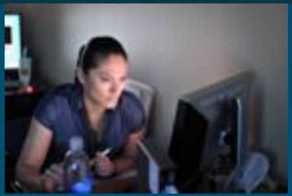
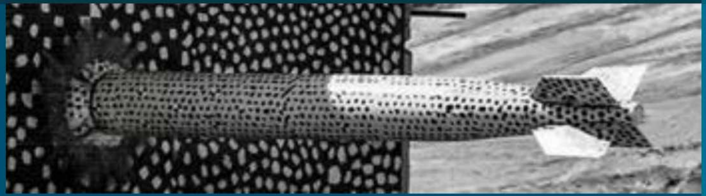
SAND2018-9081PE

High Energy Arc Fault Testing





PRESENTED BY

Marena Trujillo 1353

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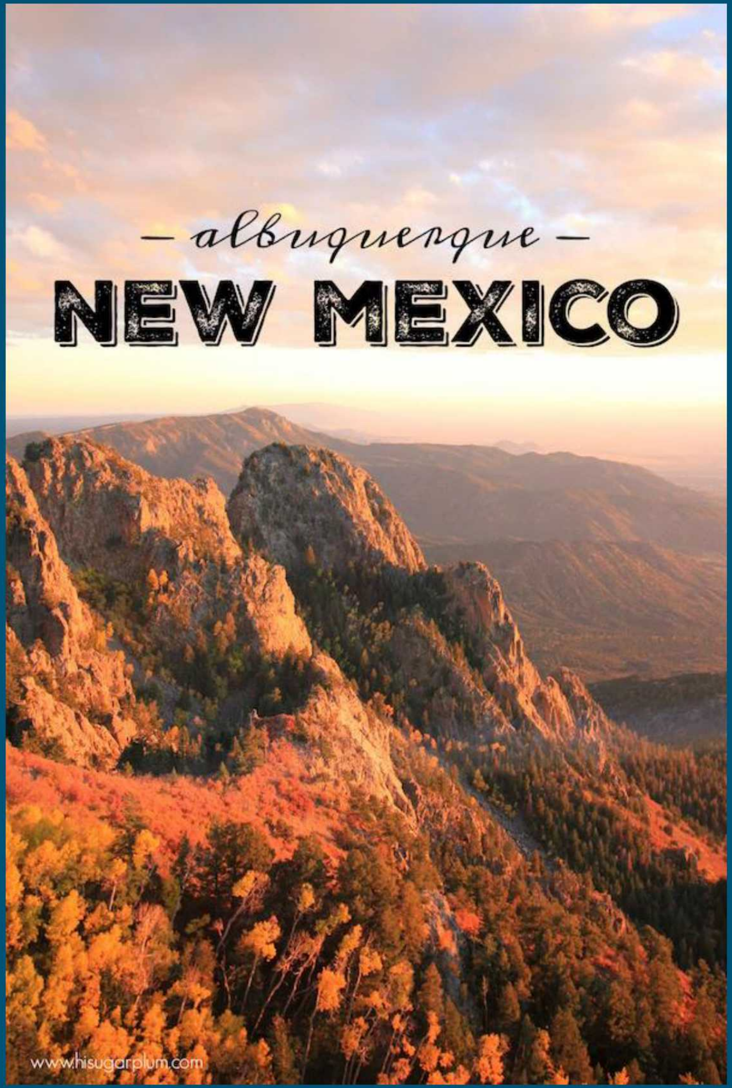
About Me



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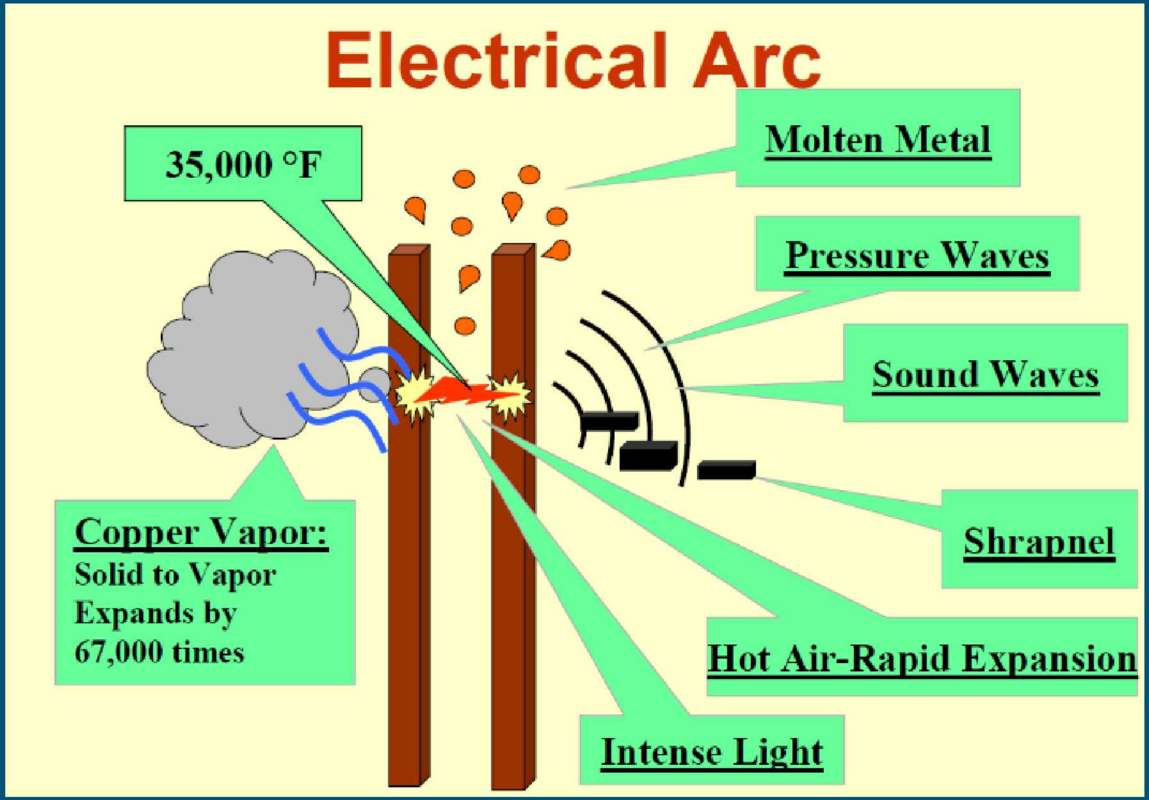
https://www.nextracker.com/2017/03/q-a-gtm-webinar-solar-field-of-dreams-tracking-your-solar-om-investment/

Purpose

To develop the ability to quantify the damage that might result from a high energy arc fault event (HEAF event) in a nuclear power plant, and ultimately to prevent HEAF events from occurring.



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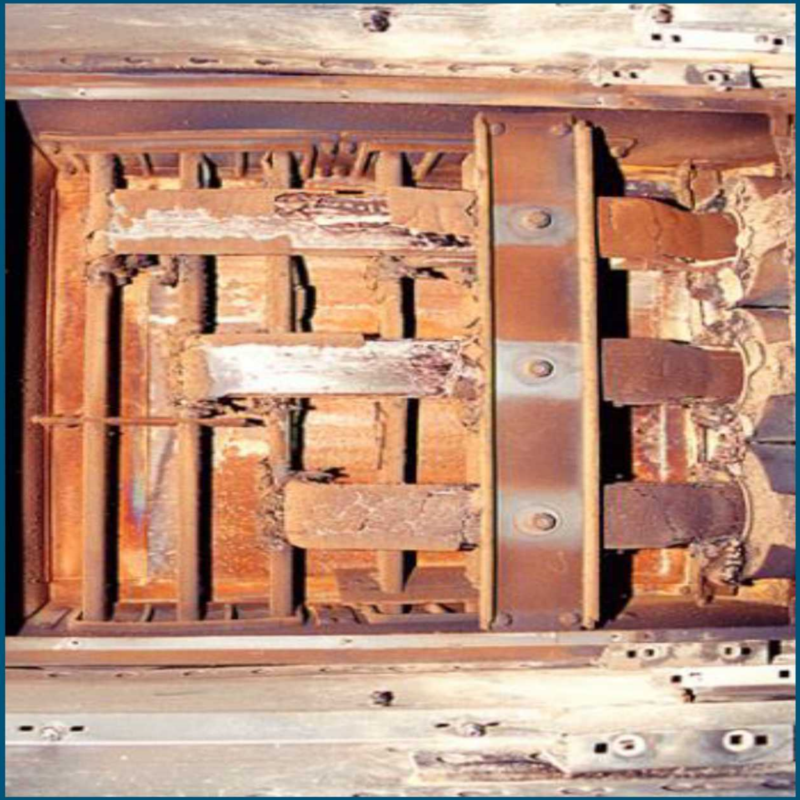
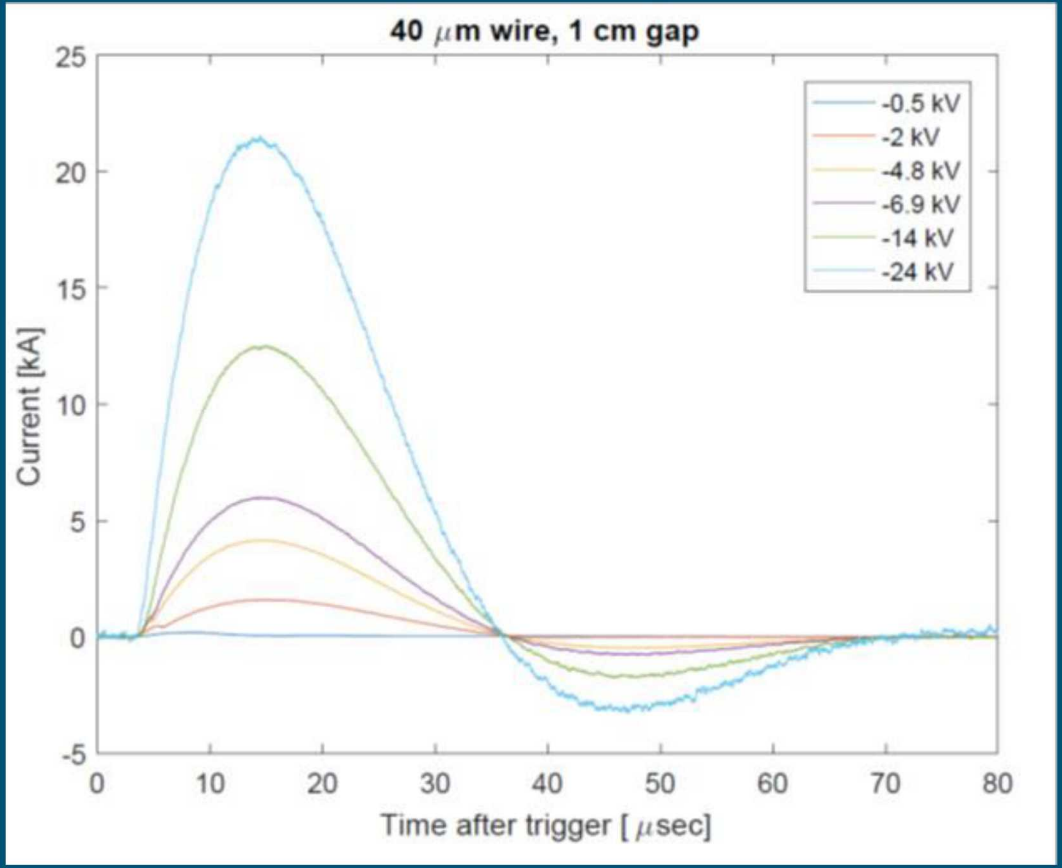
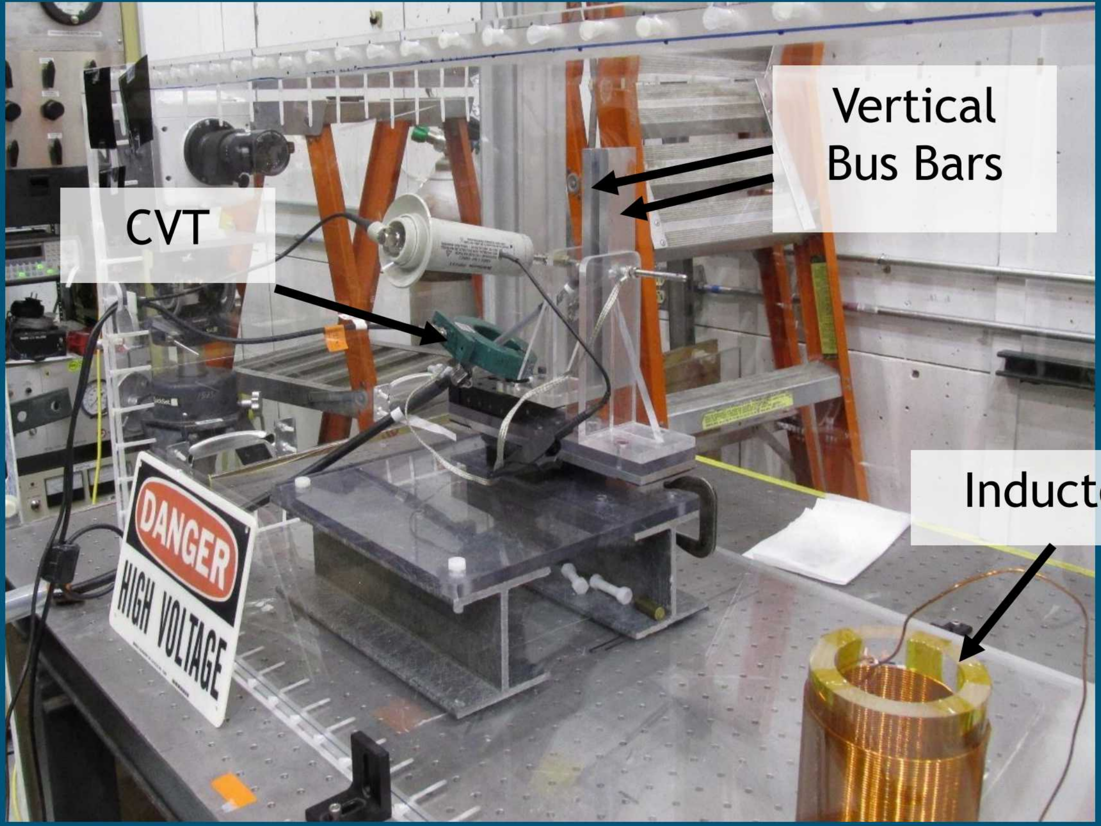


Arc fault damage in 3-phase AC junction box

Experimental Design/Initial Testing

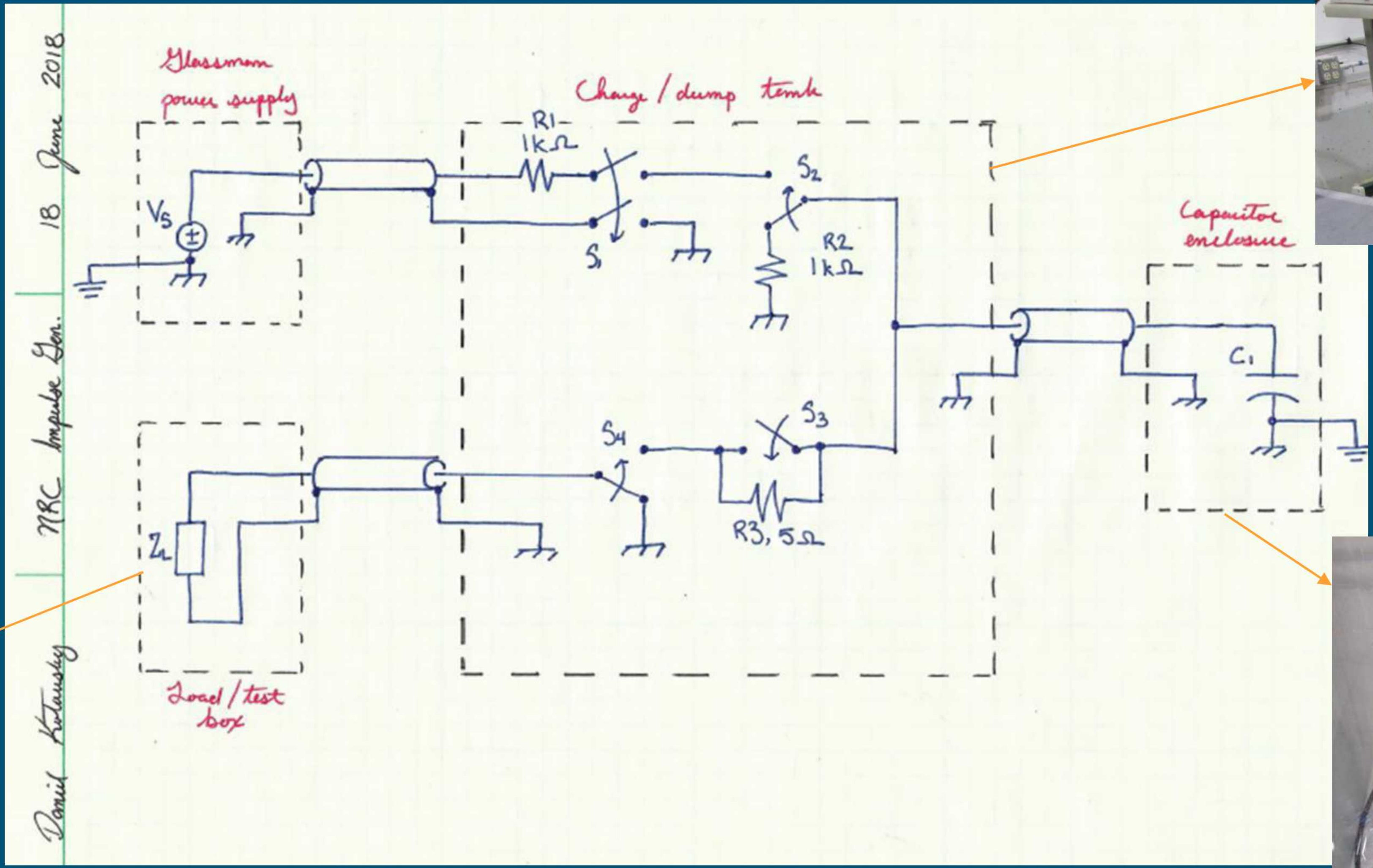
- Two 1.59”x0.39” rectangular bus bars were spaced 1 cm apart.
- Three bridge wires (40, 100 & 130µm) were tested.
- A 430µH inductor was incorporated to increase the time duration for the arc.
- Initial testing was performed using a lightning waveform simulator (480 V-24 kV, up to 20 kA, up to 200 µs)

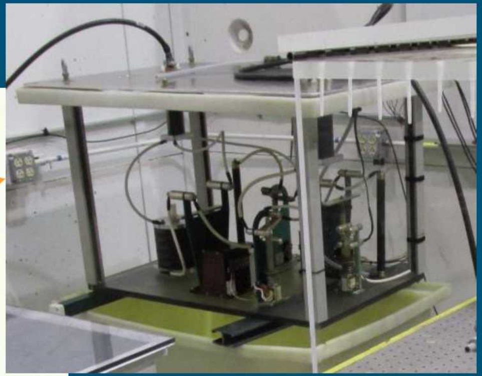




Experimental Design: new HV pulser to simulate nuclear power plant arcs

0.85 mF, 11 kV, 50 kJ capacitive discharge circuit

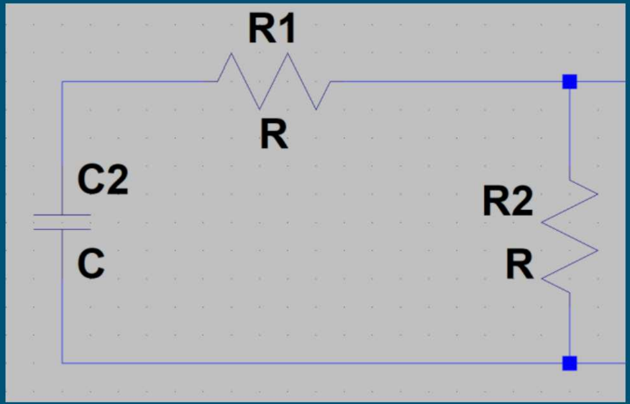




Experimental Test Matrix

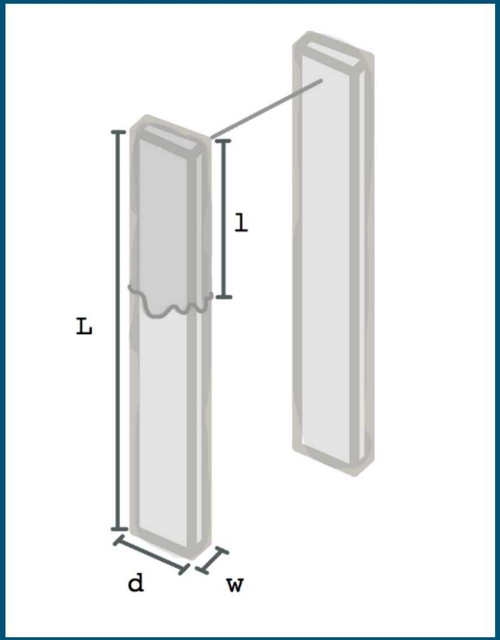
Test No. (NRC No.)	Voltage [V]	Series R [ohm]	Gap [mm]	Material
1 (3)	480	5	5	Al
2 (4)	480	5	5	Cu
3 (16)	4160	5	5	Al
4 (7)	6900	5	5	Al
5 (8) *	6900	5	5	Al
6 (9)	6900	5	5	Cu
7 (13)	6900	5	10	Al
8 (14)	6900	5	10	Cu
9 (1)	480	10	5	Al
10 (2)	480	10	5	Cu
11 (15)	4160	10	5	Al
12 (5)	6900	10	5	Al
13 (6)	6900	10	5	Cu
14 (11)	6900	10	10	Al
15 (12)	6900	10	10	Cu
16 (10)	6900	20	5	Al
17 (17)	10000	33	5	Al
18 (18)	10000	33	5	Cu
19 (19)	10000	33	10	Al
20 (20)	10000	33	10	Cu

R_{arc}



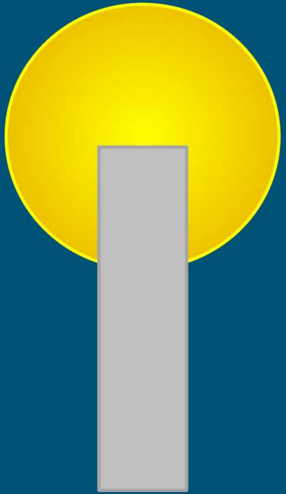
R_{series}

Predictions of bus bar mass loss due to plasma heating



$$IVT = (\Delta T)(C)(l)(w)(d) + (l)(w)(d)(\rho)(\frac{1}{M})(Hf)$$

$$(IVT)/[(\Delta T)(C)(w)(d) + (w)(d)(\rho)(\frac{1}{M})(Hf)] = l$$



Sources of Error:

- Only a fraction of the arc energy is dumped into the bus bars (18.8%).
- Resistance of the bus bars changes as the metal warms.
- Actual resistance of the system was much greater than initial estimation.

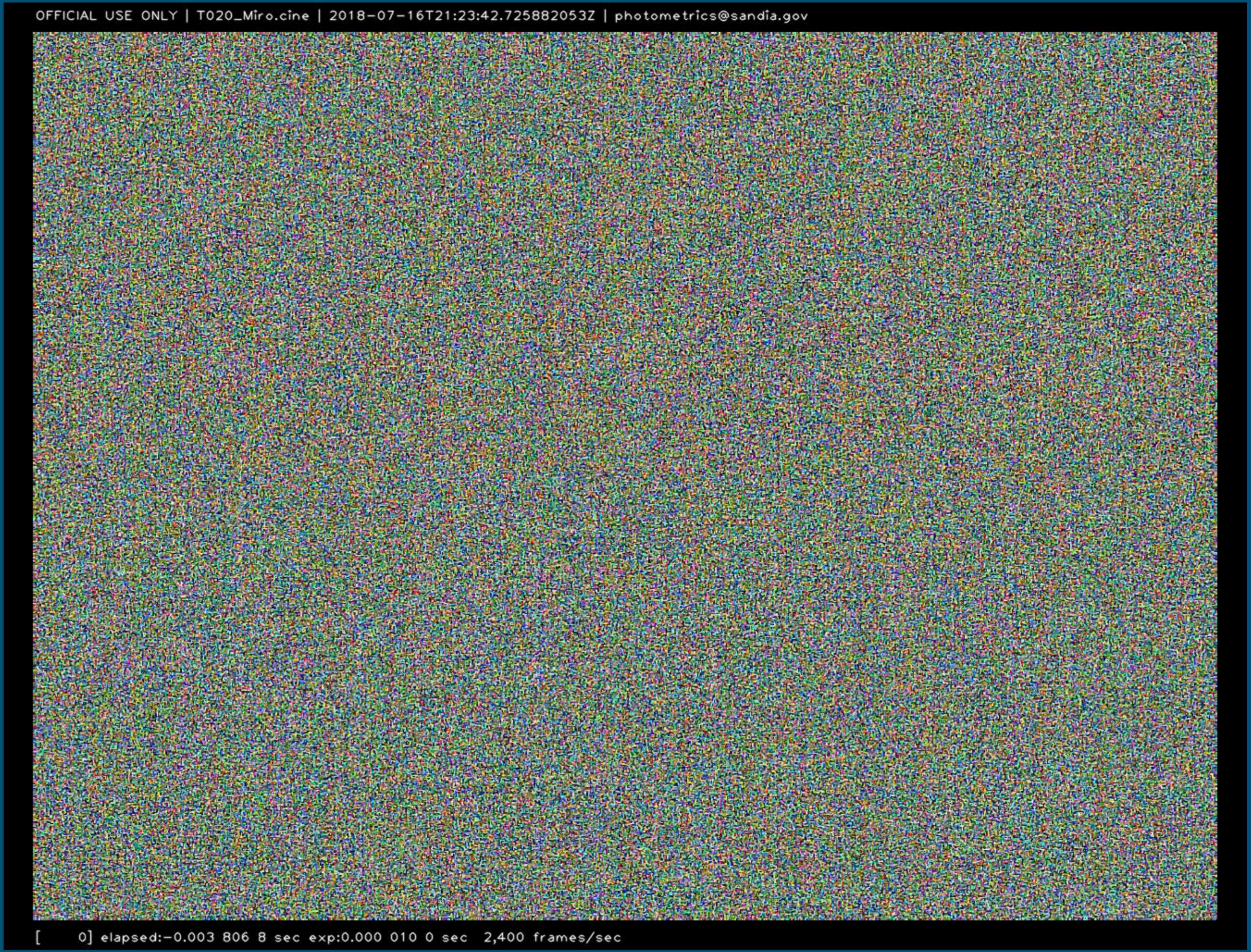
	Predicted	
Voltage	Loss (g)	Loss (g)
4200	0.012096	0.0121491
500	0.000027	0.0000243
6900	0.03593856	0.0361397
13800	0.15507072	0.1558823
13800	0.15539328	0.1562223
13800	0.156442	0.1572583
24000	0.47803392	0.4805489
24000	0.477120	0.4796181
24000	0.47593728	0.4784363
24000	0.47784576	0.4803546
24000	0.47687808	0.4793672
500	0.000000	0.0000081
6900	0.03529344	0.0354760
24000	0.47306112	0.4755387

$$IVT = (\Delta T)(C)(l)(w)(d) + (l)(w)(d)(\rho)(\frac{1}{M})(Hf) + (\Delta T2)(C)(l)(w)(d) + (l)(w)(d)(\rho)(\frac{1}{M})(Hv)$$

$$IVT = (\Delta T)(C)(l)(w)(d) + (l)(w)(d)(\rho)(\frac{1}{M})(Hf) + (\Delta T2)(C)(l)(w)(d) + (l)(w)(d)(\rho)(\frac{1}{M})(Hv) - (l)(w)(d)(\rho)(\frac{1}{M})(Hox)$$

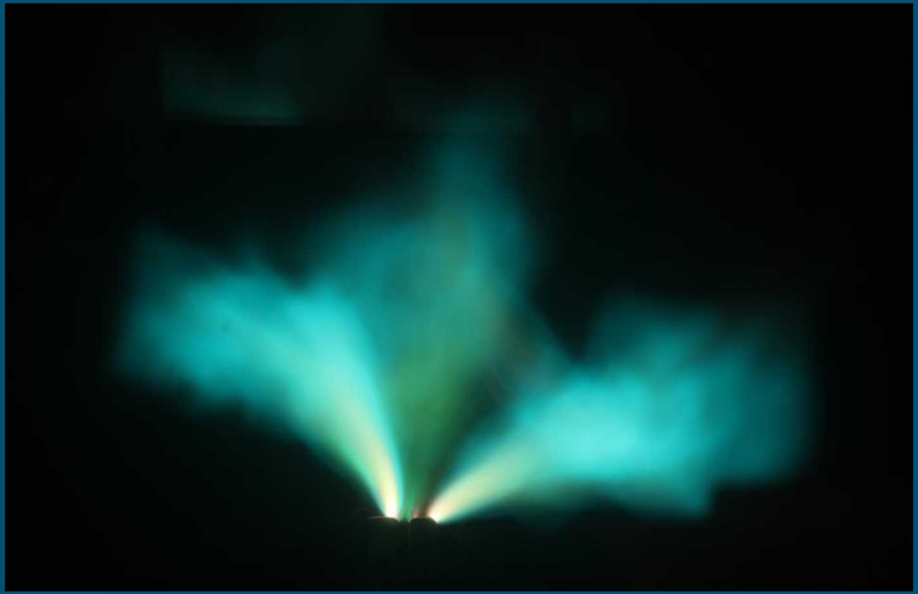
Oxidation of aluminum

Results

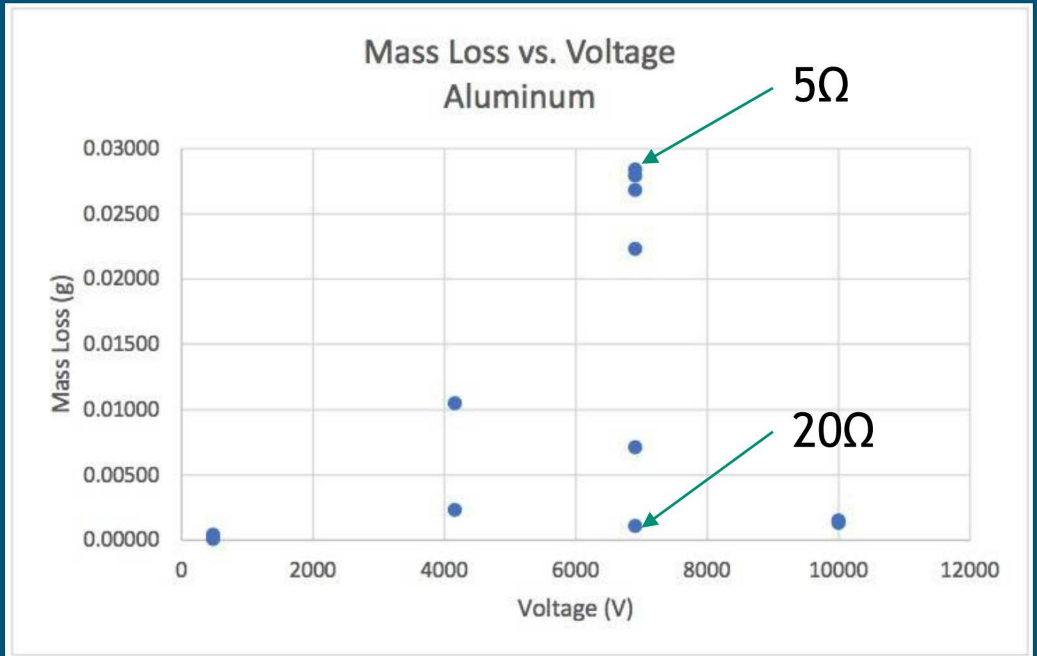

OFFICIAL USE ONLY | T020_Miro.cine | 2018-07-16T21:23:42.725882053Z | photometrics@sandia.gov
[0] elapsed:-0.003 806 8 sec exp:0.000 010 0 sec 2,400 frames/sec

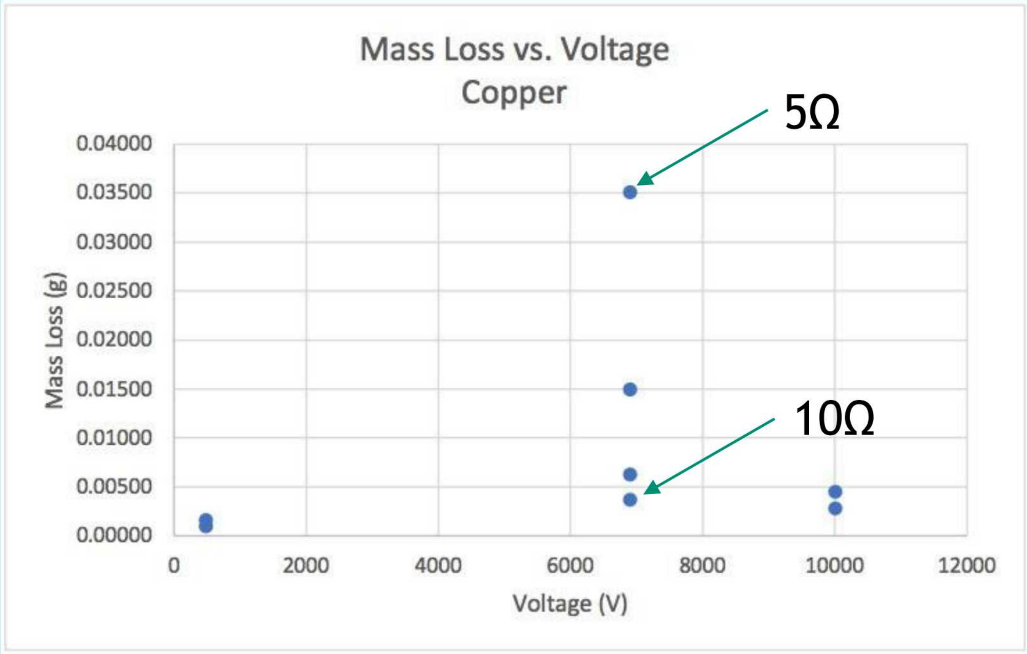
Arc Impacts on Busbars

left: test 2, 480V
right: test 20, 10kV



left: test 1, 480V
right: test 19, 10kV

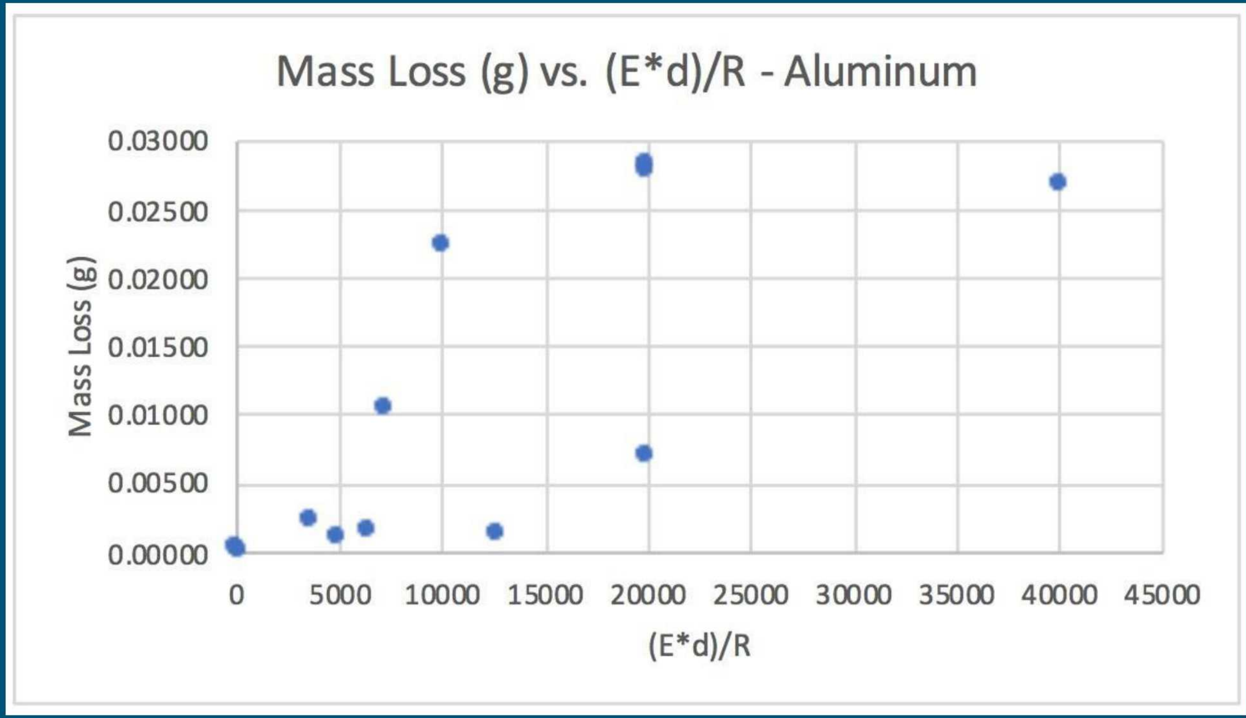


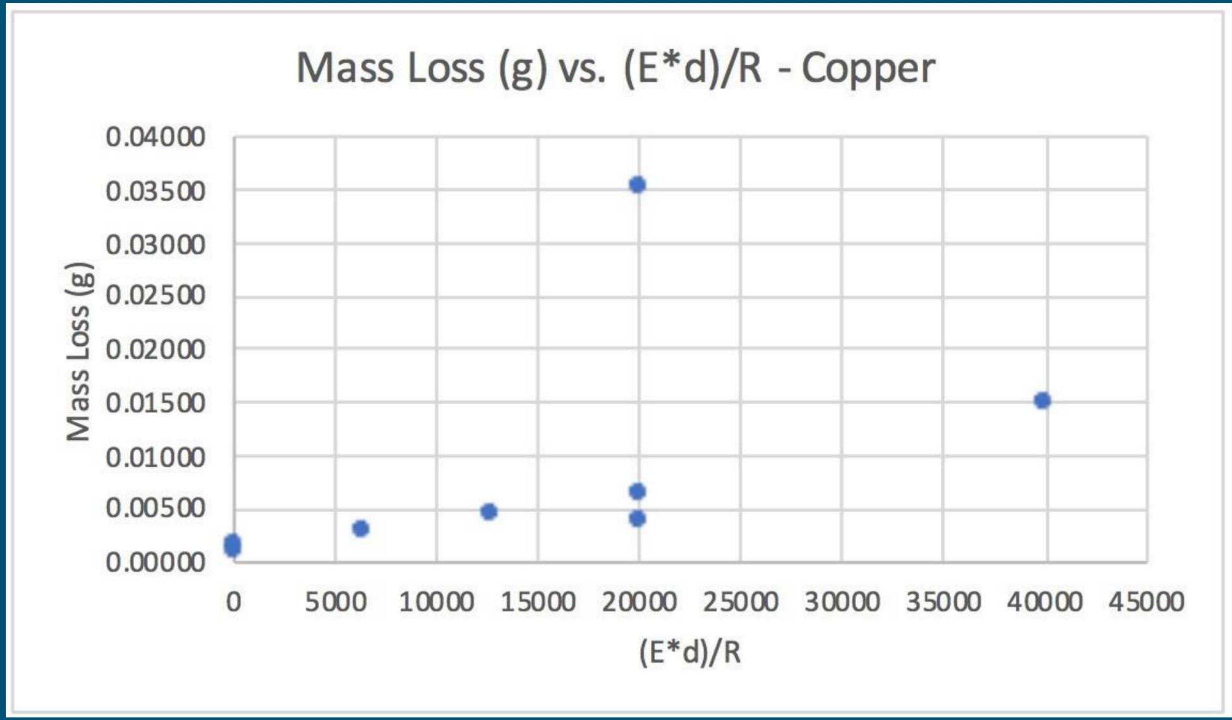


Actual

Loss (g)	Voltage (V)	Loss (g)	Voltage (V)
0.0006	480	1E-04	480
0.0002	480	0	480
0.0001	480	0.0052	4160
0.0003	480	0.0053	4160
0.0005	480	0.0136	6900
0.0005	480	0.0148	6900
0.022	6900	0.0133	6900
0.0131	6900	0.0146	6900
0.0036	6900	0.0144	6900
0.0114	6900	0.0124	6900
0.0008	480	0.0004	480
0.0008	480	0	480
0.0028	6900	0.0017	4160
0.0009	6900	0.0006	4160
0.0323	11000	0.0131	6900
0.0391	11000	0.0092	6900
0.0055	6900	0.0069	6900
0.0008	6900	0.0002	6900
0.0018	10000	0	6900
0.001	10000	0.0011	6900
0.0009	10000	0.0003	10000
0.0036	10000	0.0012	10000
0.0087	6900	1E-04	10000
0.0008	6900	0.0012	10000
		0.0004	10000
		0.0009	10000
		0.001	10000
		0.0004	10000

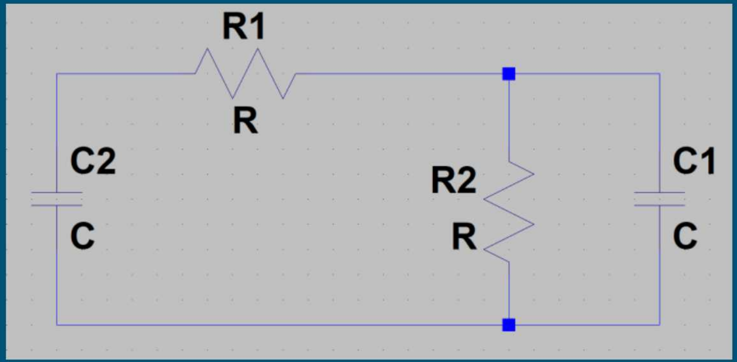
Mass loss scales with capacitor energy and arc/gap length



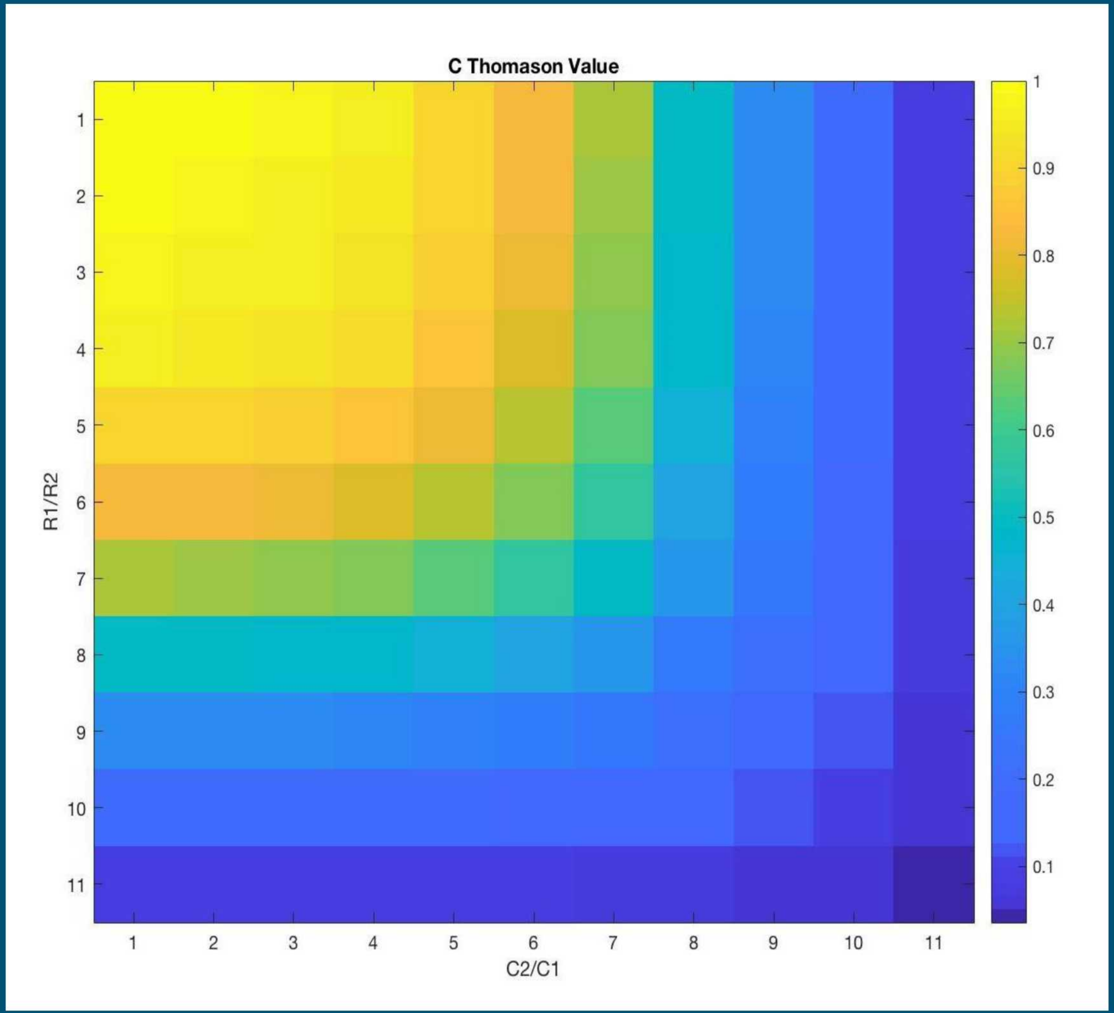


Final Thoughts

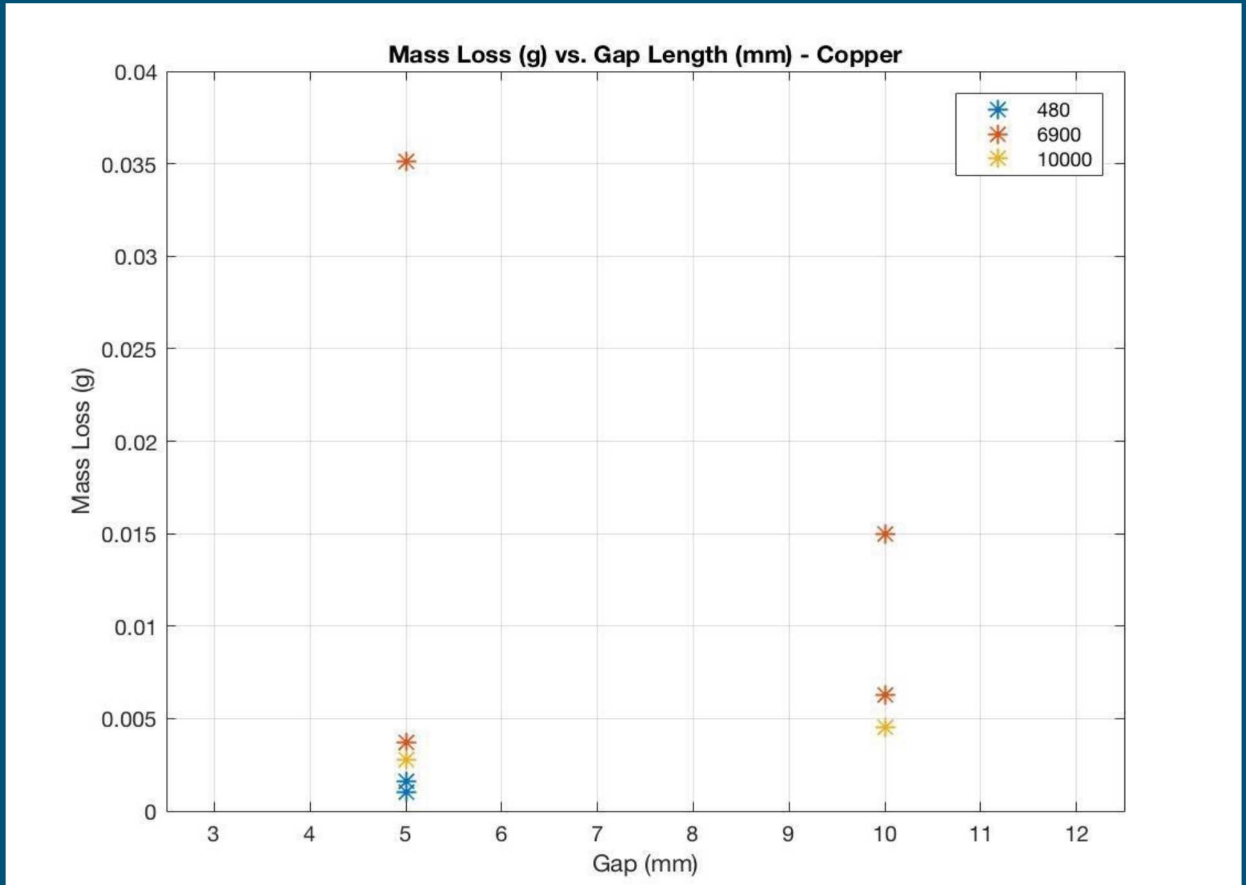
- Many factors contribute to how and when electrical breakdown occurs, which makes it a difficult phenomena to model.
- There are important precautions to take when working with high voltage.
  - Use shorting sticks to fully discharge capacitor
  - Grounding cables to short capacitors
  - Plexiglass enclosures
  - Ensure dump resistors can handle capacitor power
- Being able to build an impulse generator that produces pulses with specific rise times, fall times, etc. is an important skill to have. Different projects require different testing capabilities.

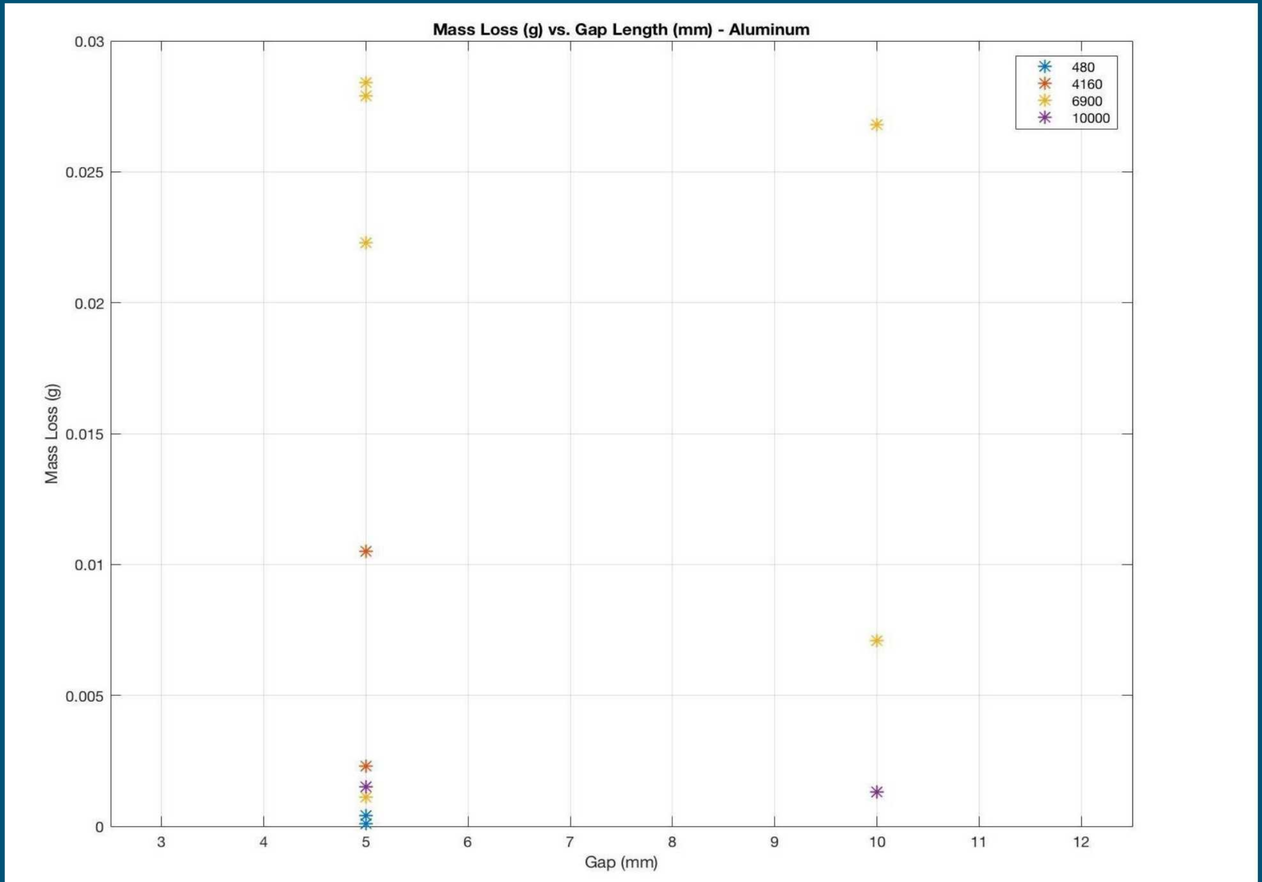


C and R value design chart to achieve desired rise time



$$R = \frac{\rho L}{A}$$


Mass Loss (g) vs. Gap Length (mm) - Copper
Mass Loss (g)
Gap (mm)
480
6900
10000
0.04
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
3
4
5
6
7
8
9
10
11
12


Mass Loss (g) vs. Gap Length (mm) - Aluminum
Mass Loss (g)
Gap (mm)
480
4160
6900
10000
0.03
0.025
0.02
0.015
0.01
0.005
0
3
4
5
6
7
8
9
10
11
12