National Aeronautics
and Space Administration


# Surge Current Withstanding Resistor Replacement for ER Carbon Composition

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# Acronyms

- ER – Established Reliability
- NEPP Program – NASA Electronic Parts and Packaging Program
- QPL – Qualified Products List
- SMD – Surface Mount Devices

# Background

- Established Reliability Carbon Composition Resistors
  - Popular in power supply applications
  - MIL-R-39008
  - Last QPL supplier exited market in 1996/Specification cancelled in 1998
- “Surge” capability was not a documented parameter in military specifications
  - Bulk carbon material effective at absorbing energy/heat during pulse without degradation
- Pockets of existing QPL inventory are becoming scarce; now more than twenty-five years old

# Work Performed

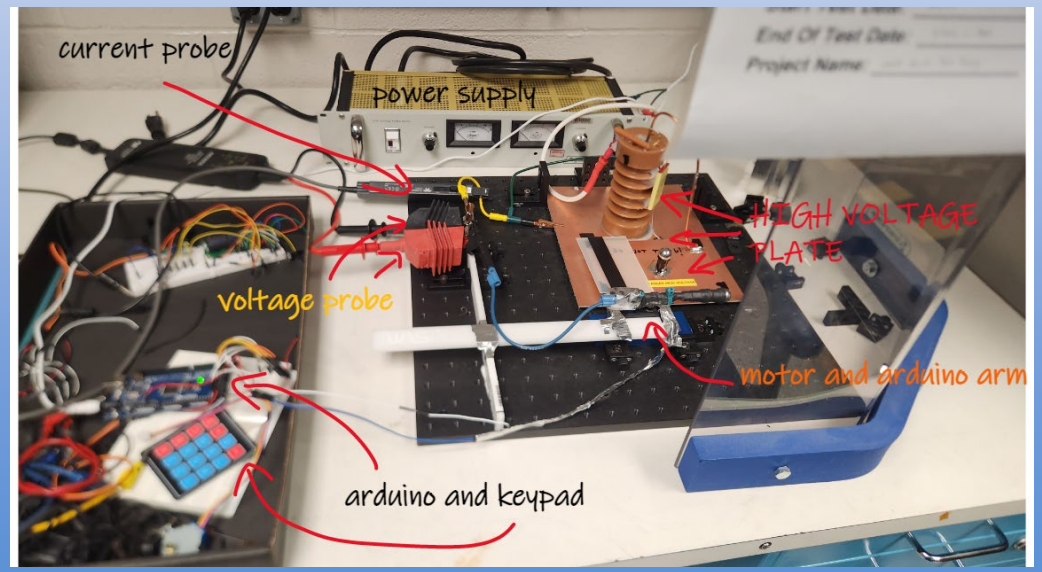
- Identify different manufacturer/technology devices advertised as “surge” resistant or replacement for carbon composition resistors. Select a cross section of manufacturers, technologies, and packages.
  - While chip components were selected, only leaded parts were able to be reliably testing in the assembled test fixture.
- Obtain samples of various parts and subject them to various voltage/energy pulses to assess susceptibility to damage.

# Manufacturer/Technology

| Manufacturer | Value (ohm) | Tolerance | Rated Voltage (Vdc) | Rated Surge (Vdc) | Package Type |
|---|---|---|---|---|---|
| A | 100 | +/- 5% | 300 | NR | Axial |
| A | 1000 | +/- 5% | 300 | NR | Axial |
| A | 10000 | +/- 5% | 300 | NR | Axial |
| A | 100000 | +/- 10% | 300 | NR | Axial |
| B | 560 | +/- 10% | 350 | 700 | Axial |
| B | 1200 | +/- 10% | 350 | 700 | Axial |
| B | 100000 | +/- 10% | 350 | 700 | Axial |
| C | 100 | +/- 10% | 350 | 700 | Axial |
| C | 2200 | +/- 10% | 350 | 700 | Axial |
| C | 10000 | +/- 10% | 350 | 700 | Axial |
| D | 220 | +/- 5% | 500 | NR | Axial |
| D | 1000 | +/- 5% | 500 | NR | Axial |
| D | 8200 | +/- 5% | 500 | NR | Axial |
| D | 47000 | +/- 5% | 500 | NR | Axial |
| E | 100000 | +/- 5% | 10000 | 10000 | Axial |
| F | 20000 | +/- 5% | 7000 | 7000 | Axial |
| F | 100000 | +/- 5% | 7000 | 7000 | Axial |
| G | 2200 | +/- 10% | 500 | 14000 | Axial |
| G | 100000 | +/- 10% | 500 | 14000 | Axial |
| H | 100 | +/- 10% | 300 | 14000 | Axial |
| H | 1000 | +/- 10% | 300 | 14000 | Axial |
| H | 100000 | +/- 10% | 300 | 7000 | Axial |
| H | 220000 | +/- 10% | 300 | 7000 | Axial |

# Test Fixture

- Initial test fixture developed in collaboration with Steve Battel, Battel Engineering Inc.
- Jacob Hobaugh (co-op, Drexel Univ) developed Arduino control system to control pulse contact mechanism.



# Testing Performed

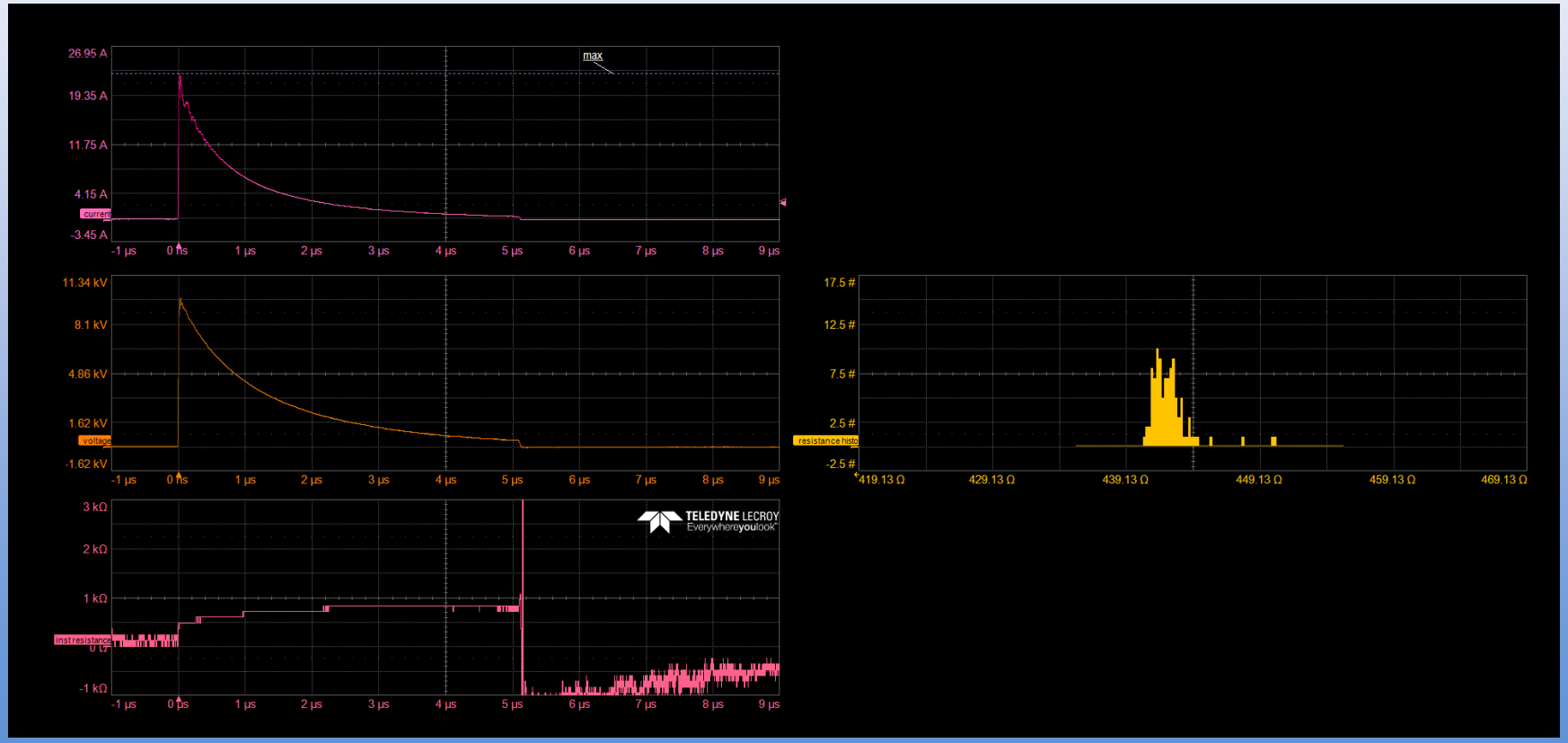
- The following testing was performed on all samples (except controls)
  - 2,000V, 10 pulses; 4,000V, 50 pulses; 10,000V, 20 pulses; 10,000V, 100 pulses
  - Testing performed by Jacob Hobaugh, Marialena Troia, Kellan McCarthy
- Note that the joule energy per pulse was calculated using

$$Energy = \frac{1}{2} C \times V^2$$

  - 2,000V, $Energy \approx \frac{1}{2}(.002\,\mu F) \times (2000\,V)^2 = 4\,mJ$ / pulse
  - 4,000V, Energy $\approx 16\,mJ$ / pulse
  - 10,000V, Energy $\approx 100\,mJ$ / pulse
  - Total Energy pulsed into each resistor = 12.840J

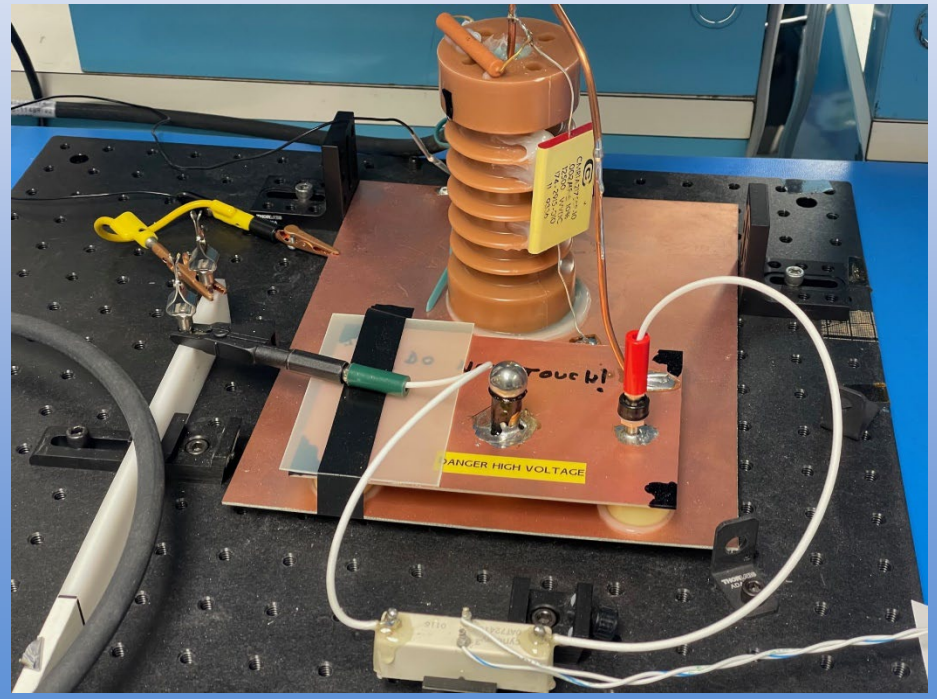
# Pulse Shape

- Manufacturer H, 1kΩ, SN3

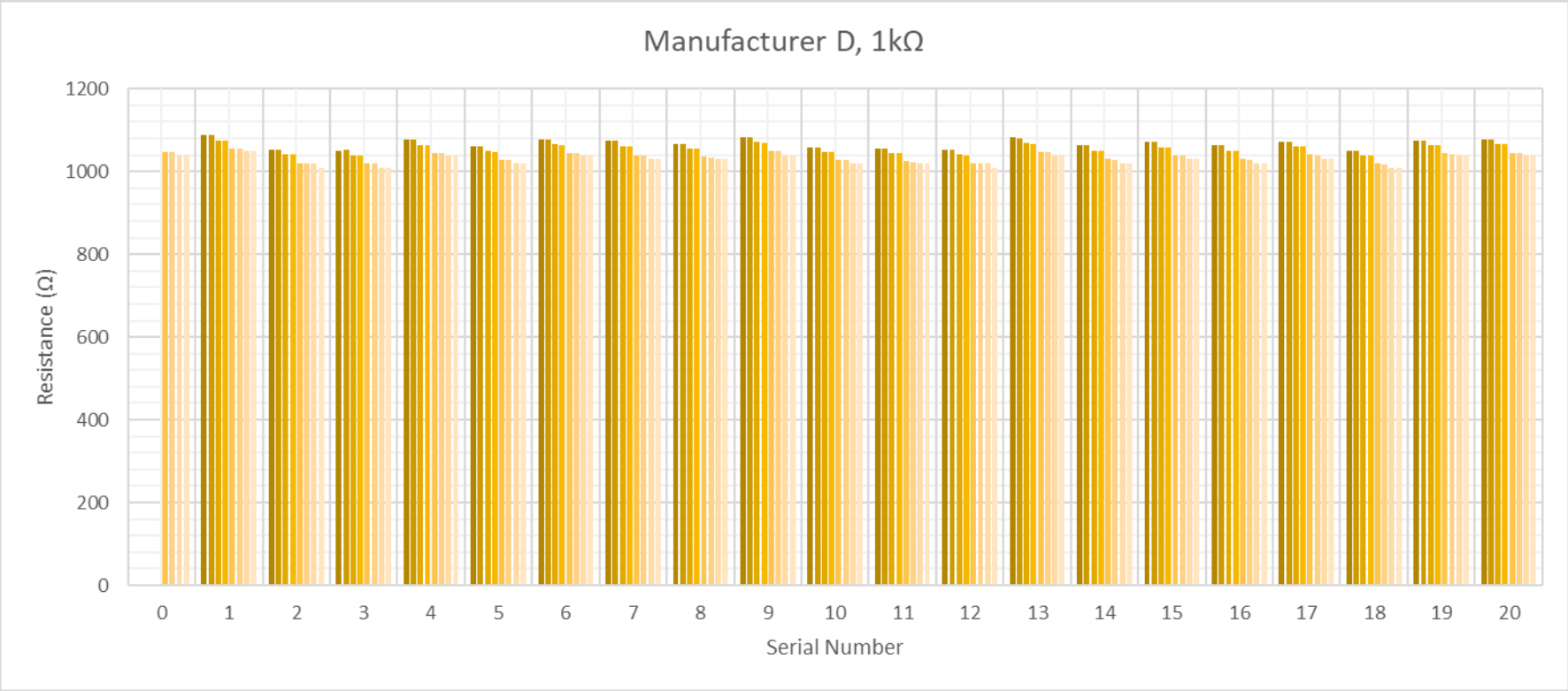


# Test Fixture - Modified

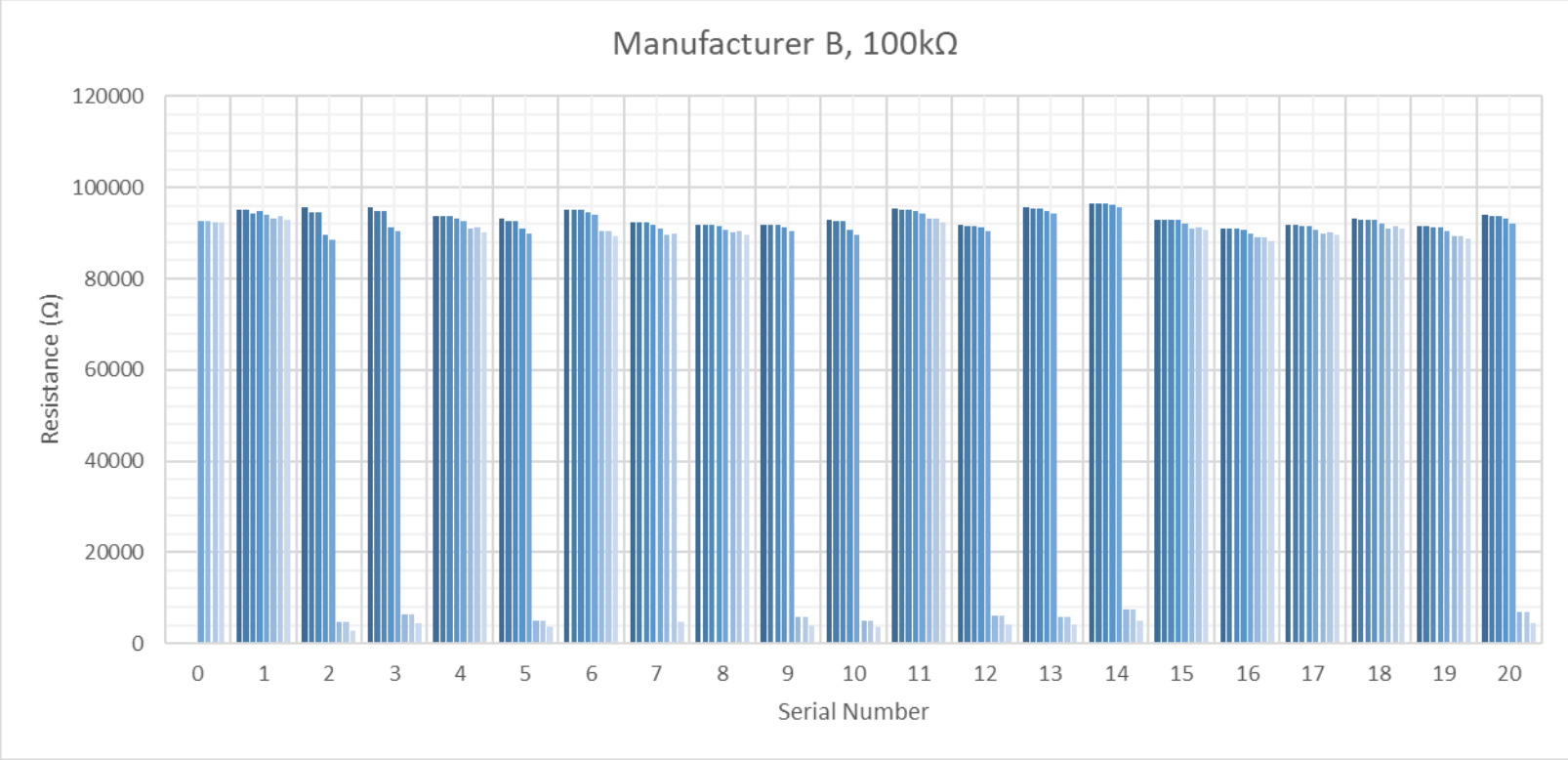
- After several thousand pulses, the ball bearing “pulser” began to weld on contact and testing had to be halted.
  - Ball bearing pulse mechanism was replaced with relay

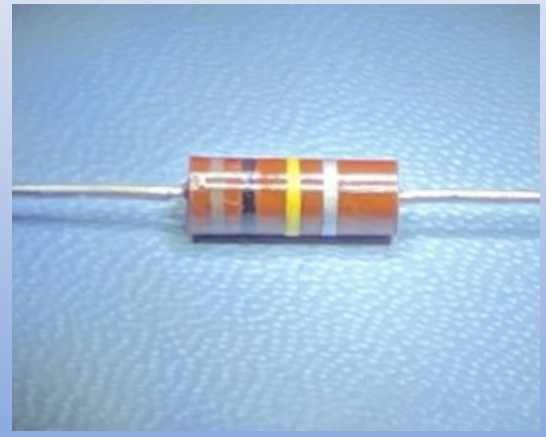



# Sample Data - Typical Resistance Degradation Over Pulse Testing

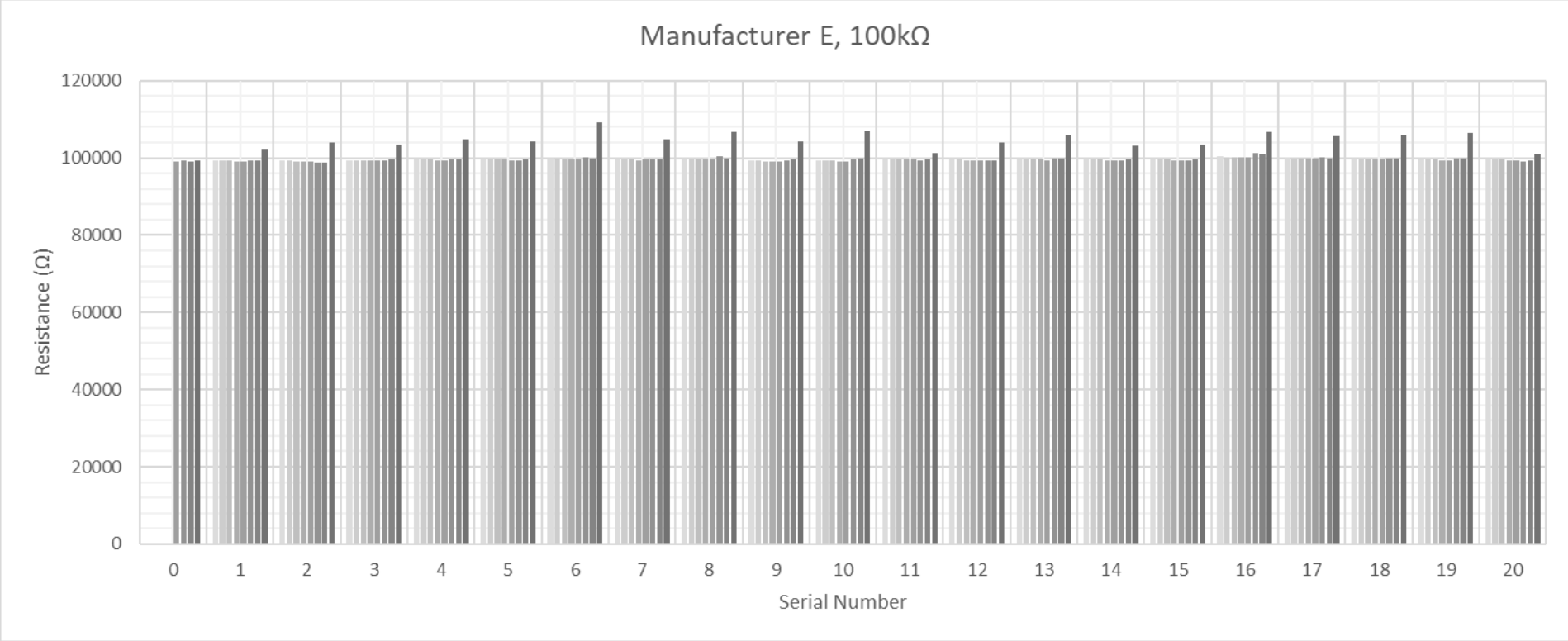


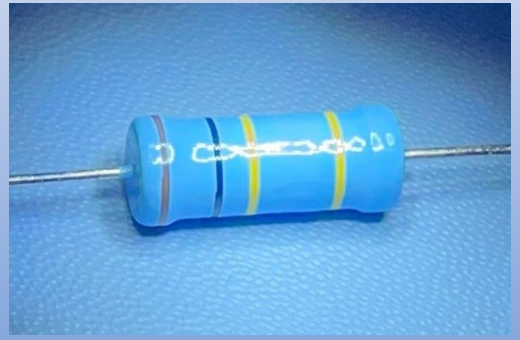

# Sample Data – Catastrophic Resistance Degradation Across Pulse Testing



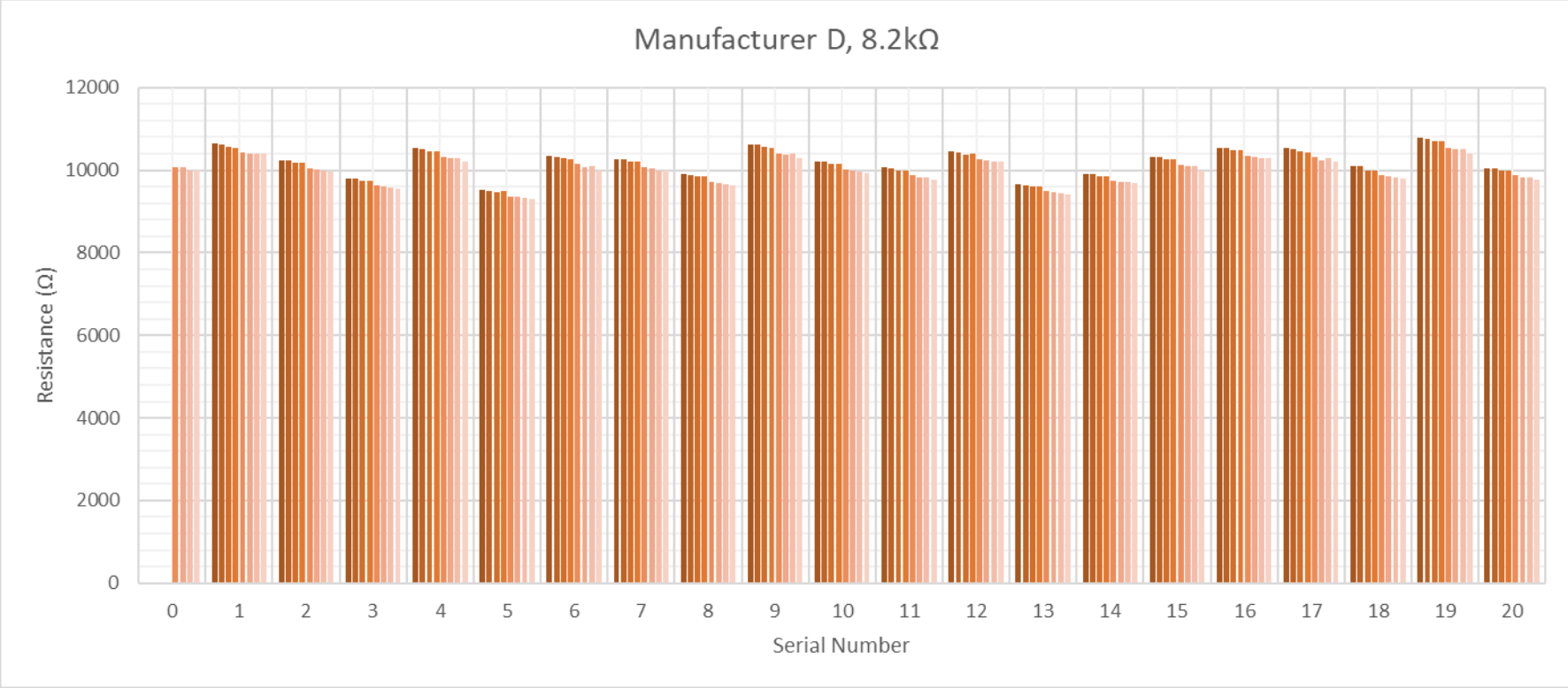



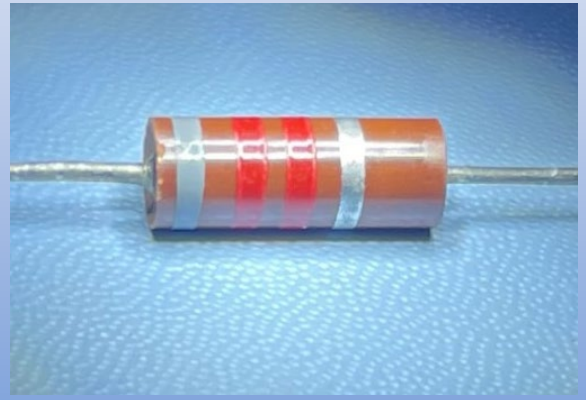
# Sample Data – Outlier Resistance Increase



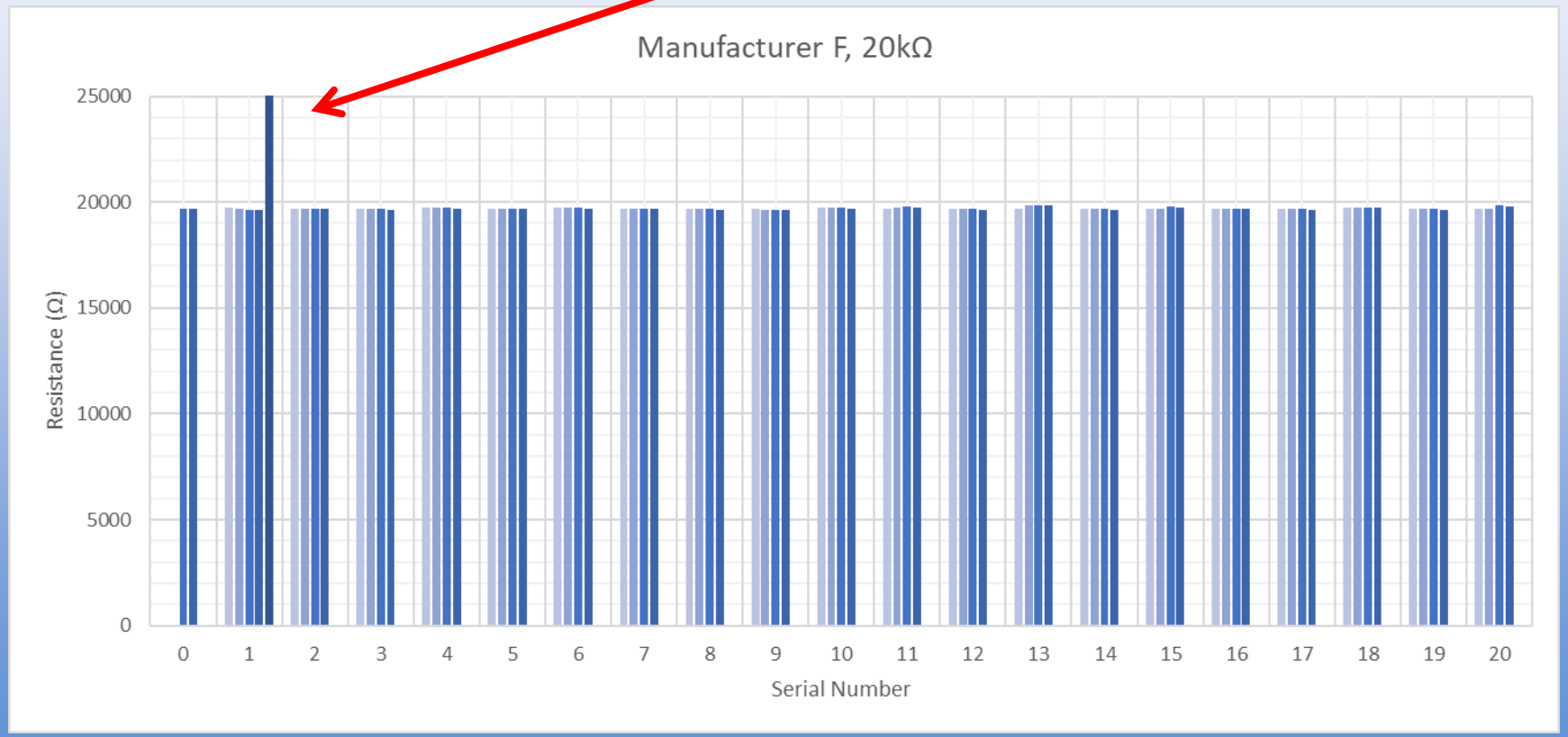
# Sample Data - Color Code Not Matching Measurement

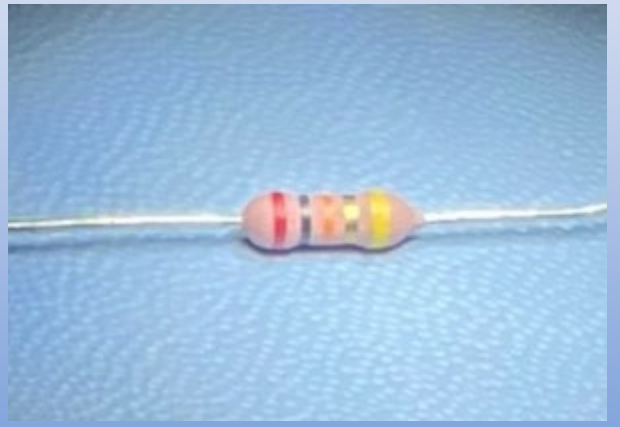


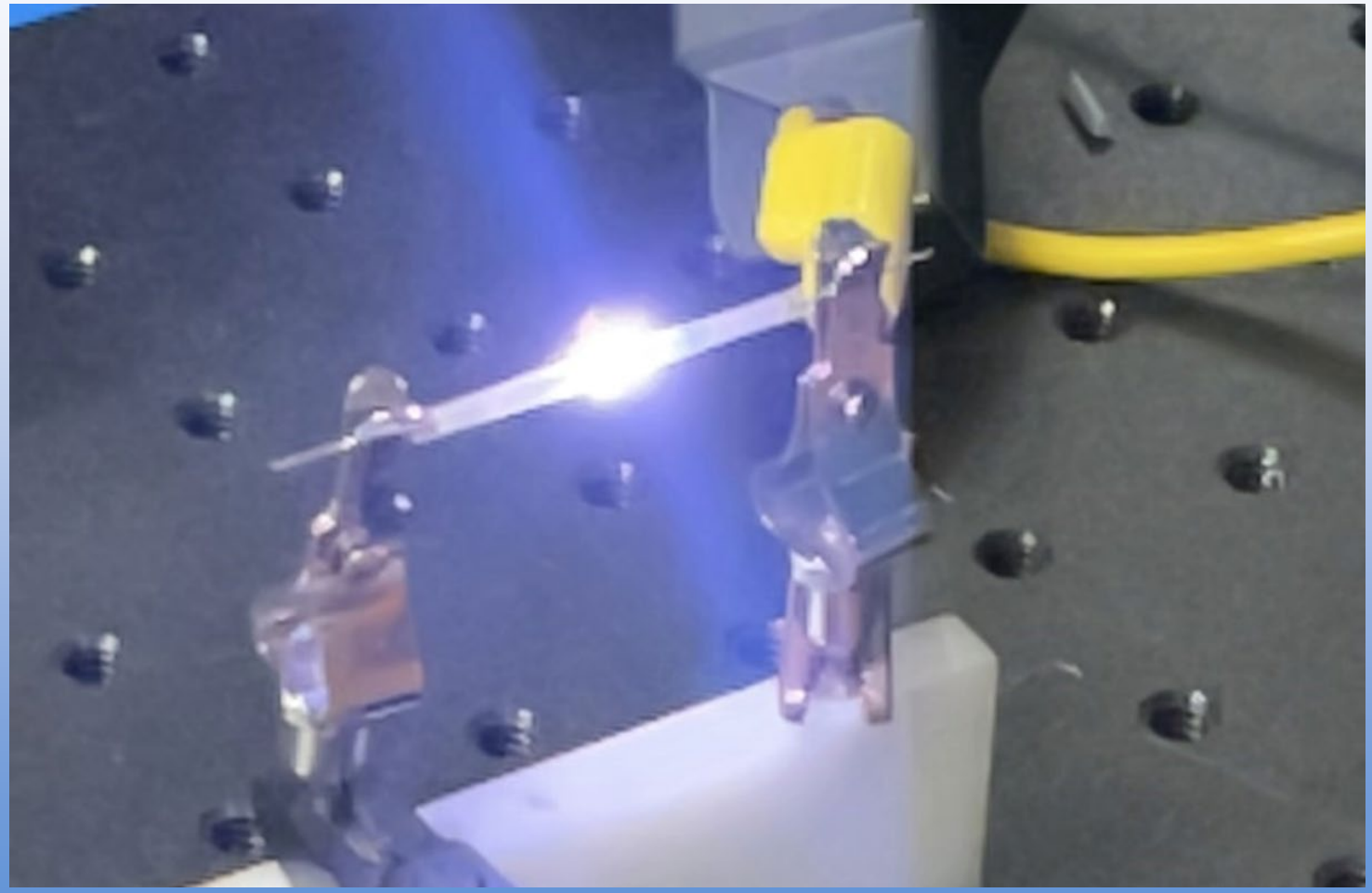
# Sample Data – Open Circuit

Part failed open circuit due to electrical overstress at 10kV

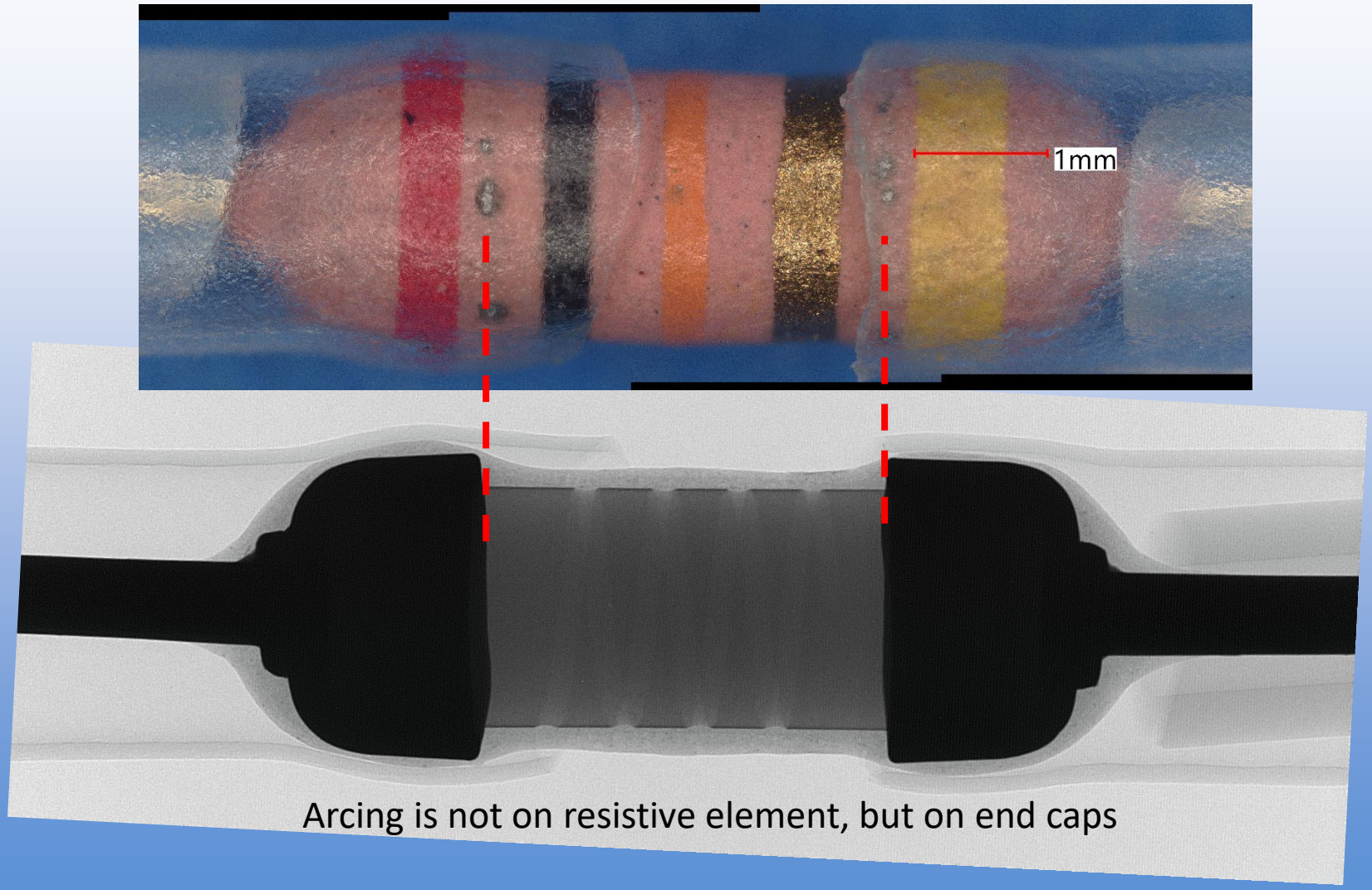


# MFR F - End Cap Shorting

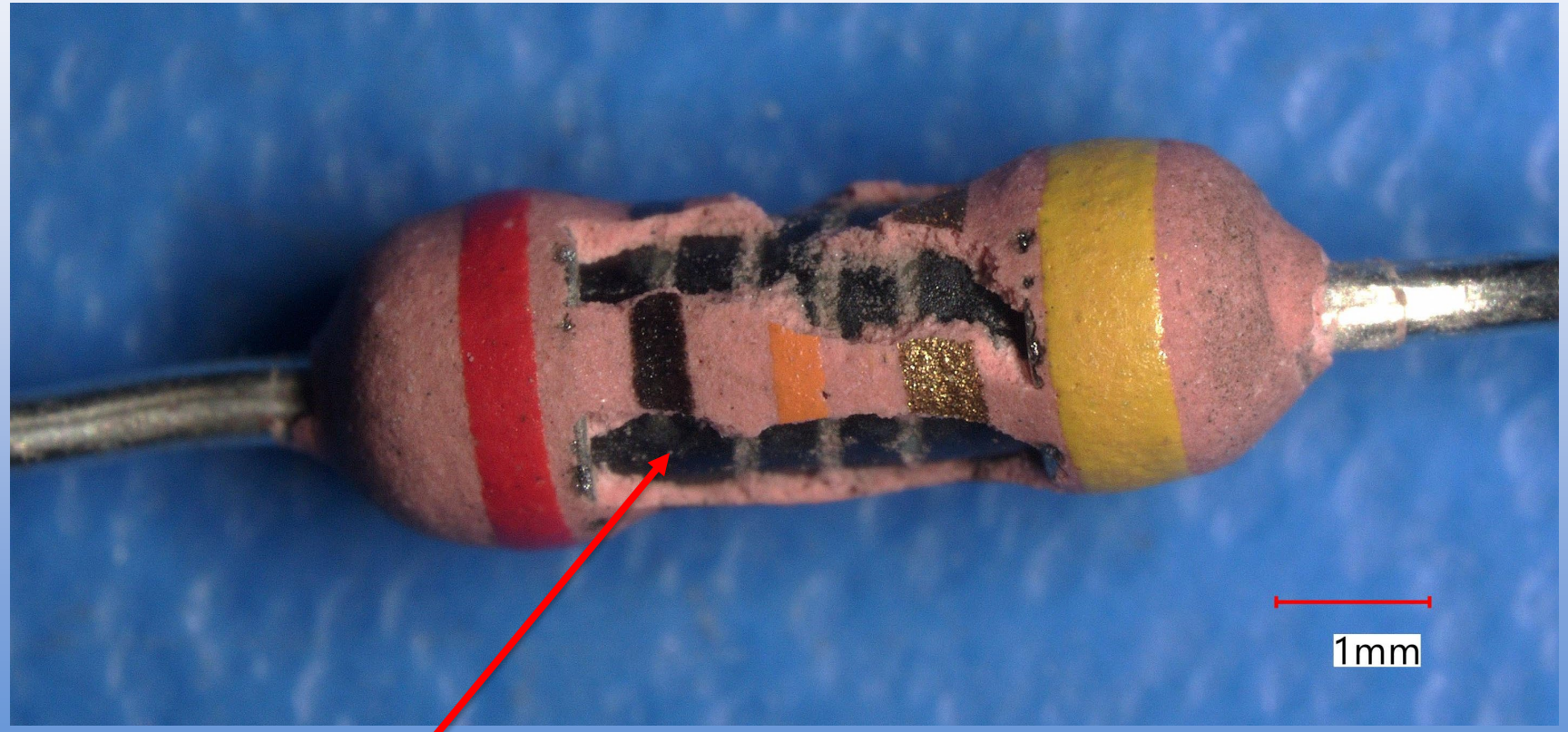


# Arcing between End Caps



# Fluoroinert Bath to Mitigate Arc Through Air

# Severe Damage of Coating of Resistor when small part is submerged in Fluoroinert



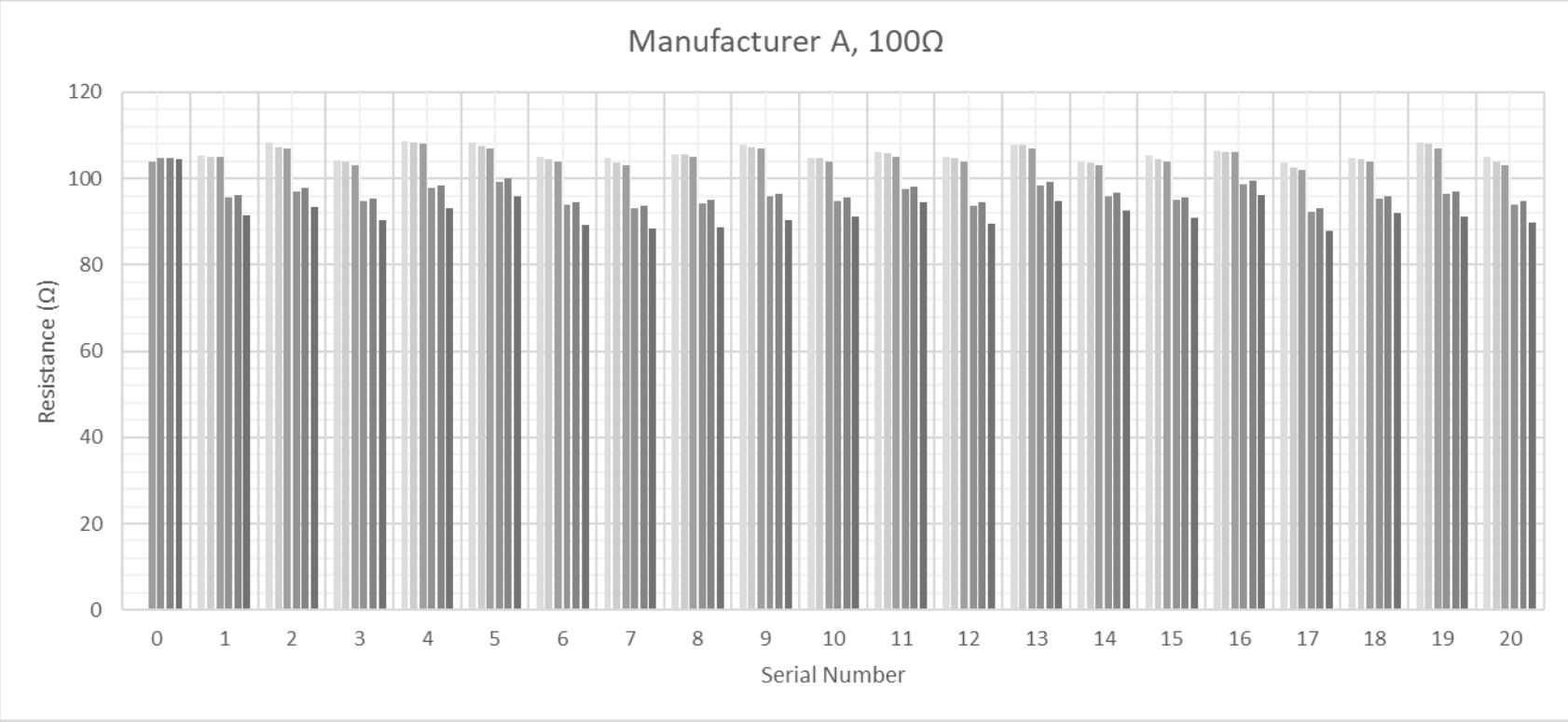

Arcing damage is in the resistive element

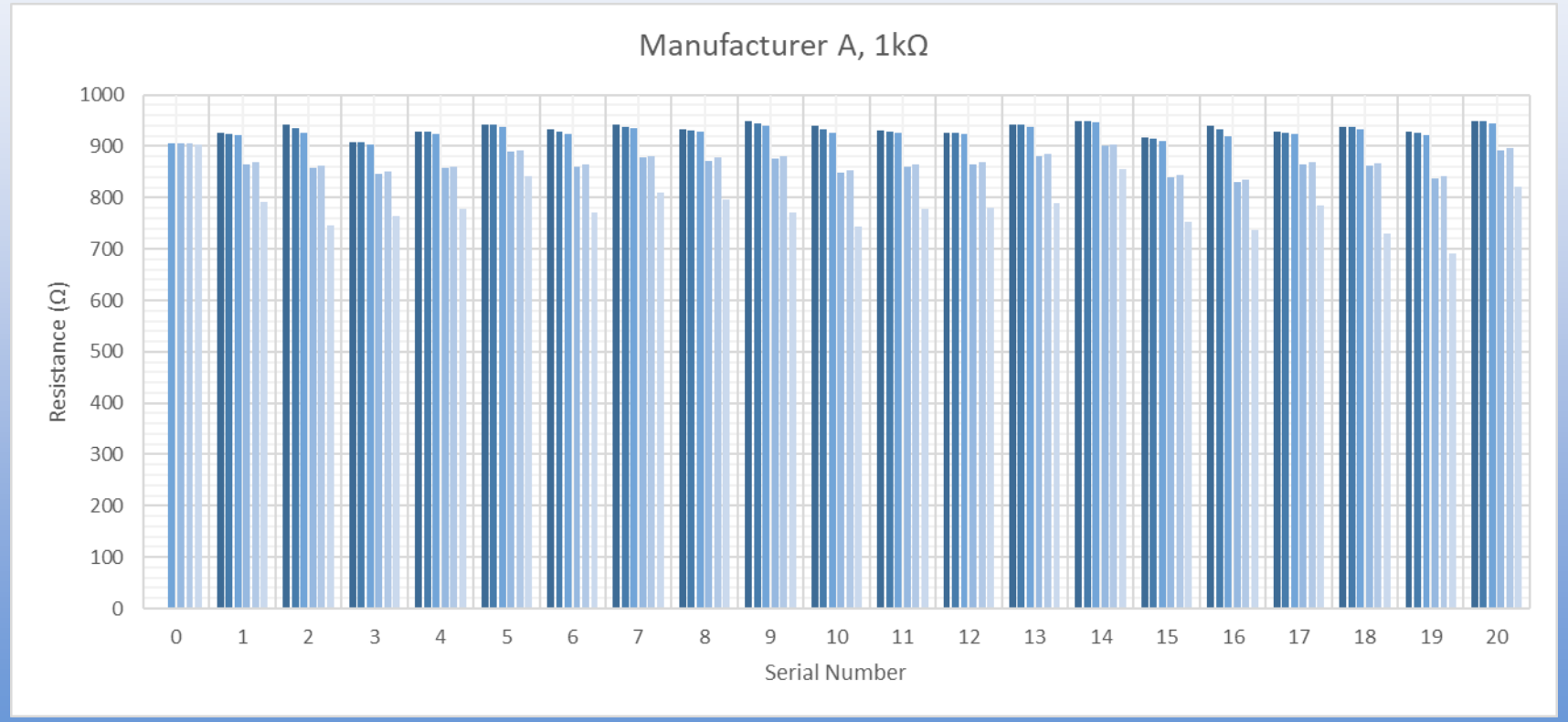
# Further Work

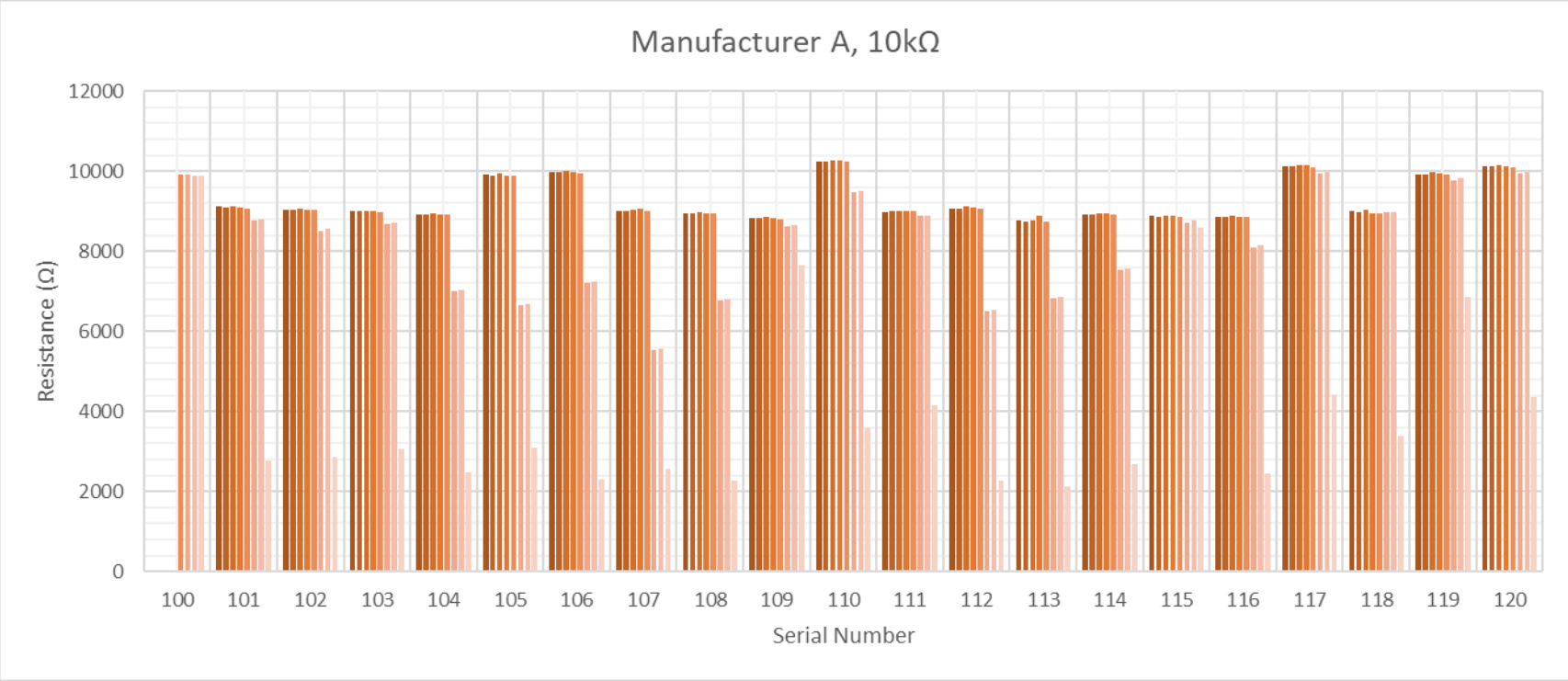
- At 10,000V, some of the smallest resistors exhibited shorting between the endcaps
  - Pulse energy was bypassing bulk material
  - Epoxy coating withstanding voltage was insufficient for 10,000V
  - Larger value capacitor will be selected and placed into the circuit, to provide more joule energy at a reduced peak voltage.
- Perform sectioning on degraded devices to document physical changes to material as a result of pulse testing.
- Assess possibility for SMD testing with minor setup changes.

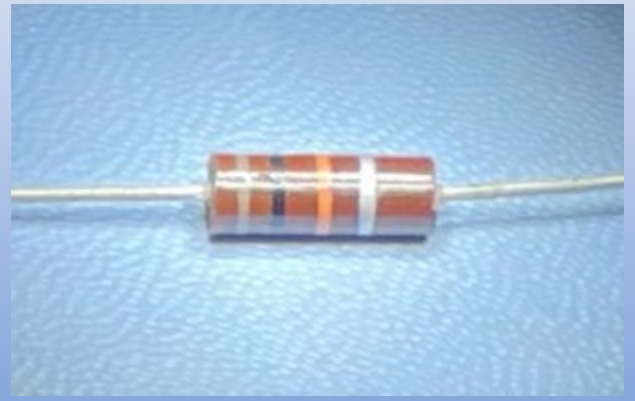
# Backup Slides

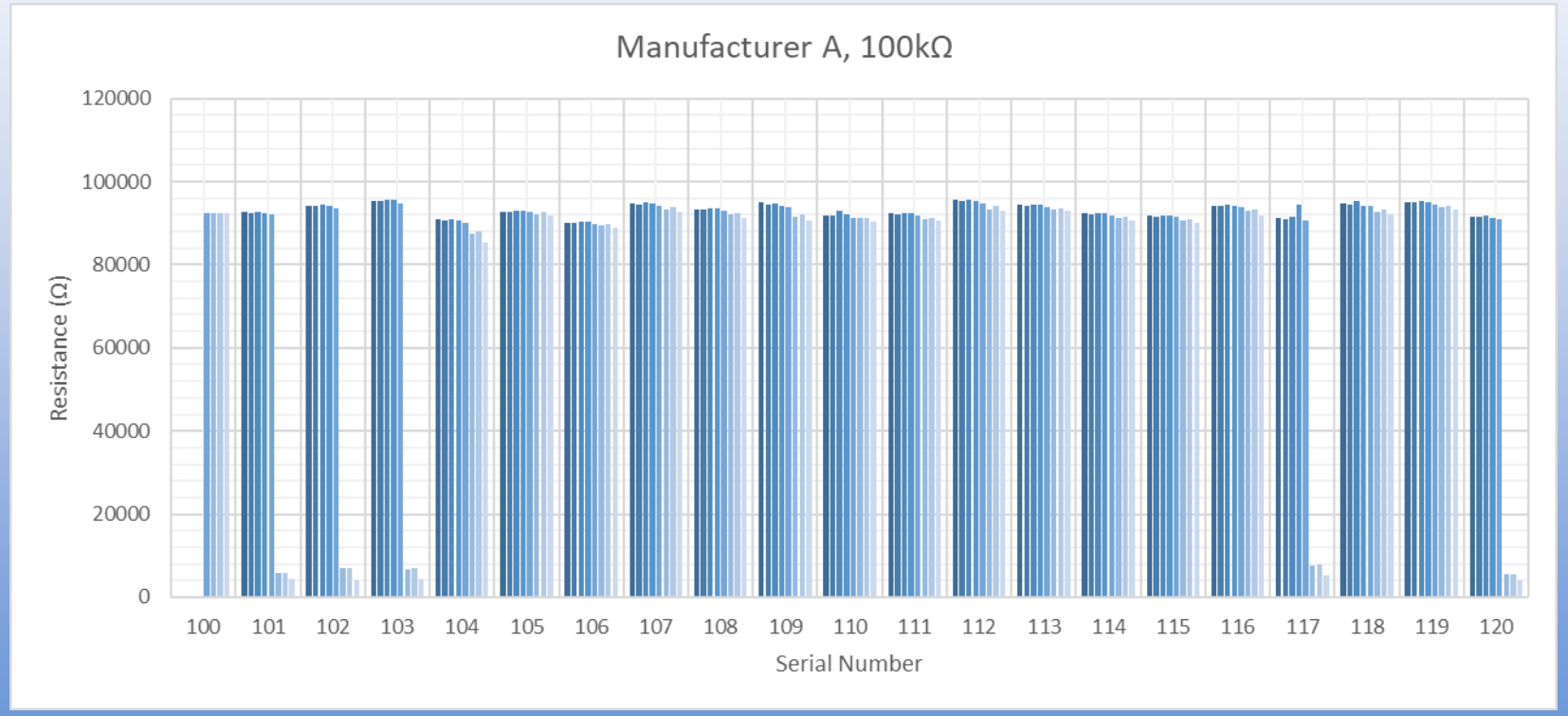
- Test Data- Remaining Sample Tests

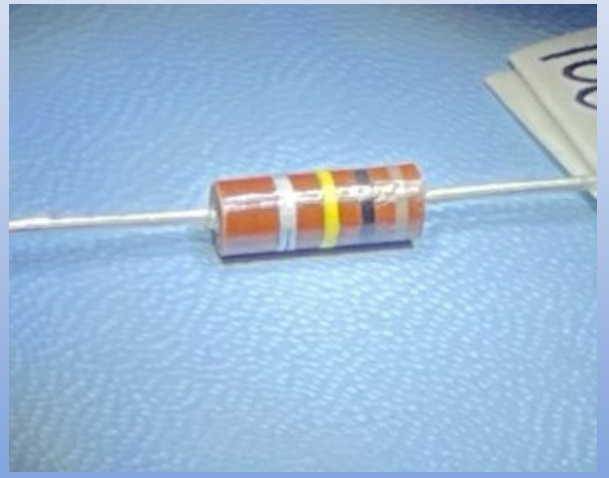

Manufacturer A, 100Ω
Resistance (Ω)
120
100
80
60
40
20
0
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
Serial Number

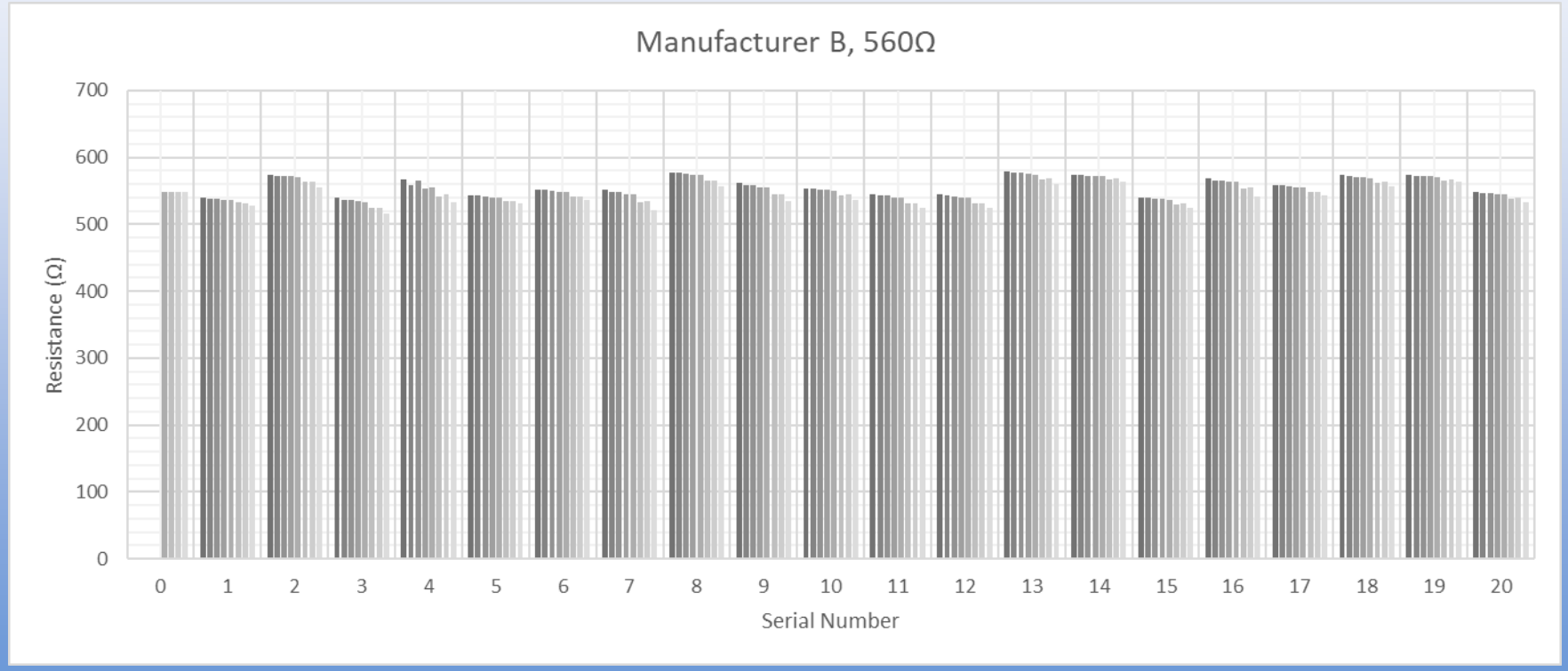

Manufacturer A, 1kΩ
Resistance (Ω)
1000
900
800
700
600
500
400
300
200
100
0
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
Serial Number

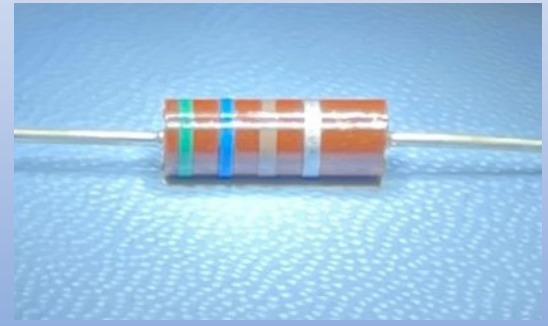

Manufacturer A, 10kΩ
Resistance (Ω)
12000
10000
8000
6000
4000
2000
0
100
101
102
103
104
105
106
107
108
109
110
111
112
113
114
115
116
117
118
119
120
Serial Number

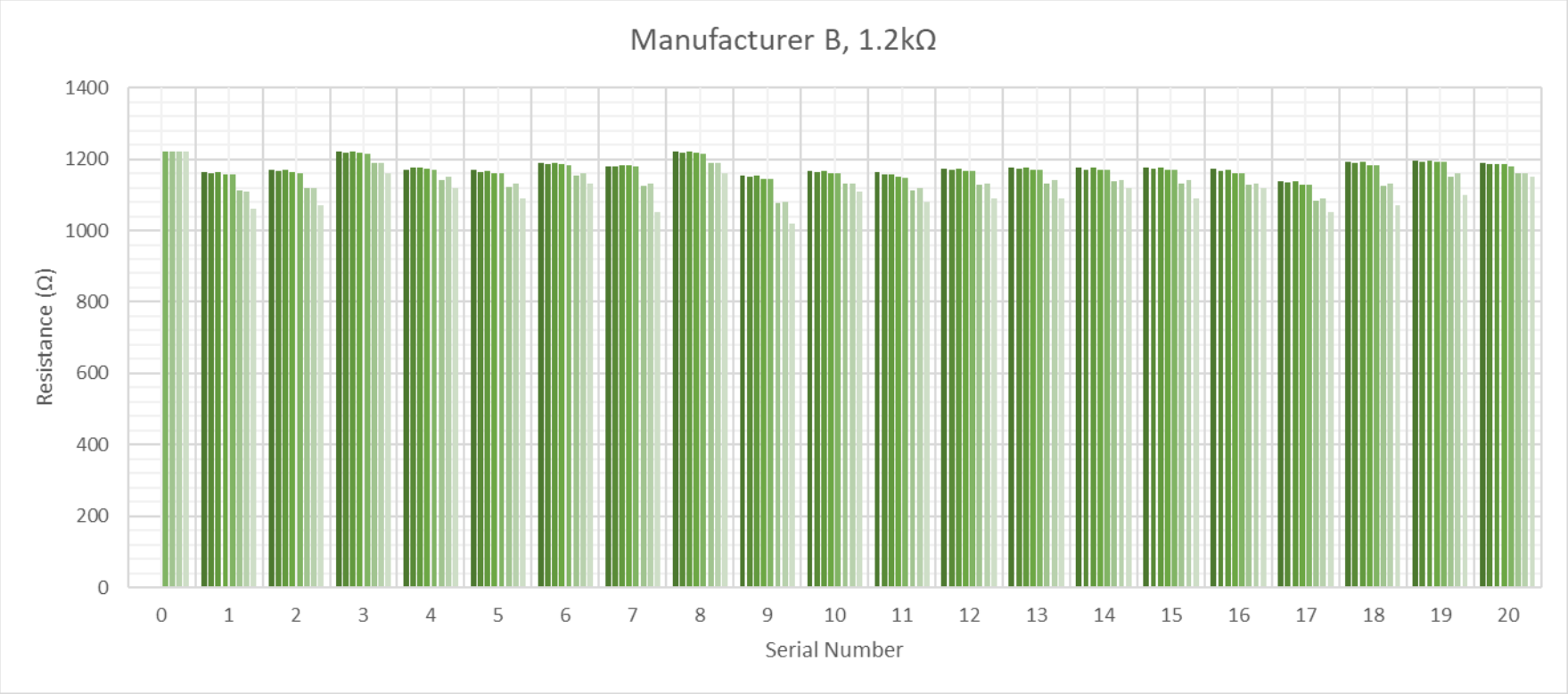


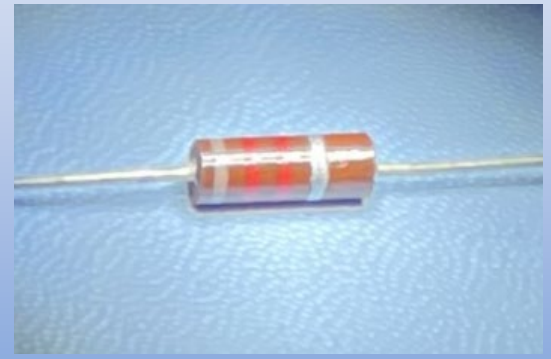

Manufacturer A, 100kΩ
120000
100000
80000
60000
40000
20000
0
Resistance (Ω)
100
101
102
103
104
105
106
107
108
109
110
111
112
113
114
115
116
117
118
119
120
Serial Number

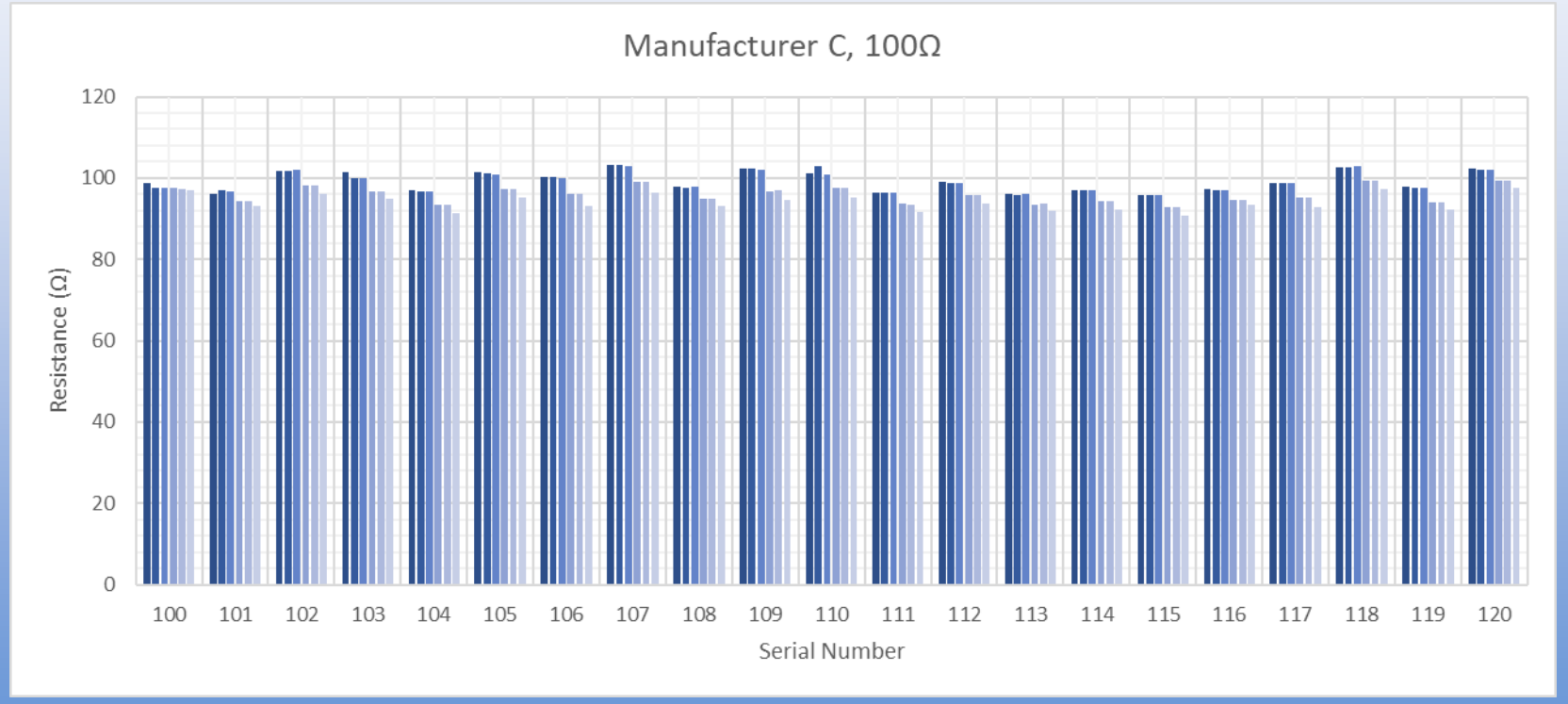


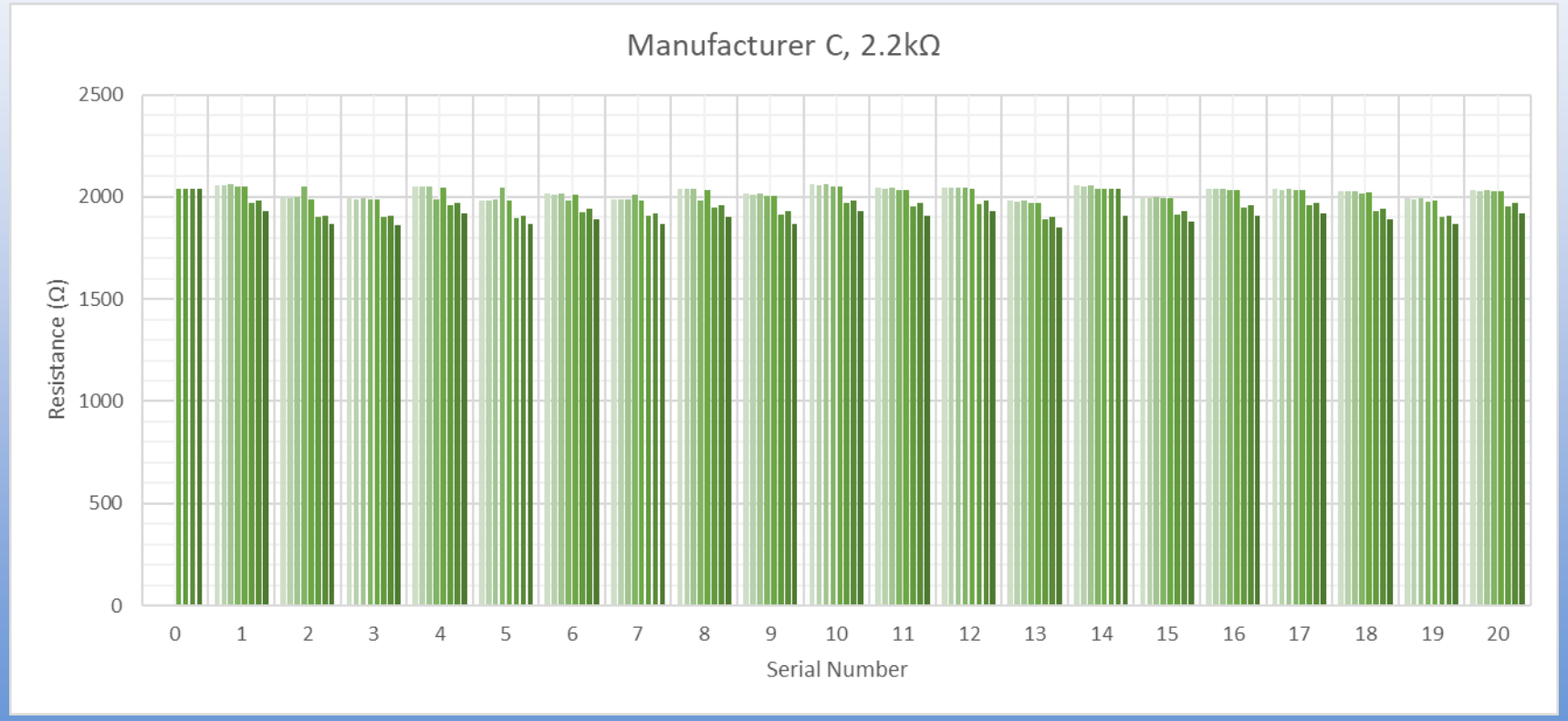

Manufacturer B, 560Ω
Resistance (Ω)
700
600
500
400
300
200
100
0
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
Serial Number

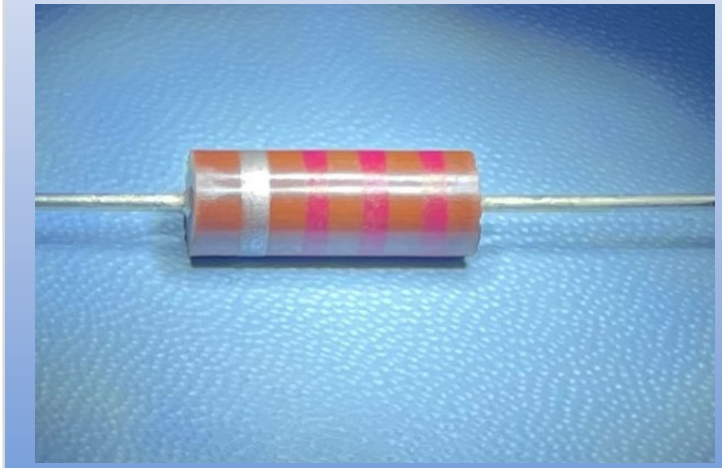


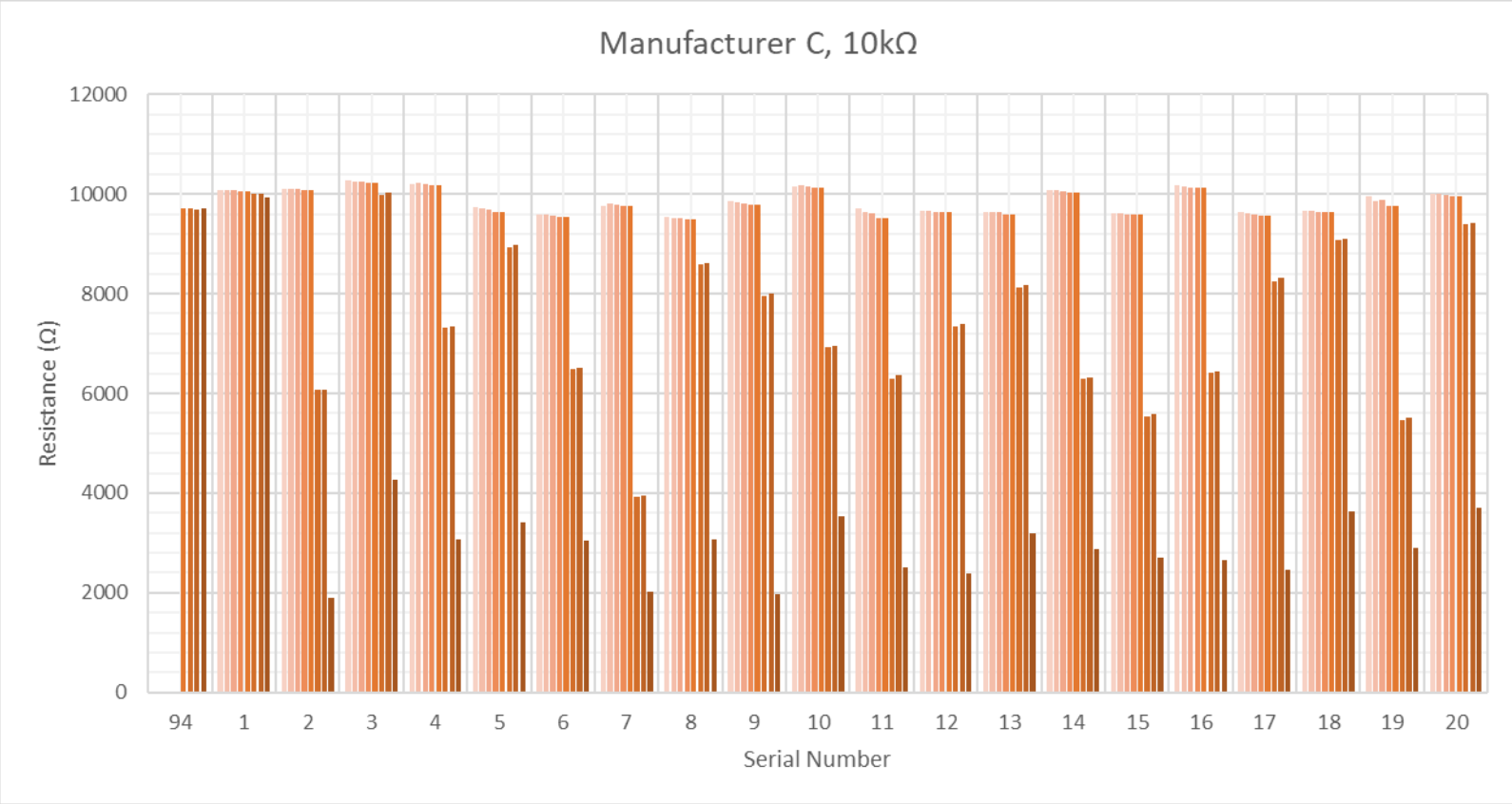

Manufacturer B, 1.2kΩ
Resistance (Ω)
1400
1200
1000
800
600
400
200
0
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
Serial Number

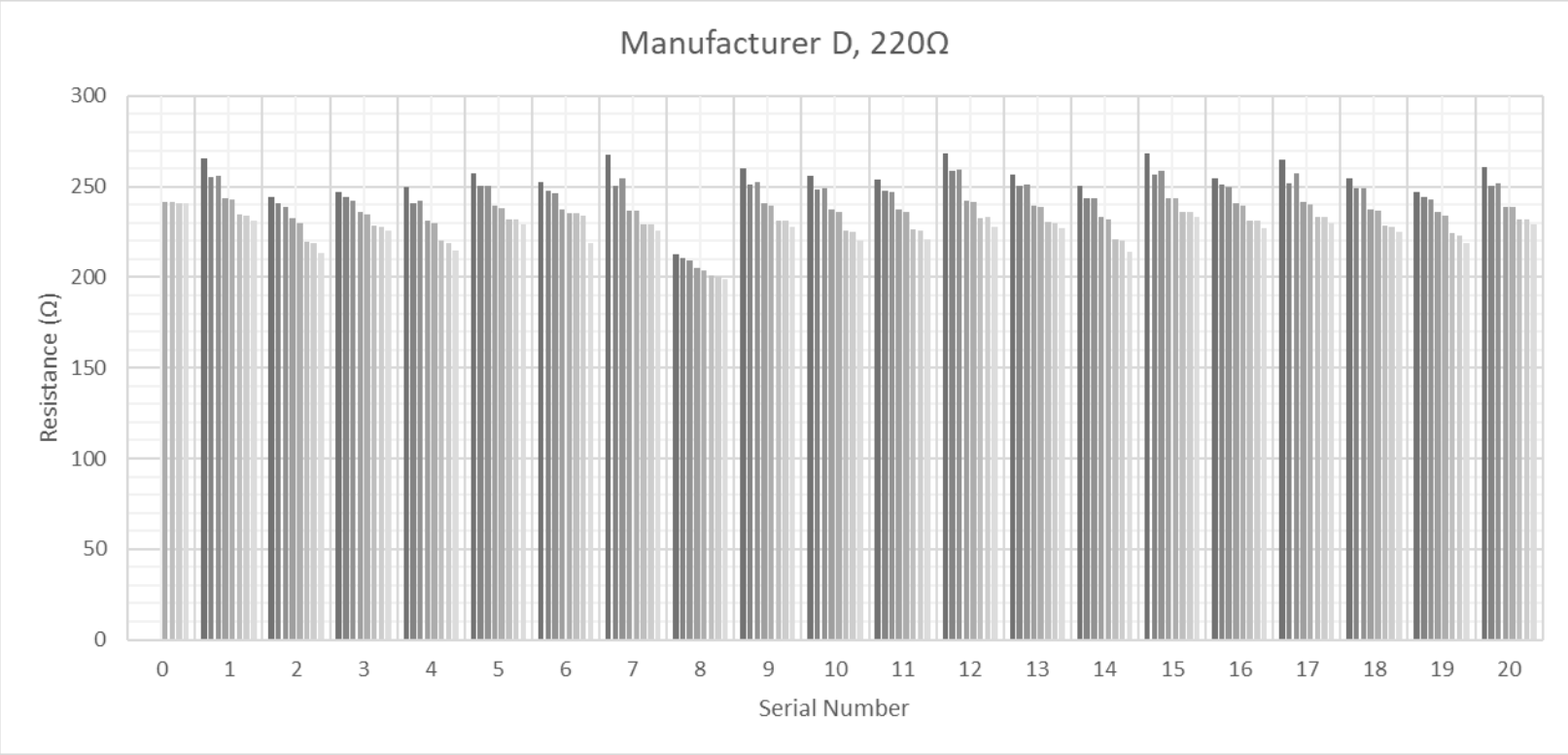


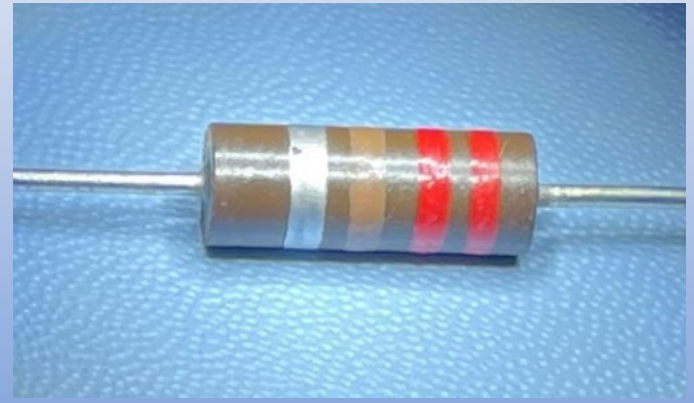

Manufacturer C, 100Ω
Resistance (Ω)
120
100
80
60
40
20
0
100 101 102 103 104 105 106 107 108 109 110 111 112 113 114 115 116 117 118 119 120
Serial Number

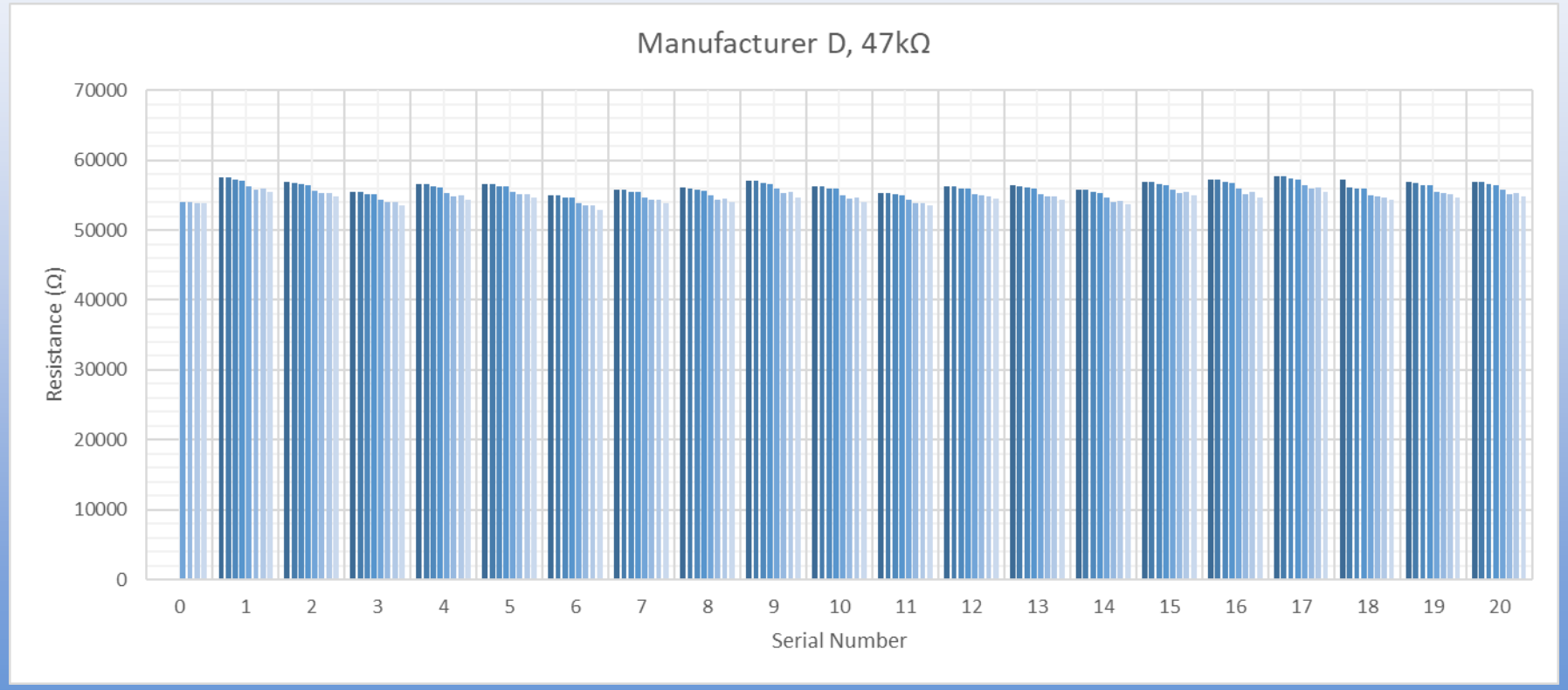

Manufacturer C, 2.2kΩ
Resistance (Ω)
2500
2000
1500
1000
500
0
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
Serial Number

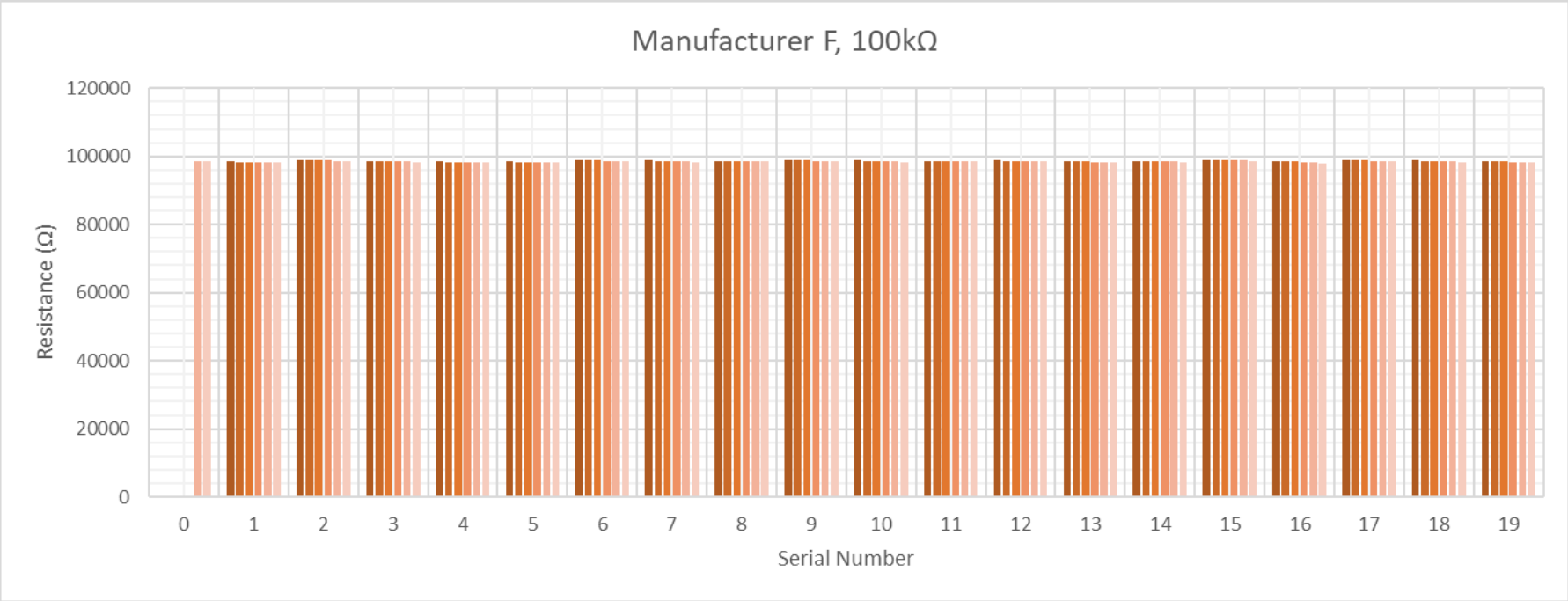


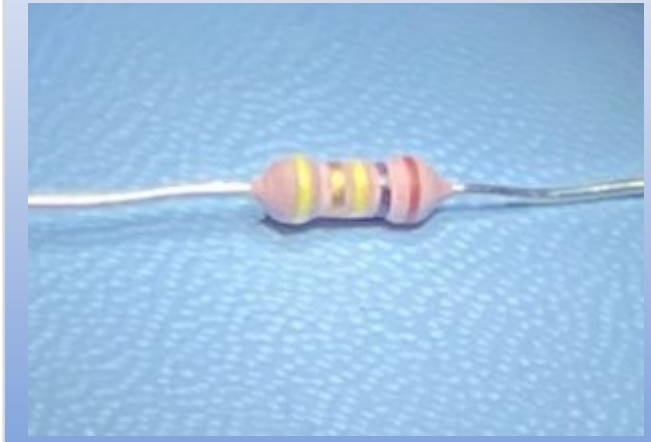

Manufacturer C, 10kΩ
Resistance (Ω)
12000
10000
8000
6000
4000
2000
0
94
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
Serial Number

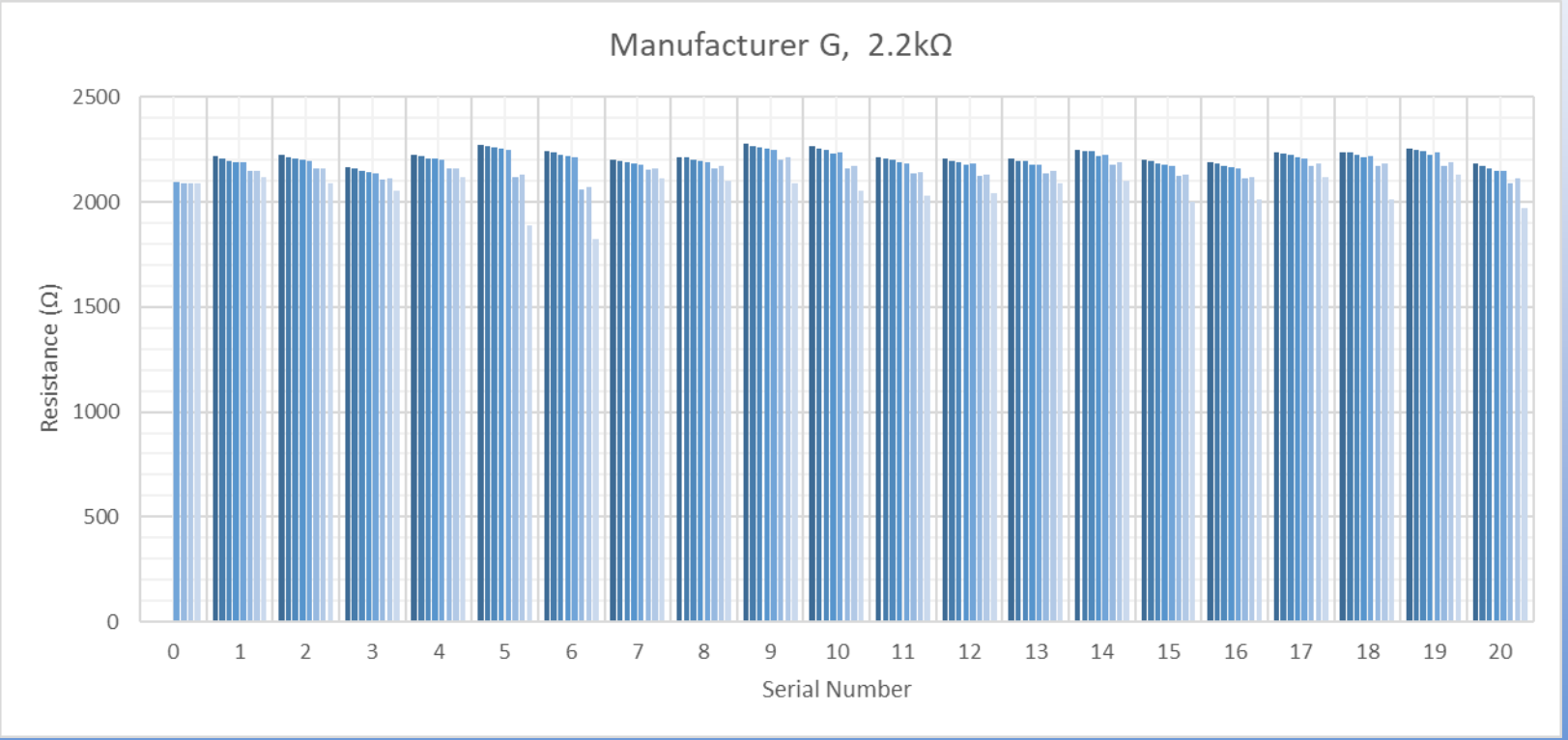

Manufacturer D, 220Ω
Resistance (Ω)
300
250
200
150
100
50
0
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
Serial Number

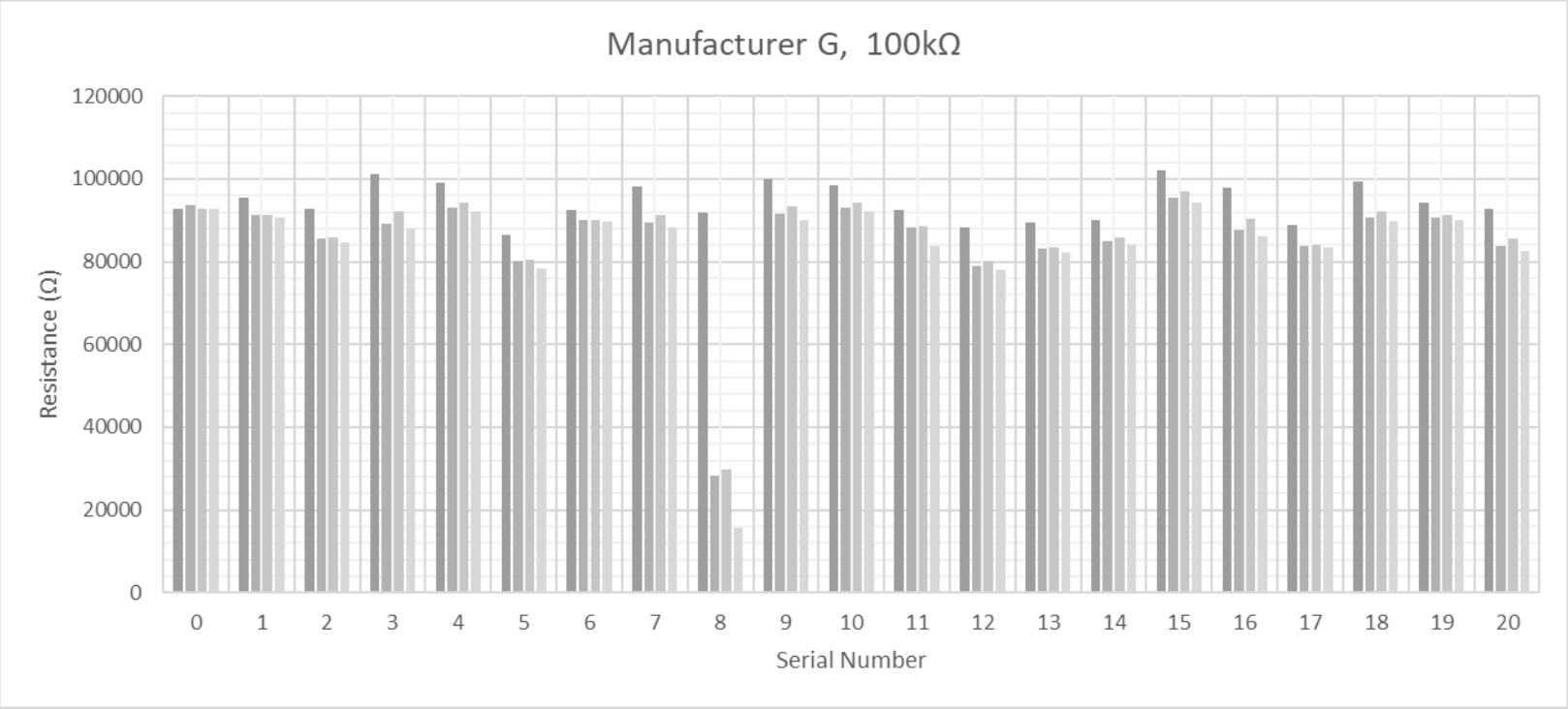


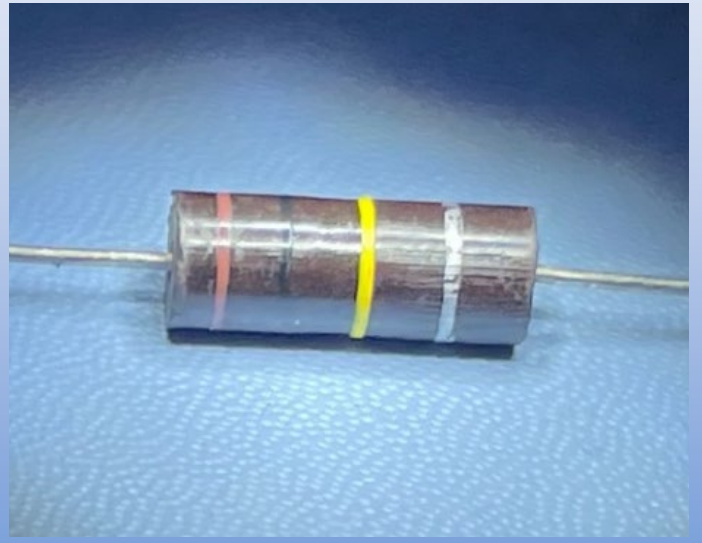

Manufacturer D, 47kΩ
Resistance (Ω)
70000
60000
50000
40000
30000
20000
10000
0
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
Serial Number

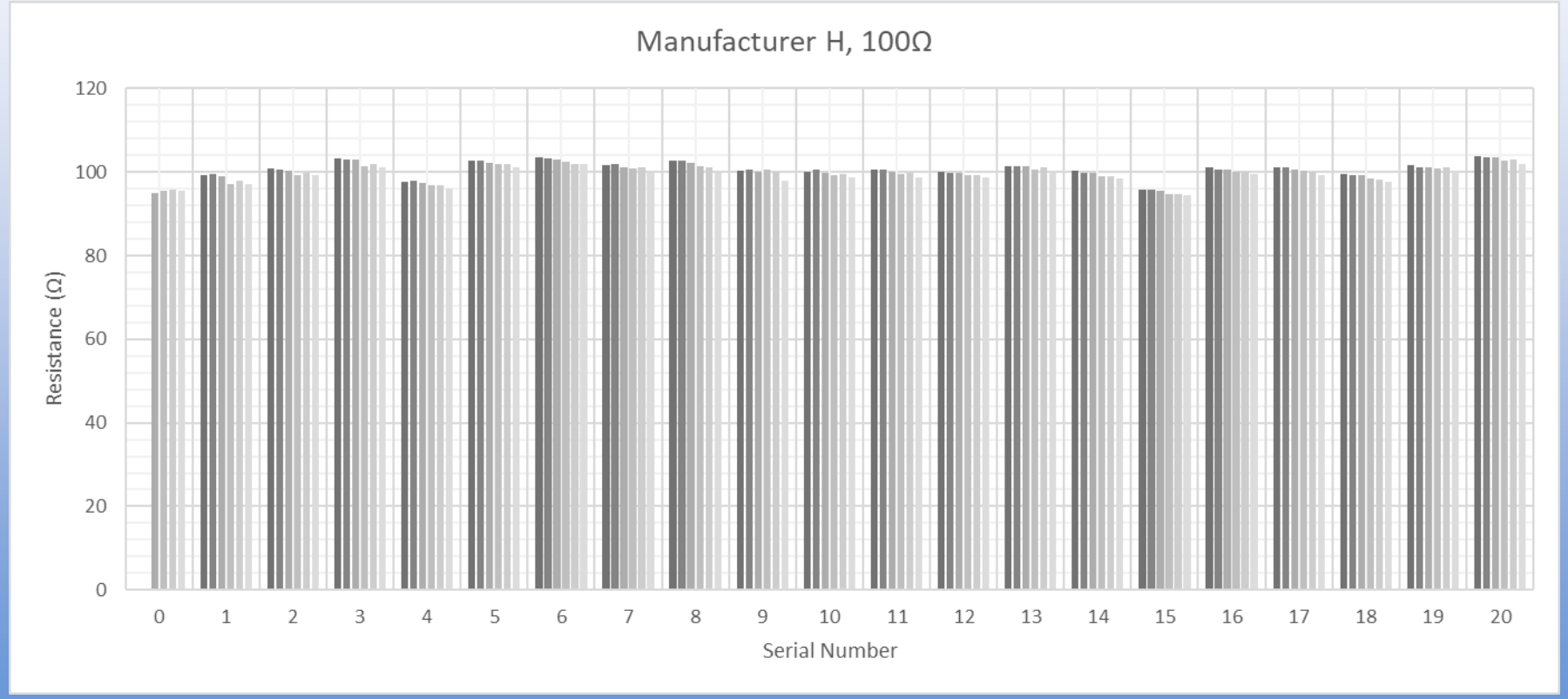

Manufacturer F, 100kΩ
Resistance (Ω)
120000
100000
80000
60000
40000
20000
0
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19
Serial Number

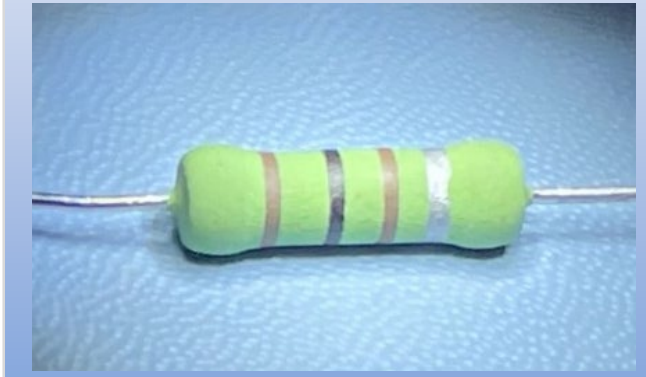


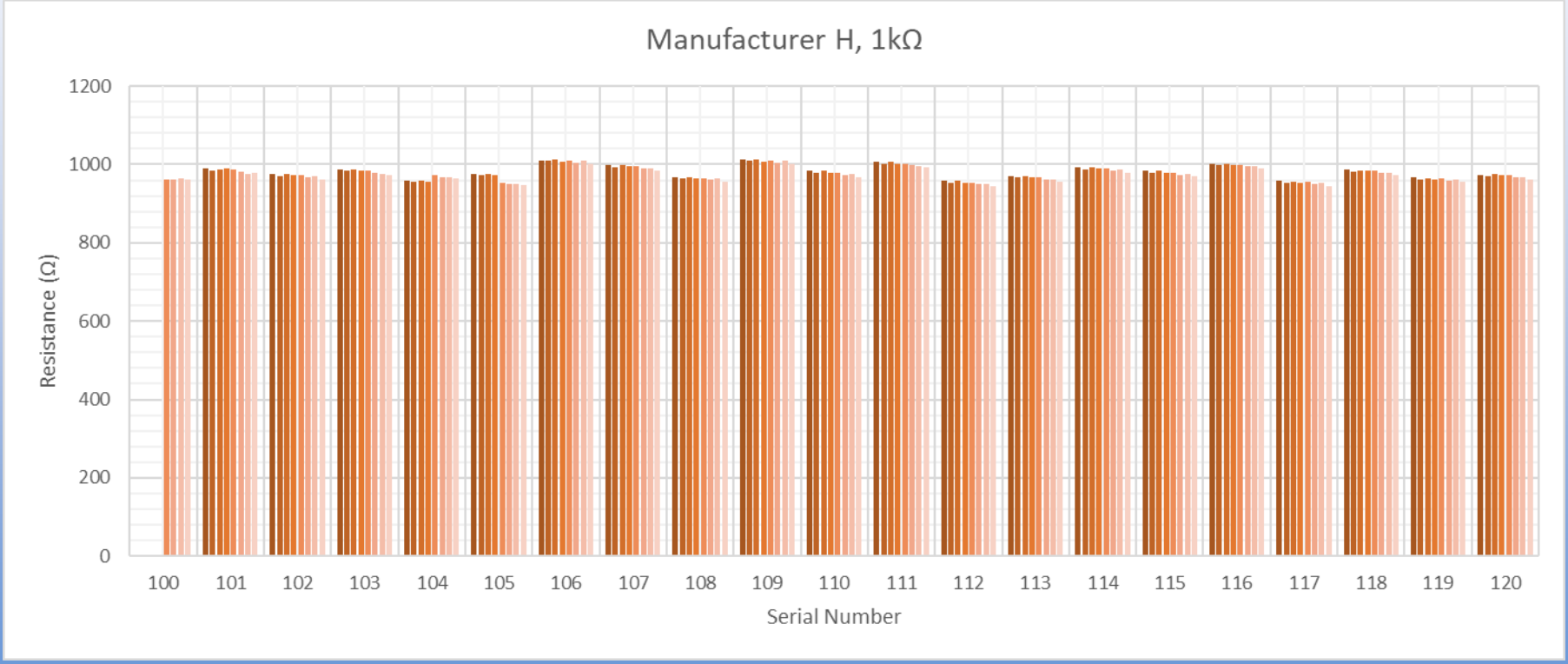

Manufacturer G, 2.2kΩ
Resistance (Ω)
2500
2000
1500
1000
500
0
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
Serial Number


Manufacturer G, 100kΩ
Resistance (Ω)
120000
100000
80000
60000
40000
20000
0
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
Serial Number

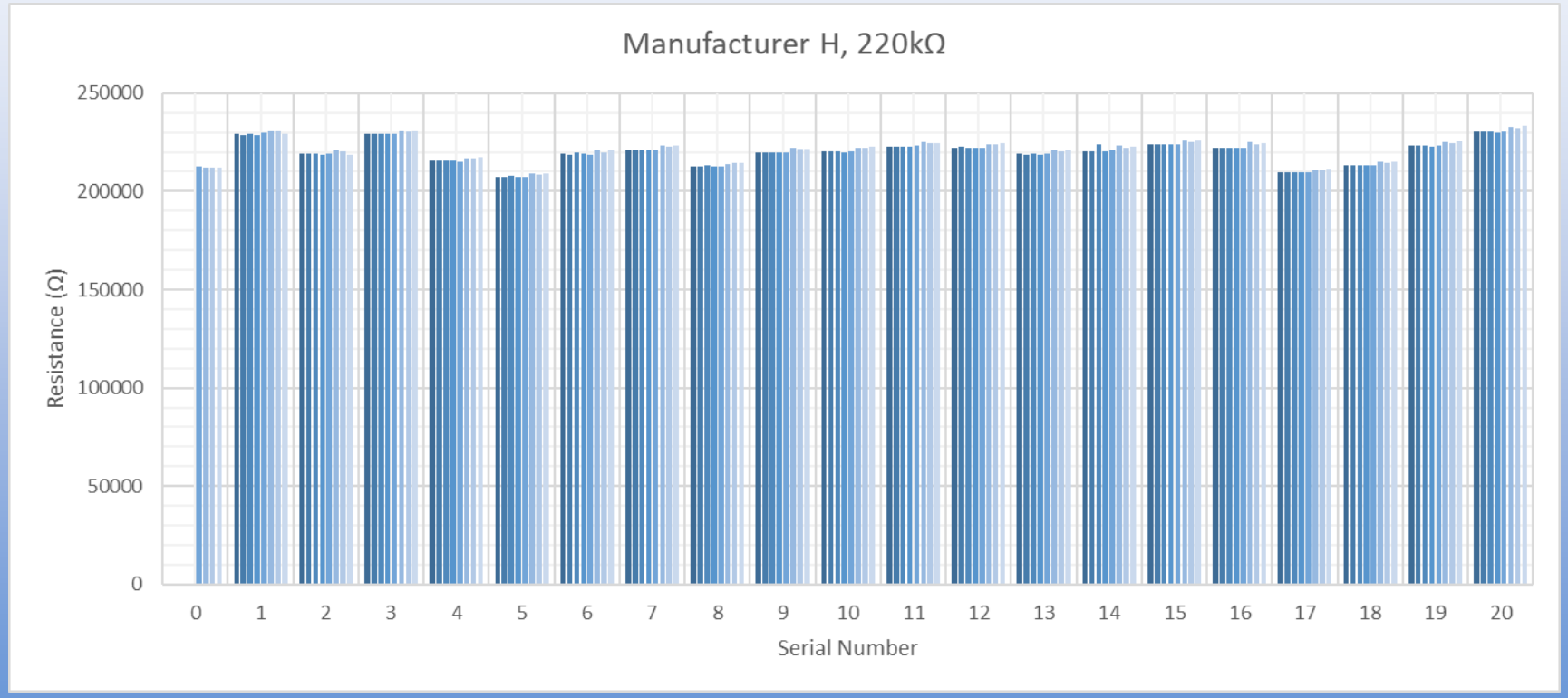



Manufacturer H, 100Ω
Resistance (Ω)
120
100
80
60
40
20
0
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
Serial Number




Manufacturer H, 1kΩ
Resistance (Ω)
1200
1000
800
600
400
200
0
100
101
102
103
104
105
106
107
108
109
110
111
112
113
114
115
116
117
118
119
120
Serial Number


Manufacturer H, 10kΩ
Resistance (Ω)
12000
10000
8000
6000
4000
2000
0
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
Serial Number


Manufacturer H, 220kΩ
Resistance (Ω)
250000
200000
150000
100000
50000
0
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
Serial Number