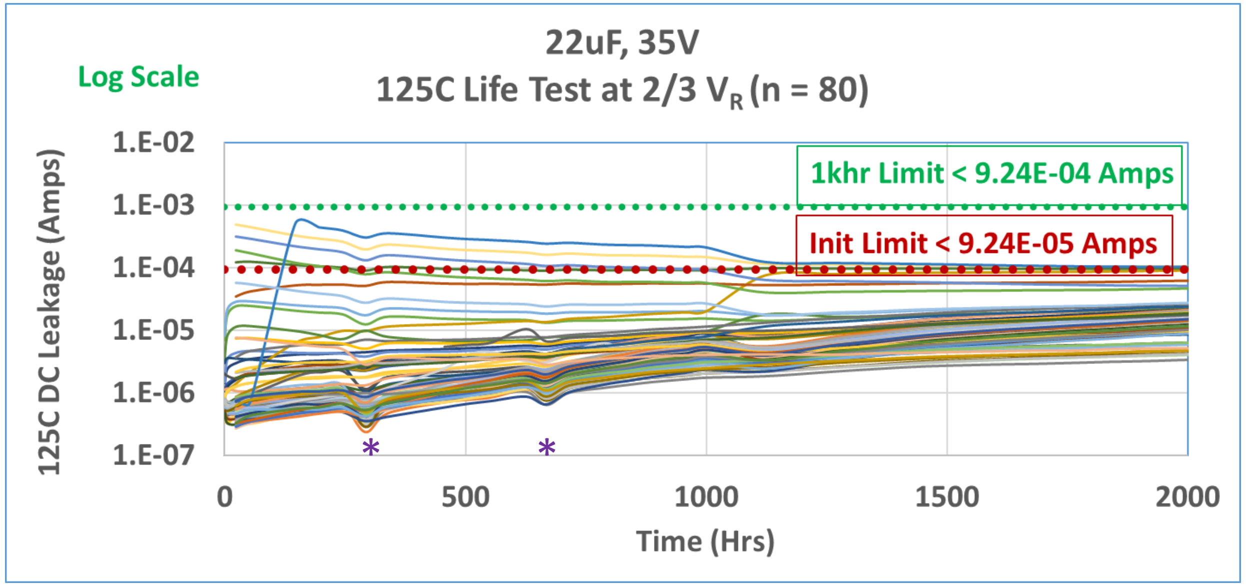
- ✓ ***All Devices meet Initial DCL Limits at 25°C and 85°C***
- ✓ ***PWB assembly may produce slight reduction in DCL***

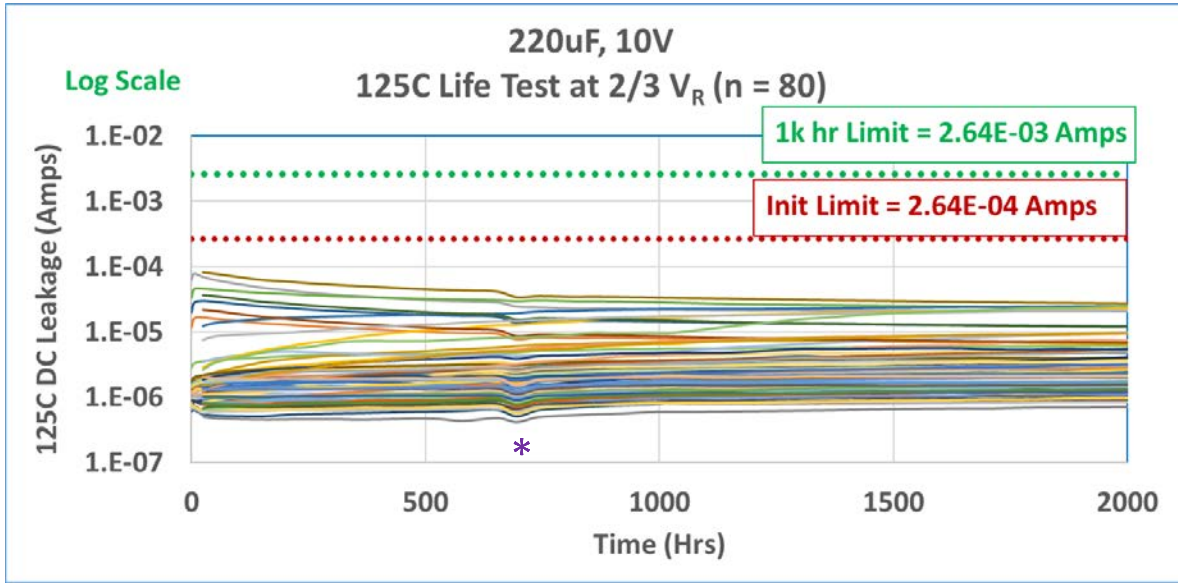




Extended Life Testing – 2000 Hrs, 2/3 V_R @ 125°C *DCL*

- ✓ *A few devices have **DCL that exceeds initial limits at 125°C***
- ✓ *These same devices tend to **recover to within limits during life test***
- ✓ *Majority of Devices Begin Test with Low DCL that Gradually Increases, but remains well below the liberal manufacturer-specified End-of-Life DCL limits*

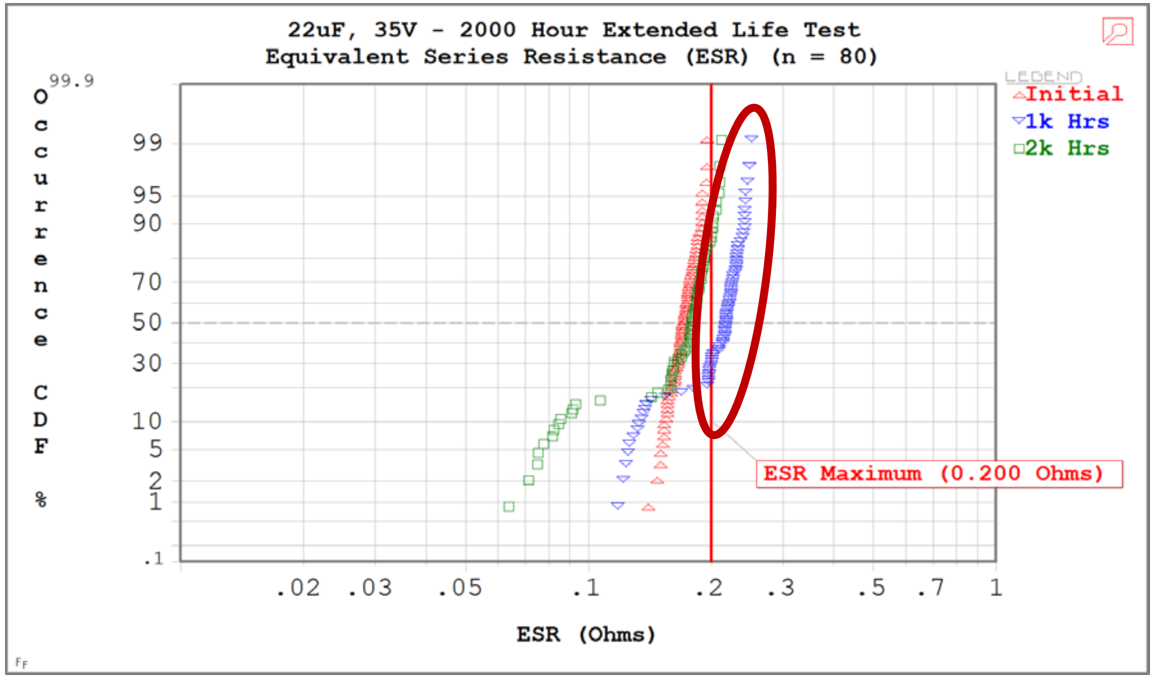




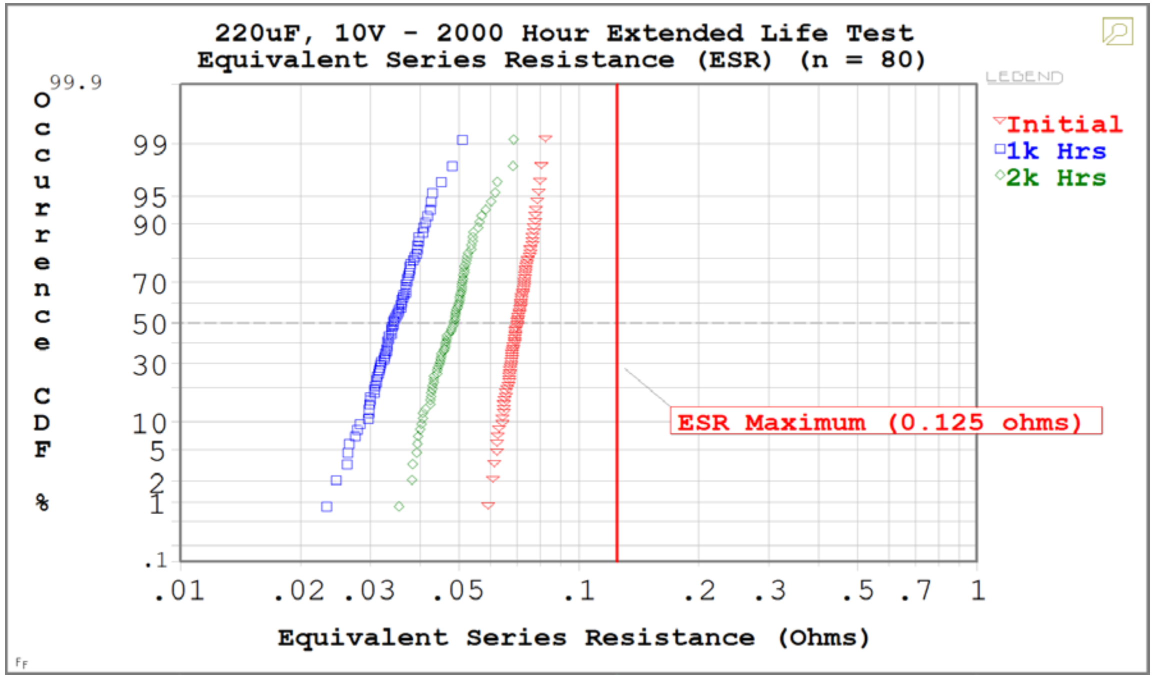
** Bumps in curves are result of temporary loss of voltage during testing during which there appears to be an annealing effect from storage at 125C*

Extended Life Testing – 2000 Hrs, 2/3 V_R @ 125°C
Equivalent Series Resistance (ESR)

- ✓ *After 1k hours 22uF, 35V lot **ESR exceeds AEC Q-200 limits by up to 25%.** However…*
- ✓ *After 2k hours 22uF, 35 lot **ESR recovers to mostly within initial specification limits***



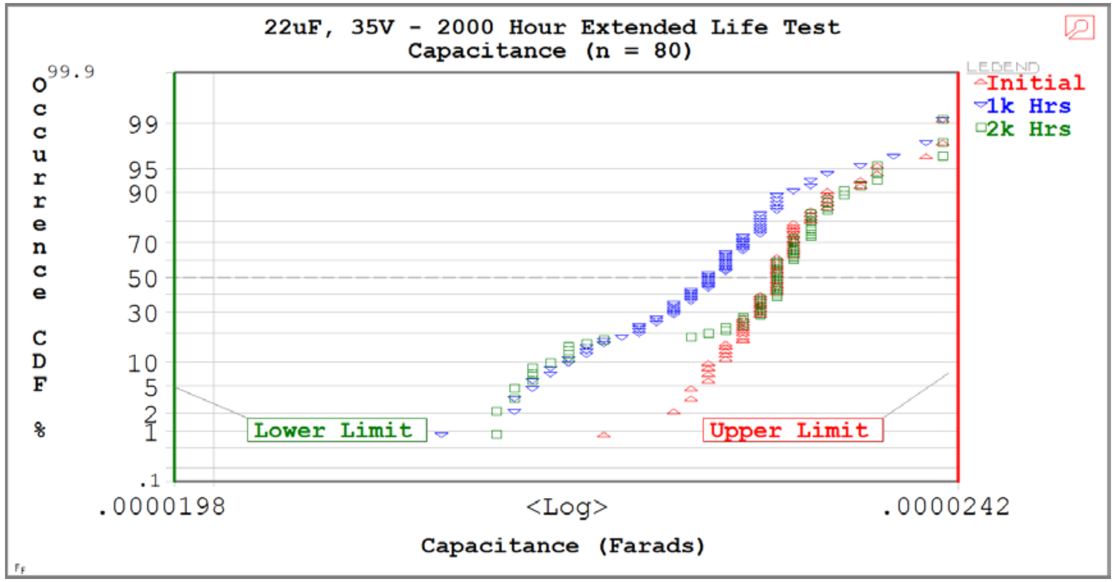
22uF, 35V - 2000 Hour Extended Life Test
Equivalent Series Resistance (ESR) (n = 80)

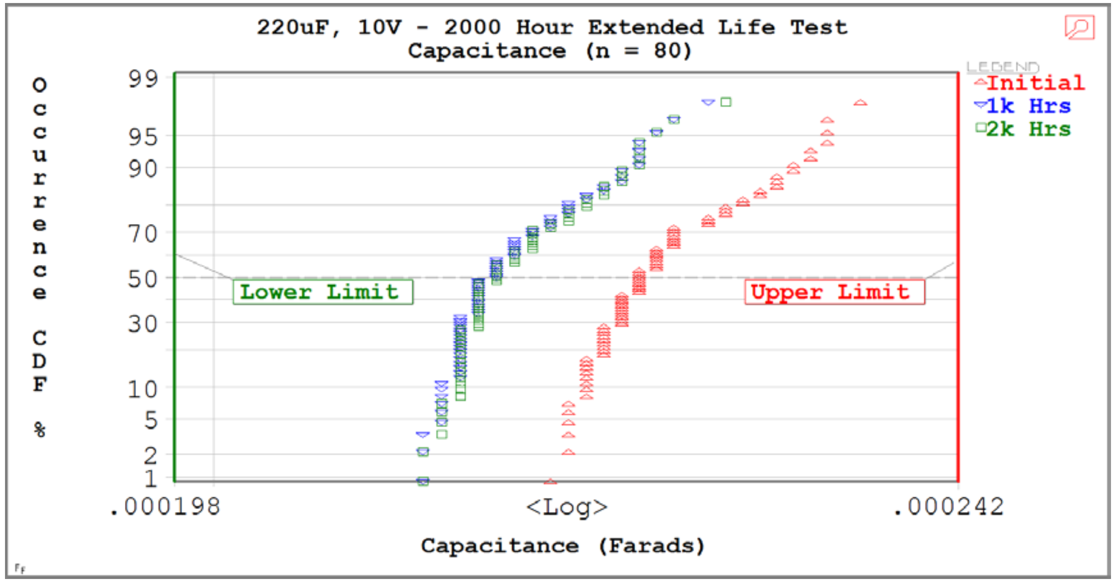


220uF, 10V - 2000 Hour Extended Life Test
Equivalent Series Resistance (ESR) (n = 80)

Extended Life Testing – 2000 Hrs, 2/3 V_R @ 125°C *Capacitance*

- ✓ ***All Devices meet AEC Q-200 Capacitance limits at 1k hours AND extended testing up to 2k hours***
- ✓ ***Changes in Capacitance are not significant during testing***

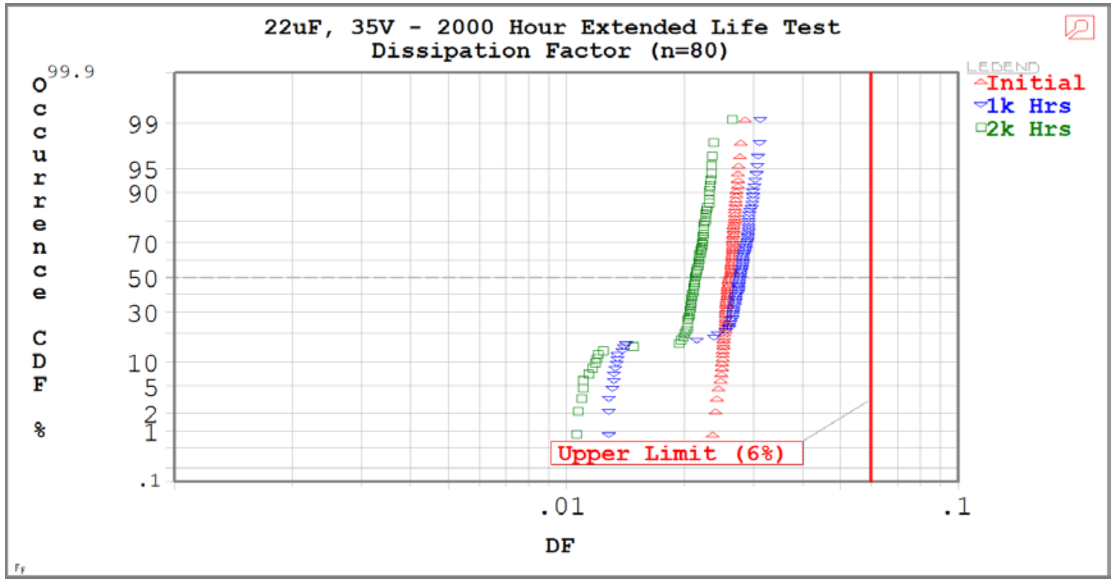


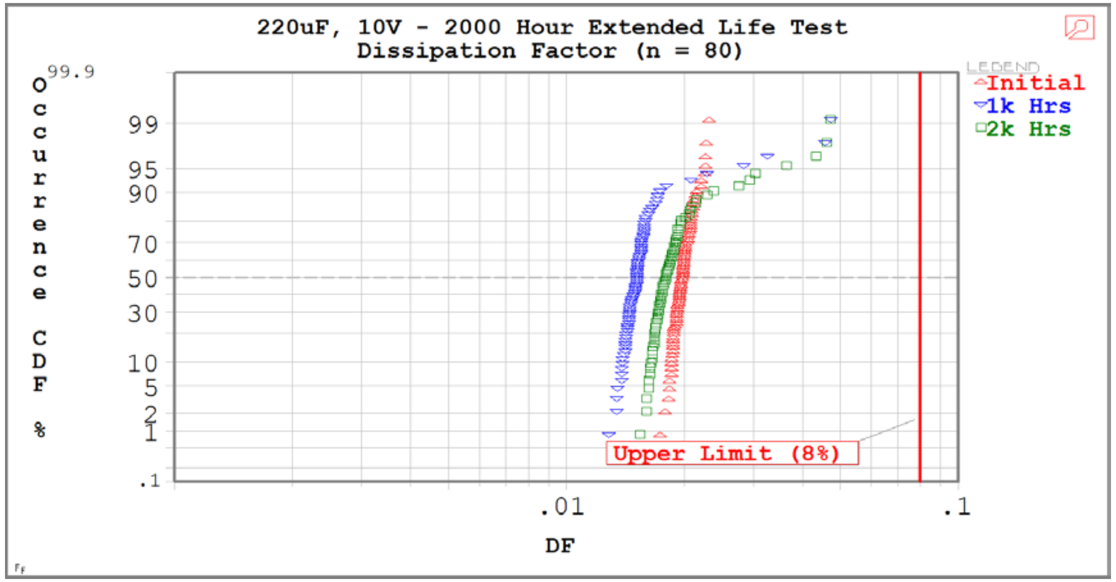


Extended Life Testing – 2000 Hrs, 2/3 V_R @ 125°C

Dissipation Factor

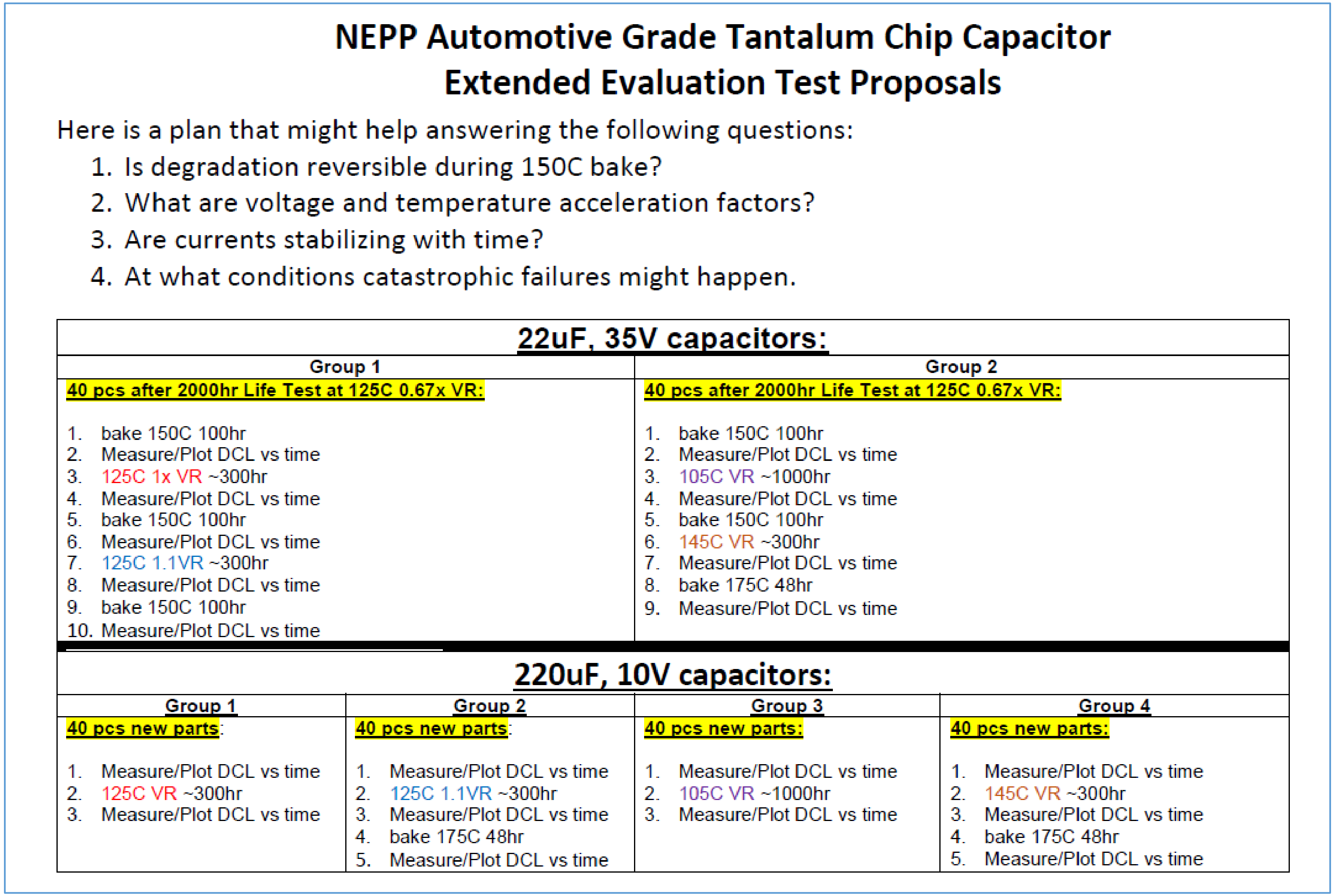
- ✓ ***All Devices meet AEC Q-200 DF limits at 1k hours AND extended testing up to 2k hours***
- ✓ ***Changes in these parameters are not significant during testing***





Accelerated & Step Stress Testing
Data Analysis in Progress

- ✓ ***The Evaluation Shown Here has been performed***
- ✓ ***Data Analysis is in Progress & Results will be Reported in the Future***



NEPP Automotive Grade Tantalum Chip Capacitor Extended Evaluation Test Proposals

Here is a plan that might help answering the following questions:

1. Is degradation reversible during 150C bake?
2. What are voltage and temperature acceleration factors?
3. Are currents stabilizing with time?
4. At what conditions catastrophic failures might happen.

22uF, 35V capacitors:

Group 1	Group 2
40 pcs after 2000hr Life Test at 125C 0.67x VR:	40 pcs after 2000hr Life Test at 125C 0.67x VR:
1. bake 150C 100hr 2. Measure/Plot DCL vs time 3. 125C 1x VR ~300hr 4. Measure/Plot DCL vs time 5. bake 150C 100hr 6. Measure/Plot DCL vs time 7. 125C 1.1VR ~300hr 8. Measure/Plot DCL vs time 9. bake 150C 100hr 10. Measure/Plot DCL vs time	1. bake 150C 100hr 2. Measure/Plot DCL vs time 3. 105C VR ~1000hr 4. Measure/Plot DCL vs time 5. bake 150C 100hr 6. 145C VR ~300hr 7. Measure/Plot DCL vs time 8. bake 175C 48hr 9. Measure/Plot DCL vs time

220uF, 10V capacitors:

Group 1	Group 2	Group 3	Group 4
40 pcs new parts:	40 pcs new parts:	40 pcs new parts:	40 pcs new parts:
1. Measure/Plot DCL vs time 2. 125C VR ~300hr 3. Measure/Plot DCL vs time	1. Measure/Plot DCL vs time 2. 125C 1.1VR ~300hr 3. Measure/Plot DCL vs time 4. bake 175C 48hr 5. Measure/Plot DCL vs time	1. Measure/Plot DCL vs time 2. 105C VR ~1000hr 3. Measure/Plot DCL vs time	1. Measure/Plot DCL vs time 2. 145C VR ~300hr 3. Measure/Plot DCL vs time 4. bake 175C 48hr 5. Measure/Plot DCL vs time

Conclusions

- ✓ Construction analysis identified generally good construction
  - ✓ Possible voids/cracks in anode due to riser wire weld to anode?
  - ✓ Possible excessive MnO_2 on riser wire?

- ✓ X-ray found concern with anode alignment within molded encapsulation
  - ✓ Possible increased risk of handling or moisture degradation?

- ✓ As-received a few devices exceed parametric specifications (C, ESR, 125°C DCL)

The above 'less than optimum' features are the same ones we sometimes encounter with MIL-grade Ta chip capacitors and thus these automotive grade capacitors can be considered no worse in comparison

Conclusions (continued)

- ✓ **Long-term life test performance meets AEC Q-200 specification limits**

- ✓ **Accelerated Stress Testing may provide insights into degradation mechanisms**
    - ✓ **Results of Testing In Review and Will be Reported in Future**

The results of this analysis are encouraging for these 2 lots of Automotive Grade Ta Capacitors, but more testing of more variations are needed along with completion of the analysis of the step stress testing before we can recommend them for flight