Engineering Memorandum

Date: May 25, 2022

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To: Professor Saucier

Title: Solar Panel Arcing Technical Report

References:

[1]Saucier, William, "High Voltage Considerations in a Plasma Environment," *Space Environments II*, California Polytechnic State University, 2022.

Revision History:

Version	Date	Comments
1	5/24/2022	Document creation
2	5/25/2022	Final document format

1.0 Table of Contents

2.0 Background

- **In low pressure environments, high voltage arcing has occurred on space vehicles. Arcing generally causes large temperature and current fluctuations.**
  - Temperature is a major concern on spacecraft since the instruments on most vehicles are sensitive to large fluctuations in temperature.
  - In the event of an arc, power systems are prone to power shortages or surges. Either of these could irreparably damage vehicle instruments and systems.
- **Our goal was to study the effects of high voltage arcing in low pressure situations.**
  - We could use anodes and cathodes linked to a power source and isolated in a vacuum chamber to accomplish this.

3.0 Objectives

- Objective 1: Analyze the relationship between pressure and distance for electrical arcing to occur
- Objective 2: Demonstrate and quantify the reduction in performance of solar arrays from exposure to electrical arcing

4.0 Summary

- **We were able to successfully create arcs with the solar panel in several different configurations.**
  - This process gave us a much more comprehensive view on how arcing can affect solar panels.
- **Along with different configurations, we tested several materials as our anodes and cathodes in order to see how this affected the arcing behavior.**
  - The main effect we saw with this change was a drop or increase in arc voltage. With lower voltage thresholds, arcing happens more often and then the negative effects are magnified.
- **We are able to draw the conclusion that arcing from almost any direction will degrade the performance of a solar cell.**
  - Some configurations of the solar cell on the setup caused more damage. All positions caused at least a small drop in performance.

5.0 Nomenclature/Definitions

- I - current
- V - voltage
- Se - Solar Constant

6.0 Methodology

Part A

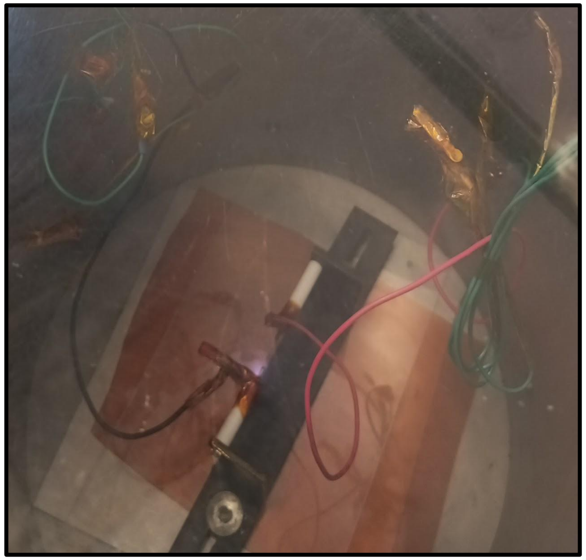
- **Paschen Curve Determination**

Part B

- **Solar Cell I-V Curve Determination (Pre-Arc)**
- **Solar Cell Arcing Procedure**
- **Solar Cell I-V Curve Determination (Post-Arc)**

6.0 Methodology

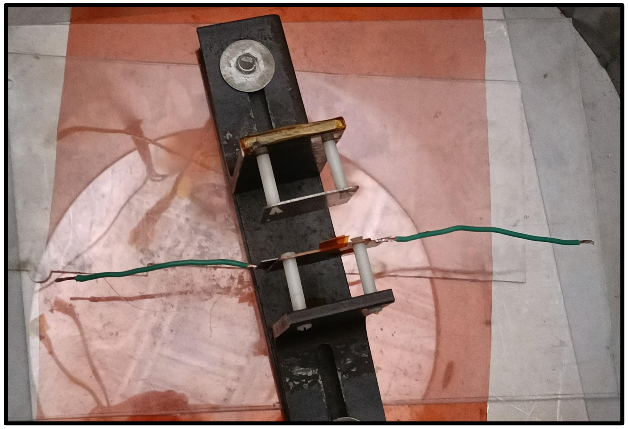
- **Paschen Curve Determination**
  - Construct the cathode-anode assembly with a stainless steel cathode pin
    - Use the respective anode pin material for each curve
  - Measure and set the distance between the cathode and anode pins
  - Place the assembly in the vacuum chamber and connect the leads from the electrical feed-through to the pins
  - Seal the vacuum chamber
  - Run the vacuum chamber to the first desired chamber pressure
  - Turn on the high voltage power supply and increase the voltage until visual confirmation of arcing in the chamber
  - Record the pressure and voltage
  - Reset the power supply, pump down the chamber, and repeat for each chamber pressure and anode pin material



6.0 Methodology

- **Solar Cell I-V Curve Determination**
  - Strip the ends of two wires
  - Solder wires to solar cell such that a voltage can be measured when placed in sunlight
  - Connect the DC Load supply to the ends of wires on the solar cell
  - Measure and record the open circuit voltage
  - Turn on the DC Load supply and set the current to 50 mA
  - Increase the current through the solar cell, recording the voltage at each current value
    - Use finer increments near the final voltage drop

6.0 Methodology



- **Solar Cell Arcing Procedure**
  - Construct the cathode-anode plate assembly
  - Attach the solar cell facing one side of the cathode-anode plate assembly using Kapton tape
  - Place the assembly in the vacuum chamber and connect the leads from the electrical feed-through to the plates
  - Seal the vacuum chamber
  - Run the vacuum chamber to the desired pressure
  - Turn on the high voltage power supply and increase the voltage until visual confirmation of arcing in the chamber
  - Record the pressure and voltage
  - After 3 minutes of arcing, reset the power supply, pump down the chamber, and repeat for each solar panel orientation

6.0 Methodology

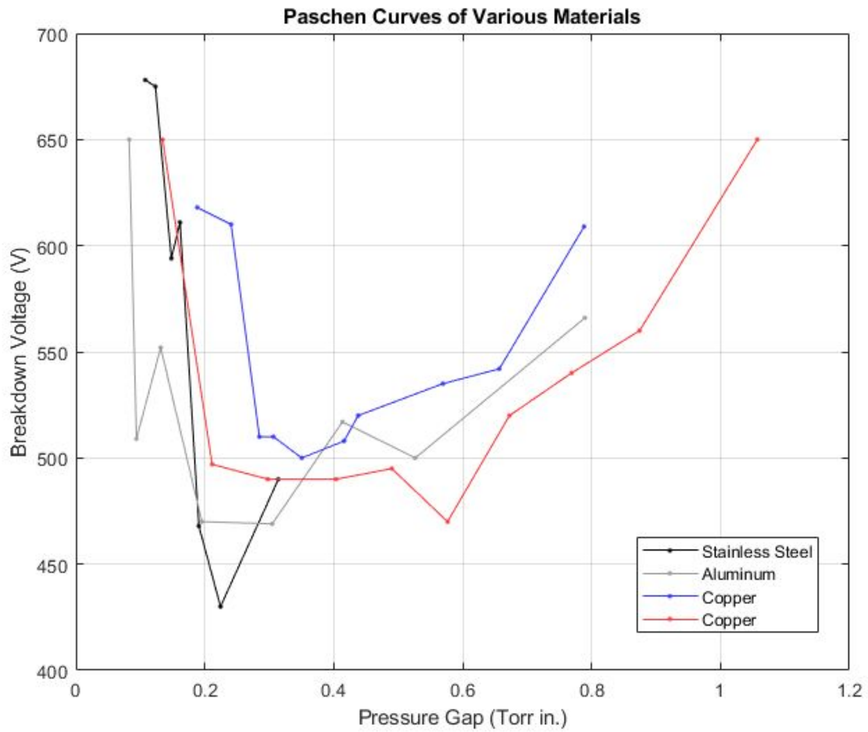
- **Arcing Platform Dimensions:**
  - Distance between anode and cathode: 0.84 in.
  - Anode Length: 0.61 in.
  - Cathode Length: 0.845
  - Approximate distance from chamber edge: 8 in.
- **Solar Cell Dimensions**
  - Length: 2.63 in.
  - Width: 1.45 in.
  - Thickness: ~0.05 in.

7.0 Assumptions / Limitations

- **Assumptions**
  - The solar cell was not subject to any sources of degradation other than induced electrical arcing between load tests
- **Limitations**
  - Time constraints with testing all anode configurations
  - Time constraints with all groups using a single DC Load supply and vacuum chamber
  - Only a single solar cell type and area was tested

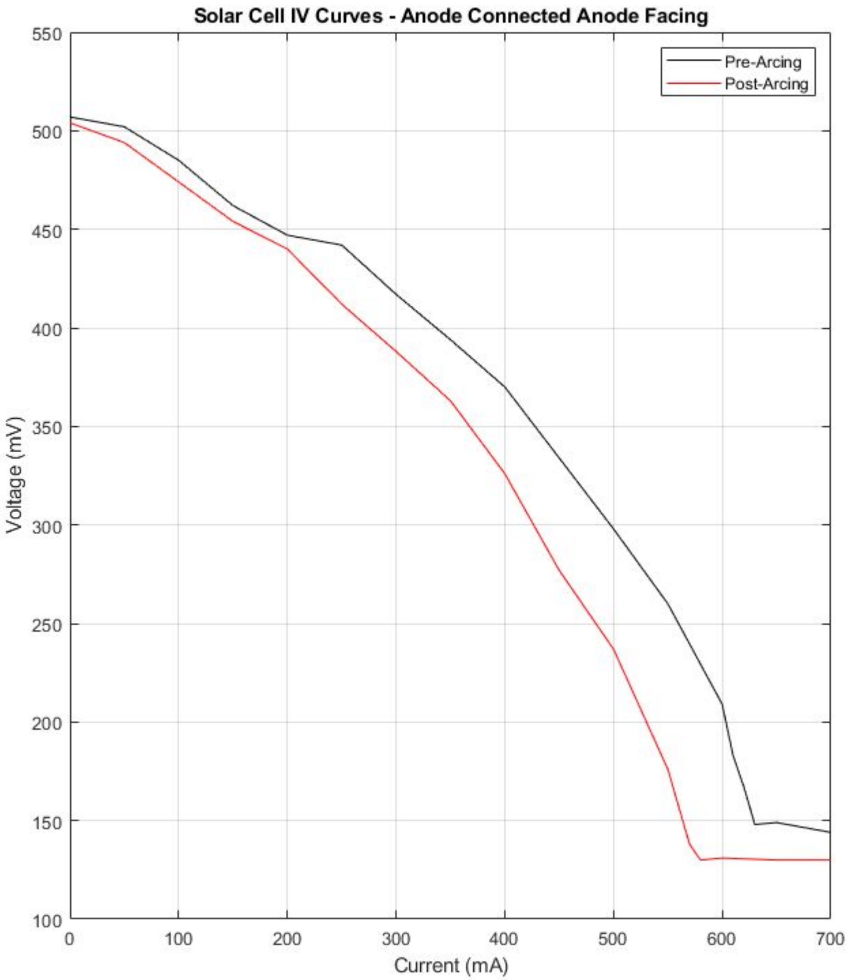
8.0 Results

- **Paschen Curves**
  - Stainless steel had the lowest breakdown voltage, but only at a specific pressure gap
  - Copper had the highest breakdown voltages in one run but performed average during the other run



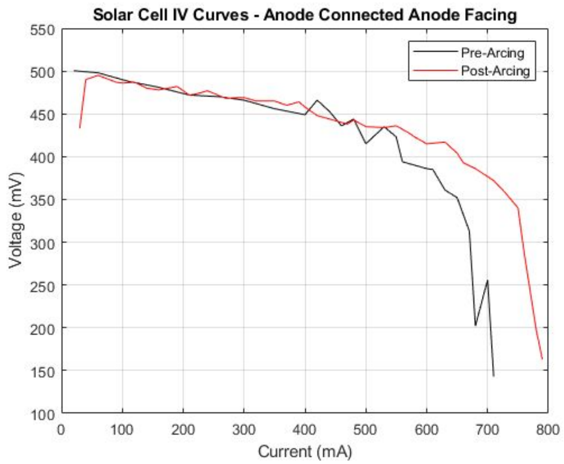
8.0 Results

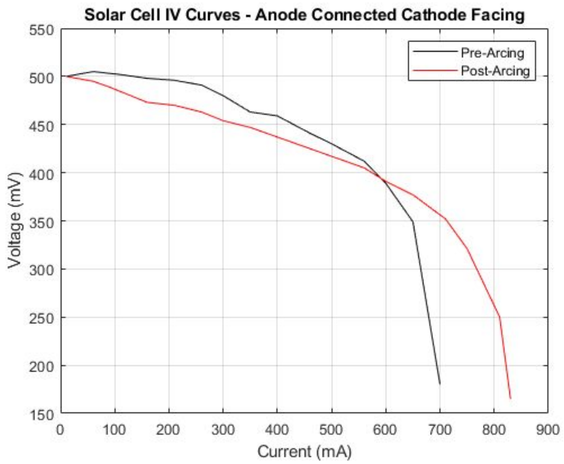
- **Solar Cell I-V Curves**
  - Open circuit voltage is very similar with a 0.6% decrease from initial testing to post-arcing
  - Small decrease in solar cell voltage at lower current
  - Significant decrease in solar cell voltage at higher current
  - 9.7% decrease in short circuit voltage from 144 mV to 130 mV

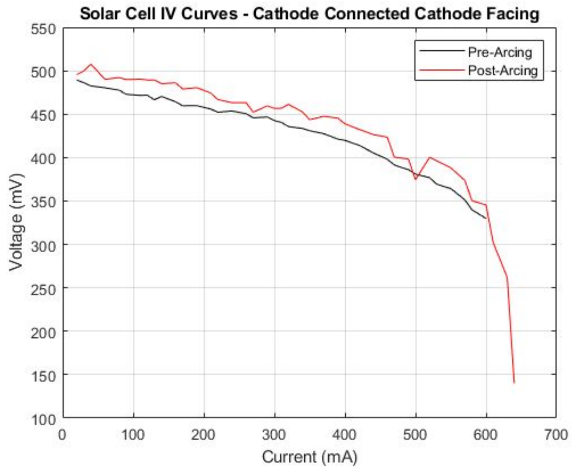


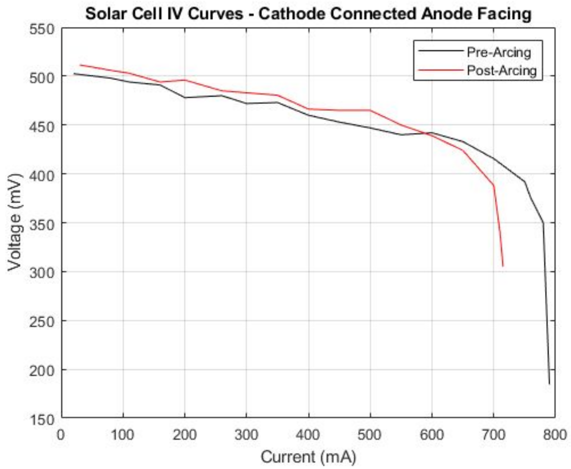
8.0 Results

- **Solar Cell I-V Curves (All Orientations)**









8.5 Improvements to Lab

- **Environmental Effects**
  - There was about an hour between the initial and post-arcing load tests, so the voltage from the cell could have decreased due to the sun being lower on the horizon, especially as the tests were conducted in the late afternoon
- **Improvements**
  - More consistent solar cell performance from the box
  - More durable solar cells that will not be destroyed by incident contact with certain objects

9.0 Conclusion

- **Anode Determination**
  - Copper was found to be the most consistent anode to cause arcing at the highest breakdown voltages, though stainless steel was effective as well at lower pressure gaps.
  - Aluminum was an average anode and stainless steel wasn't consistently as good as copper.
  - As such, if given a choice between the three above materials for an anode, copper will on average be the best choice.
  - Plasma arcing was found to decrease the overall effectiveness of the solar cell, so choosing the material that has the highest breakdown voltage on average is key for improving the longevity and effectiveness of electronic components.

9.0 Conclusion

- **Solar Cell Orientation**
  - We found that the solar cell orientation that produced the least degradation in efficiency was when the cell was connected to the cathode and facing the anode. The most degradation was when the cell was connected to the cathode and faced the cathode. The other two orientations were comparable in their degradation.
  - As such, orienting the solar cell such that it is connected to the cathode and facing the anode is the optimal orientation when considering the effects of plasma arcing on the solar cell.

10.0 Appendices

- **Lab 3: High Voltage Considerations in a Plasma Environment**
  - Saucier, William C. "High Voltage Considerations in a Plasma Environment," *Space Environments II*, California Polytechnic State University, 2022.