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20-2152-RR52166

Kansas Aviation Research and Technology (KART)

Zone 3: Fastener “Direct” Attachment Data Base Test Report

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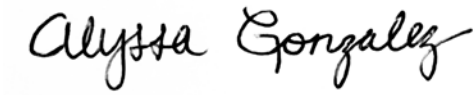
Report No: 20-2152-RR52166

Revision -	
Written by: 	Date: 01/13/2021
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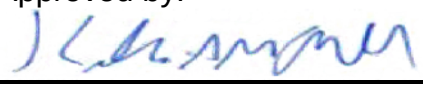
Approved by: 	Date: 02/22/2021

Section	Description
All	Initial Release of Document

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List of Abbreviations, Acronyms, and Symbols

A, Amp	Amperes
ARP	Aerospace Recommended Practice
C	Coulomb
°F	Degrees Fahrenheit
DC, dc	Direct Current
DEL	Direct Effects of Lightning
ETL	Environmental Test Laboratory
EUT	Equipment Under Test
Hz	Hertz (measure of Frequency)
KART	Kansas Aviation Research and Technology
kA	Kilo amperes
kA^2s	Kilo amperes squared seconds (measure of action integral)
kHz	Kilohertz
MHz	Megahertz
µJ	micro joules
µΩ	Micro ohms
µs	Microseconds
mΩ	Milliohms
ms	Milliseconds
NIAR	National Institute for Aviation Research
Ω	Ohms
RH	Relative humidity
SAE	Society of Automotive Engineers
TP	Test point

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1.0 References and Applicable Documents

Unless otherwise noted, the revision at the time of the releases of this document shall apply.

1.1 Specifications and Standards

Document Number	Description
SAE Aerospace ARP 5412B Revised 2013	Aircraft Lightning Environment and Related Test Waveforms
SAE Aerospace ARP 5414B Reaffirmed 2012	Aircraft Lightning Zone
SAE Aerospace ARP 5416A Revised 2013	Aircraft Lightning Test Methods
SAE Aerospace ARP 5577 Reaffirmed 2008	Aircraft Lightning Direct Effects Certification
AGATE Rev C	Lightning Direct Effects Handbook

2.0 Scope

This document contains the test results for high current direct effects of lightning testing of the KART Zone 3 Direct Attachment Data Base test articles listed in Table 1. This test was performed in accordance with the test methods defined in SAE ARP 5416A, with the waveform parameters defined in SAE ARP 5412B based on the aircraft lightning zones in ARP 5414B.

Testing took place at the NIAR Environmental Test Lab located at 3800 S. Oliver Wichita, Kansas 67210 and took place from January 5, 2021 to January 7, 2021.

The test data is provided in Appendix A. Photographs of the test setups can be found in Appendix B. Test logs are provided in Appendix C. Appendix D contains the test article engineering drawings.

3.0 General Requirements

This report is a summary of the equipment tested, test environment used, test procedures used, and the results of the testing performed at the NIAR Environmental Test Laboratory on the KART test articles.

Test article design

The test article design represented generic aluminum wing skin fuel tank structure. The test articles consist of two flat skin panels fastened to an angle bracket representative of internal structure. Fay sealant at mating surfaces and fastener shank sealant (PR-1440 Class B) was applied, as is common in fuel tank regions. To prevent melt-through of the skin panels, the thinnest recommended aluminum wing-skin was selected, at 0.080" thick.

Alodine (chem film) and fuel tank primer were applied to all surfaces of the test panels. Topcoat was applied to the exterior side only after assembly. Fuel tank primer and topcoat were not applied in a two-inch strip around the perimeter of the exterior skin panels to allow bonding to the generator return. One additional bonding location was defined on the L-bracket representative stringer to simulate current flow through internal structure.

Although protective seal caps or daub sealant are generally used for many standard production fuel tank installations, they were excluded from this testing to determine the performance of the fastener installations themselves without containment of the caps.

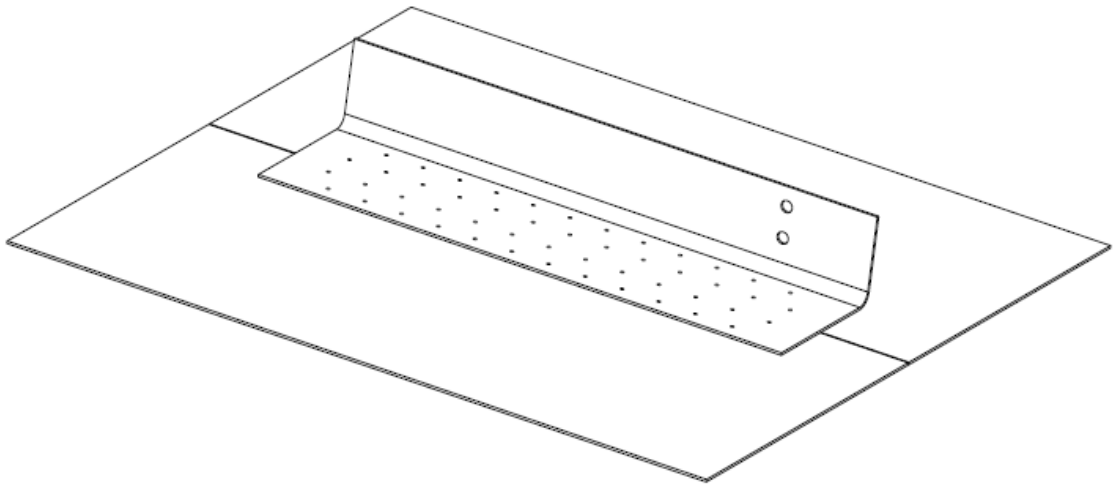


Figure 1: Inside view of test article showing the angle bracket fastened to the skin flat panels

The following is a listing of the test articles that were evaluated:

Table 1- Test Matrix

Part #	Serial #	Description	Fastener Pin	Fastener Collar	Comments
ZN35700-051A	83386 A	Transition fit Hi-Lok	HL11VBJ5-3	HL70-5	Primary test panel, **tested**
ZN35700-051B	83386 B	Transition fit Hi-Lok	HL11VBJ5-3	HL70-5	Duplicate panel, not tested
ZN35700-053A	83387 A	Transition fit Hi-Lok	HL11VBJ8-3	HL70-8	Primary test panel, **tested**
ZN35700-053B	83387 B	Transition fit Hi-Lok	HL11VBJ8-3	HL70-8	Duplicate panel, not tested
ZN35700-055A	83388 A	Transition fit Hi-Lite	HST11BJ5-3	HST79CY5	Primary test panel, **tested**
ZN35700-055B	83388 B	Transition fit Hi-Lite	HST11BJ5-3	HST79CY5	Duplicate panel, **tested**
ZN35700-057A	83389 A	Transition fit Hi-Lite	HST11BJ8-3	HST79CY8	Primary test panel, **tested**
ZN35700-057B	83389 B	Transition fit Hi-Lite	HST11BJ8-3	HST79CY8	Duplicate panel, not tested
ZN35700-059A	83390 A	Rivet	NAS1097AD5	N/A	Primary test panel, **tested**
ZN35700-059B	83390 B	Rivet	NAS1097AD5	N/A	Duplicate panel, not tested
ZN35700-061A	83391 A	Rivet	NAS1097AD8	N/A	Primary test panel, **tested**
ZN35700-061B	83391 B	Rivet	NAS1097AD8	N/A	Duplicate panel, not tested

3.1 General Test Setup

General test setup guidelines are available in SAE ARP5416A. A general test setup diagram for this testing is shown in Figure 2. A list of laboratory equipment used to complete this test is listed in Table 2.

Test waveform data can be found in Appendix A of this report. Test setup pictures can be found in Appendix B of this report.

Table 2 - Equipment Used For Lightning Direct Effects

Description	Manufacturer	Model Number	Serial Number	Cal Due Date
High Current Generator	NIAR	HC1	001	N/A
Current Monitor Probe	Pearson Electronics Inc.	301X"	147836	8/28/2021
Barometric Pressure and Humidity	Extech	SD700	Q774074	2/28/2021
Oscilloscope	Yokogawa	DL850E	91P313729	9/30/2021
HV Power Supply	Spellman	SL8PN2000X4874	102151349-A00001	N/A
Current Probe 1:1500	Danisense	DS600IDSA	14170020014	12/12/2021
Current Monitor Probe	Pearson Electronics Inc.	1423	147997	8/28/2021
HV Power Supply	Spellman	STR70N6/200/3PHASE	102186808-A00003	N/A
Analog Voltage Input Module	Yokogawa	701250	91P321170	9/30/2021
Analog Voltage Input Module	Yokogawa	701250	91P321166	9/21/2021
Milliohm Meter	Hioki	RM3548	160526789	9/30/2021
4 Channel 100MHz 1GSa/s	Rigol	DS1104	DS1ZA181305414	9/30/2021
Massflow Controler Economical Gas	Omega Engineering Inc	FMA5543	483712-1	8/17/2021
0-50 L/min H2	Omega Engineering Inc	FMA5528-H2	370672-1	7/2/2021
Fuel Flow control	NIAR	FFC001	001	N/A
Digibridge	Gen Rad Inc.	1689	8243454004	2/28/2021
High-Voltage Electrostatic Voltmeter	Trek	341B-L-CE	304	8/4/2021

Flammable Gas Ignition Detection

The flammable gas ignition source detection method was utilized in accordance with SAE ARP 5416A section 7.7.2. 7% hydrogen by volume mixed with 93% air was selected as the gas mixture for the flammable gas detection method.

The test setup consists of a fuel flow setup and a voltage spark source setup. The fuel flow setup includes the hydrogen and air mass flow controllers, and the associating tubing, hoses, and test chamber containing the flammable gas mixture, with the foil blowout panel. The spark source setup consists of the spark source circuit, the high voltage power supply, the electrostatic voltmeter, and the oscilloscope for the electrostatic voltmeter. The spark source capacitance is measured with a capacitance bridge.

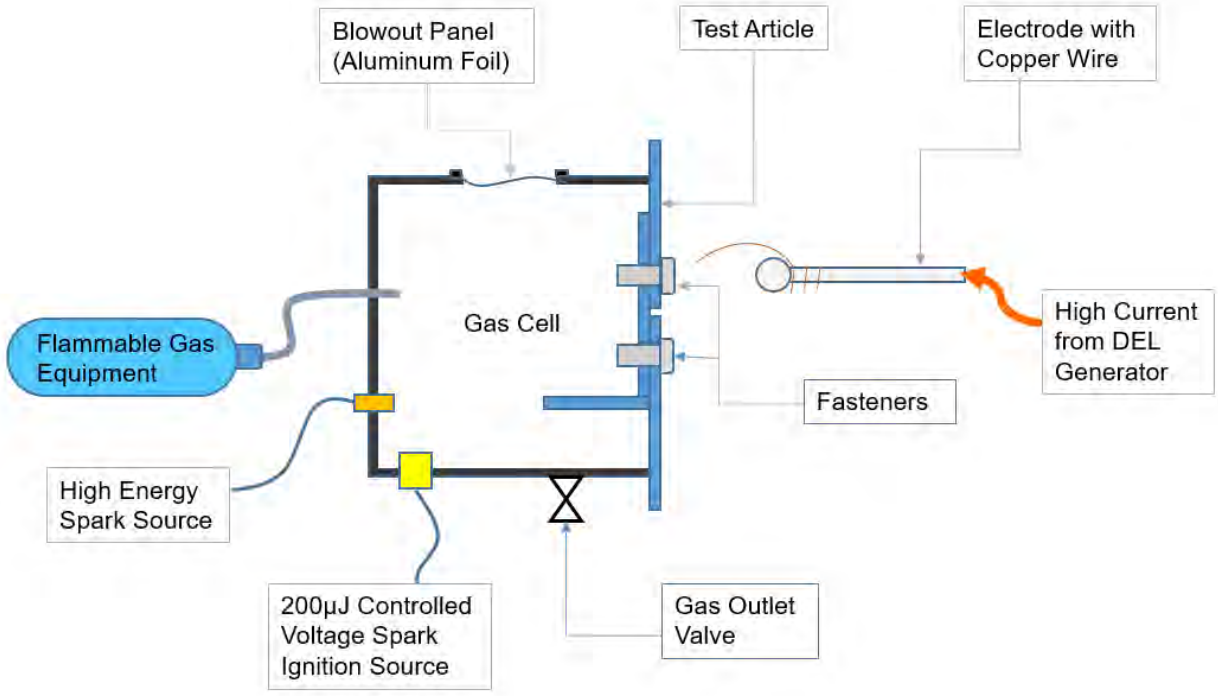


Figure 2: Test Setup Diagram

High Current Generator

The test panels are installed near the output of the high current generator, allowing the arc to be discharged into the panel via the jet-diverting electrode. The panels are electrically bonded to the generator return. General test setup photos are shown in Appendix B: Figure 1 and Figure 2.

A high current probe connected to an oscilloscope recorder for each waveform Component A/5, B, and C*, records the waveform output of the generator. The required parameters for each waveform Component are listed in Table 3, Table 4, and Table 5.

Waveform verification is performed by discharging a high-current shot into an aluminum plate terminated to the generator return.

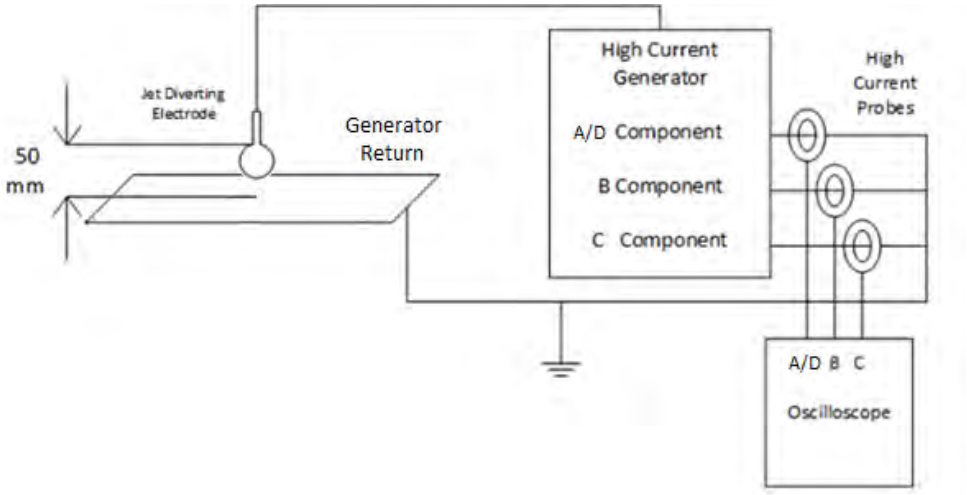


Figure 3: Waveform Verification Setup

The arc is directed to the selected test location using an initiating wire that extends from the jet-diverting electrode to 50 mm from the surface of the test article, as depicted in Figure 4.

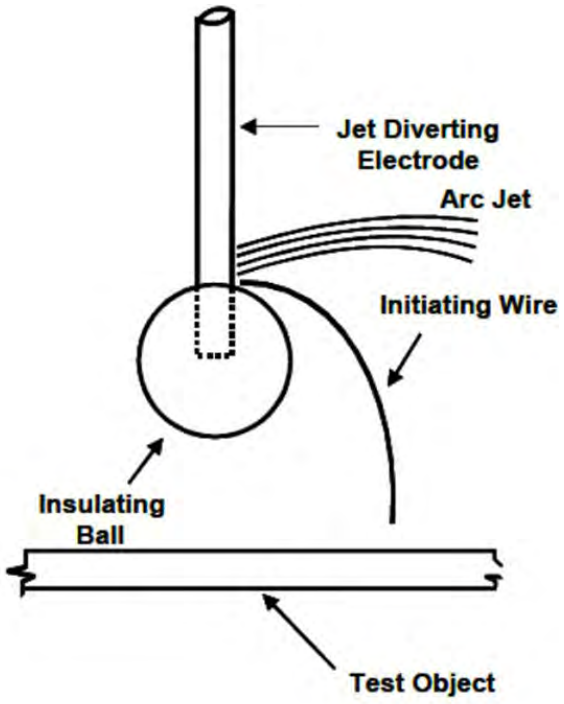


Figure 4: Jet-Diverting Electrode

Table 3: Component A/5 Requirement

Peak Amplitude	40kA ± 10%
Action Integral	80kA^{2}s ± 20%
Rise Time to 90% Peak	< 50µs
Total Duration	< 500µs

Table 4: Component B Requirement

Average Amplitude	2kA ± 20%
Charge Transfer	10C ± 10%
Total Duration	5ms ± 10%

Table 5: Component C* Requirement

Average Amplitude	≥ 400A
Charge Transfer	18C ± 20%
Total Duration	45ms ± 20%

3.2 Test Witnessing

Testing was conducted by NIAR's Brian Mamaril, Alyssa Gonzalez, and Rebeka Khajehpour.

4.0 Testing

Generator waveform verifications were performed into an aluminum panel terminated to the generator return via formed copper straps. After the waveform verification was completed, the first test panel was installed. A minimum of three fastener test points (TP) per panel were selected at the farthest locations from each other as possible to avoid effects of conditioning from one test point to the next. A spare panel for each configuration was made in case of a fastener failure or an invalid test.

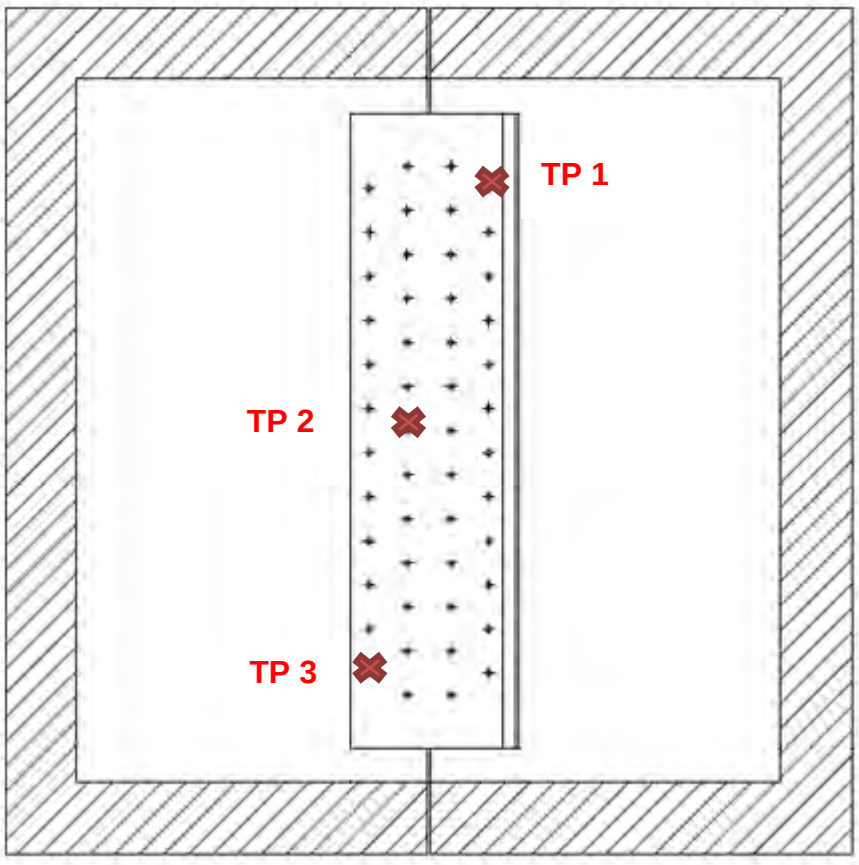


Figure 5: Test Point Location (interior side view)

All test panels were clamped into the test fixture and covered with Gorilla tape to insulate all fasteners and surfaces around the test point to act as a dielectric in the regions where arc attachment was not desired. The selected fastener test point was left without tape, and the initiating wire was directed to the head of the fastener for the

selected test point. A fiberglass frame was added between the panel and the fixture to further insulate from inadvertent arcing between the test panel and the fixture.

Gas flammability verification was performed prior to testing per the procedure in SAE ARP 5416A Section 7.7.2. Nine successful ignitions were completed with an arc energy of 200µJ or less.

Test Procedure

1. Initiate a lightning discharge to an aluminum dummy test article to verify that the output of the lightning generator falls within the required waveform parameters.
2. Seal the flammable gas chamber and perform the flammable gas verification procedure to show that the gas mixture will ignite at least nine out of ten times.
3. Install the test article onto the test fixture with C-clamps,
4. Seal gas test chamber and fill the chamber with the flammable gas mixture, displacing 5 test volumes.
5. Initiate a lightning discharge to the test article.
6. If ignition due to the lightning test did not occur, ignite the flammable gas mixture with the controlled voltage spark ignition source to prove that the atmosphere was ignitable during the lightning test.
7. Repeat steps 3-6 for each test point on each test article.

The first panel tested was ZN35700-055 SN: 83388A. TP 1 and TP 2 were completed, but the Component A action integral fell below the waveform specifications. TP 3 was completed and met all waveform parameters. An additional fourth test was performed on this panel, for the purpose of verifying the waveform output of the generator. After the waveforms were verified, the duplicate panel ZN35700-055 SN: 83388B was successfully tested for TP1 and TP2.

All other test panels were tested without ignition at TP 1, 2, and 3. No other duplicate test panels or additional test points were tested. The waveform data for each test is listed in Appendix A.

The post-test gas flammability verification was successfully completed after each test point. The spark ignition energies for each test point are shown in Table 6.

Table 6: Gas Calibration and Post-test Gas Flammability Verification Data

Trial or Test Point	Spark Energy, µJ	Ignition on 1st spark?
Gas Cal 1	190.2	yes
Gas Cal 2	180.7	yes
Gas Cal 3	185.5	yes
Gas Cal 4	162.4	yes
Gas Cal 5	149.4	yes
Gas Cal 6	166.9	yes
Gas Cal 7	162.4	yes
Gas Cal 8	166.9	yes
Gas Cal 9	166.9	yes
"-055 A" TP1 (waveform not met)	166.1	yes
"-055 A" TP2 (waveform not met)	157.3	yes
"-055 A" TP3	184.6	yes
"-055 A" TP4 (TP for generator waveform check)	175.2	yes
"-055 B" TP1	144.4	yes
"-055 B" TP2	170.6	yes
"-053 A" TP1	189.3	yes
"-053 A" TP2	157.3	yes
"-053 A" TP3	199.0	yes
"-051 A" TP1	194.2	yes
"-051 A" TP2	185.5	yes
"-051 A" TP3	171.5	yes
"-059 A" TP1	162.5	yes
"-059 A" TP2	190.3	yes
"-059 A" TP3	190.3	yes
"-057 A" TP1	190.3	yes
"-057 A" TP2	195.2	yes
"-057 A" TP3	195.2	yes
"-061 A" TP1	190.3	yes
"-061 A" TP2	200.08	yes
"-061 A" TP3	185.5	yes

5.0 Conclusions

No test point from any test article produced an ignition source during this testing. All lightning tests were validated by the post-test ignition of the flammable mixture using the 200 µJ voltage spark source.

Visible damage to the fasteners as a result of lightning testing included melting, welding, and scorching on the front (exterior) side of the test article. No visible damage was evident on the back (interior) side of the test panels. A sample photo of the fastener damage is shown in Figure 5.

Figure 6: Sample Photo of Fastener Head Damage

The test article designs evaluated in this test were determined to be sufficient to withstand direct attachment to fasteners in Zone 3 with waveform Components A/5, B, and C*.

Appendix A - Test Data

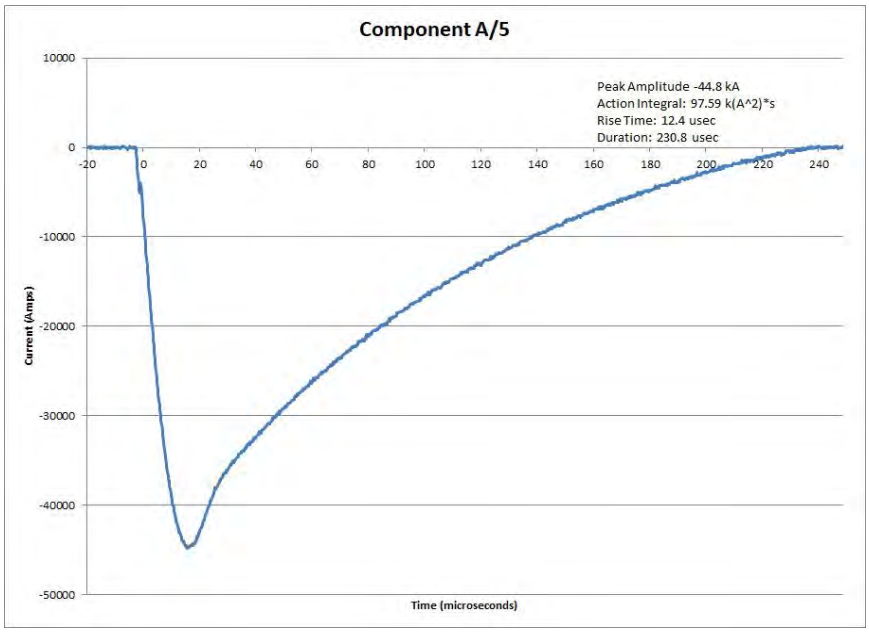


Figure 1: Arc Entry Test - 83386A - Zone 3 - TP1 - Component A5

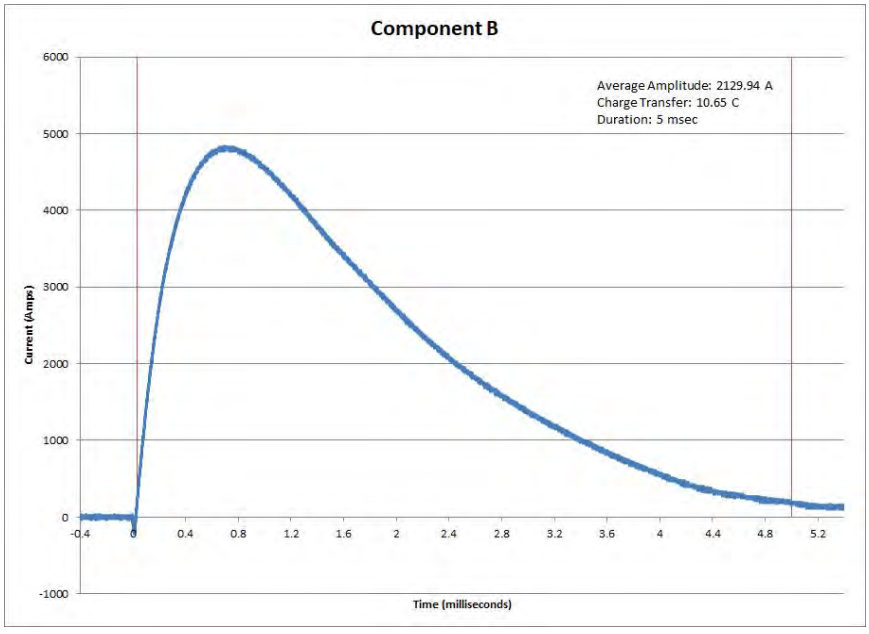


Figure 2: Arc Entry Test - 83386A - Zone 3 - TP1 - Component B

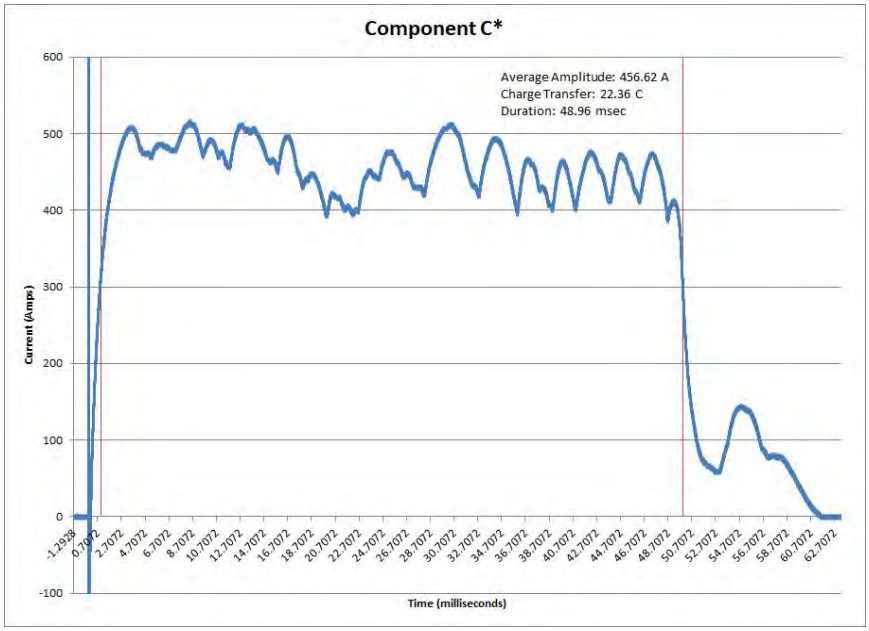


Figure 3: Arc Entry Test - 83386A - Zone 3 - TP1 - Component C*

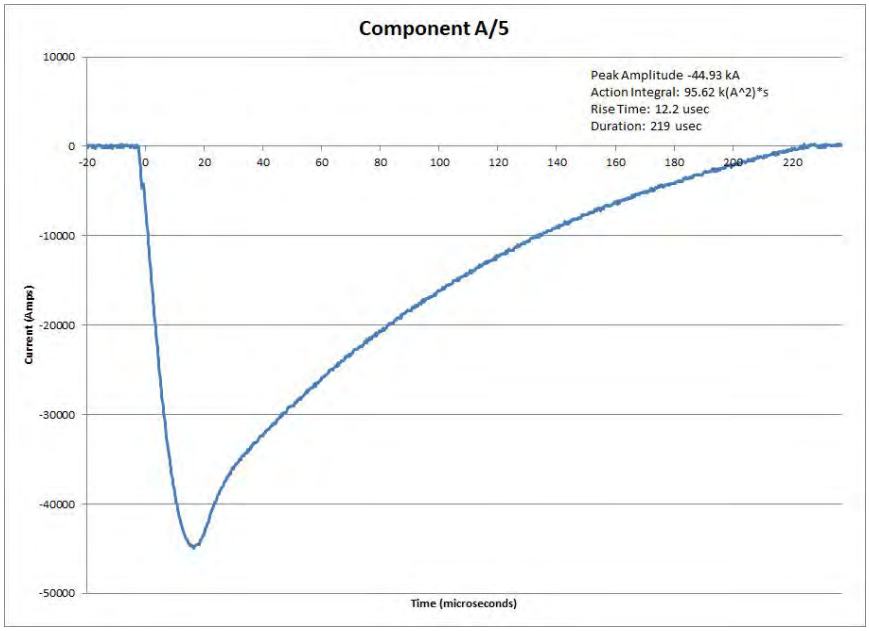


Figure 4: Arc Entry Test - 83386A - Zone 3 - TP2 - Component A5

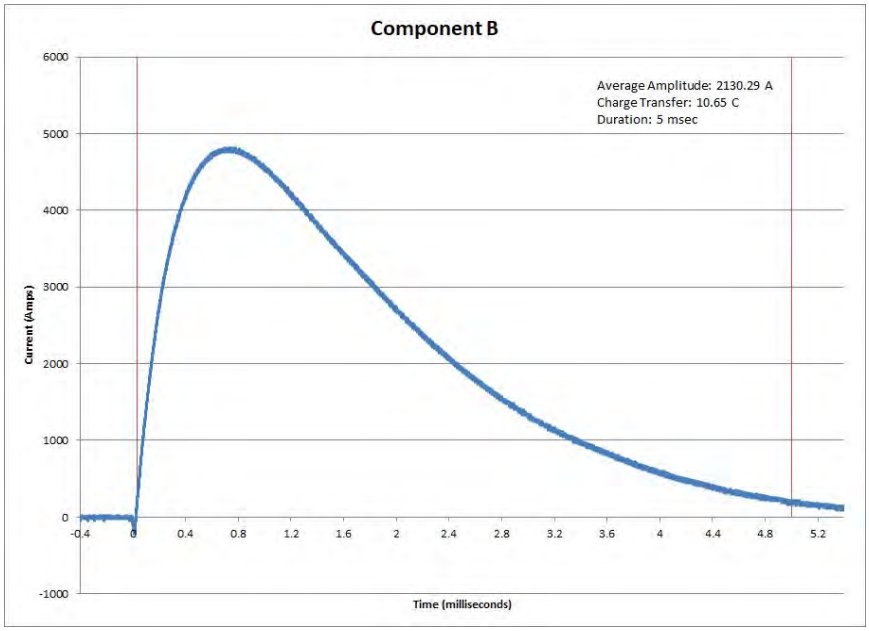


Figure 5: Arc Entry Test - 83386A - Zone 3 - TP2 - Component B

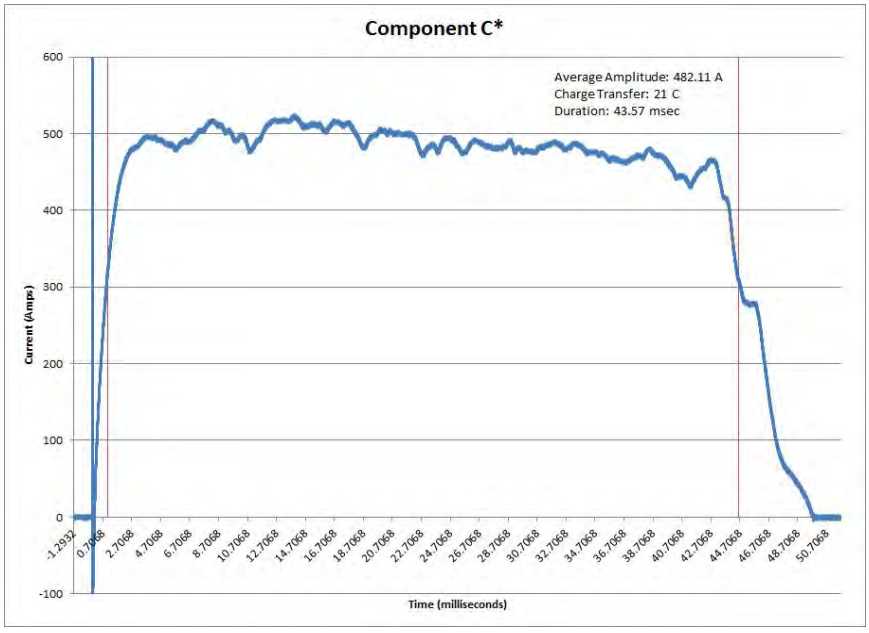


Figure 6: Arc Entry Test - 83386A - Zone 3 - TP2 - Component C*

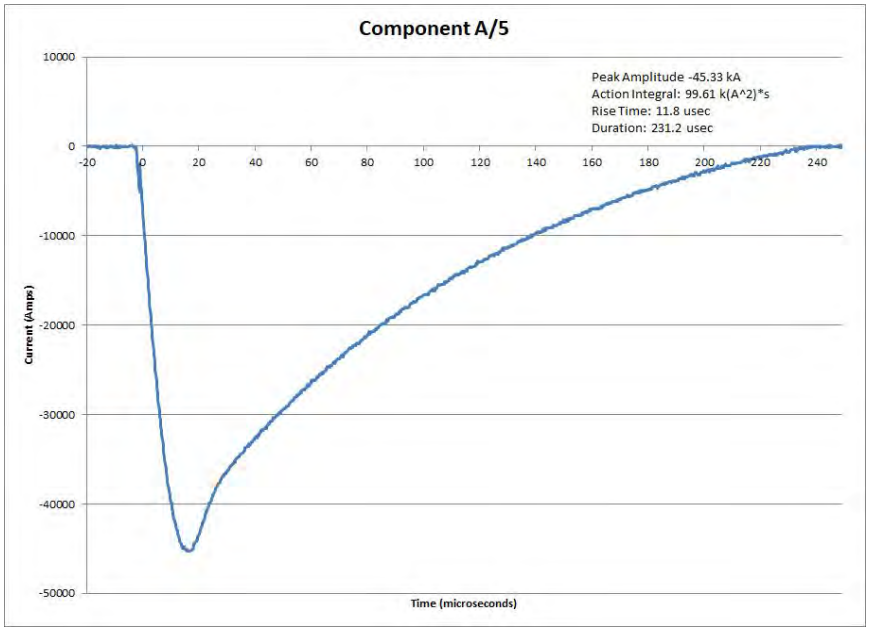


Figure 7: Arc Entry Test - 83386A - Zone 3 - TP3 - Component A5

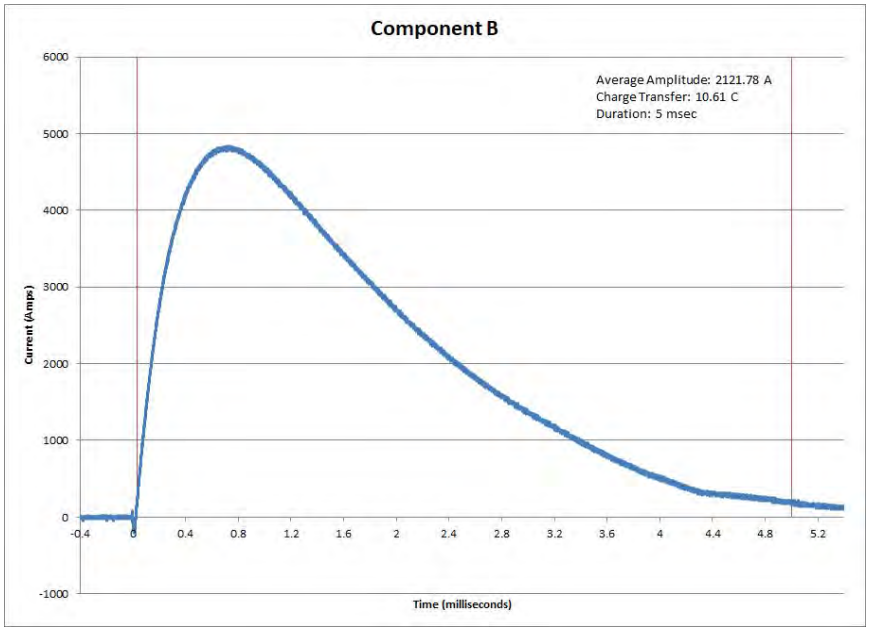


Figure 8: Arc Entry Test - 83386A - Zone 3 - TP3 - Component B

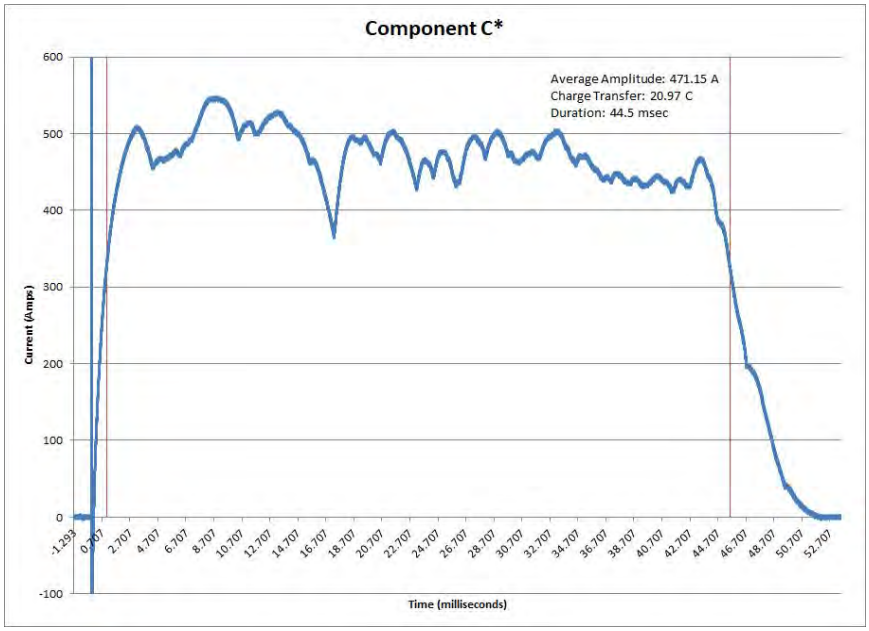


Figure 9: Arc Entry Test - 83386A - Zone 3 - TP3 - Component C*

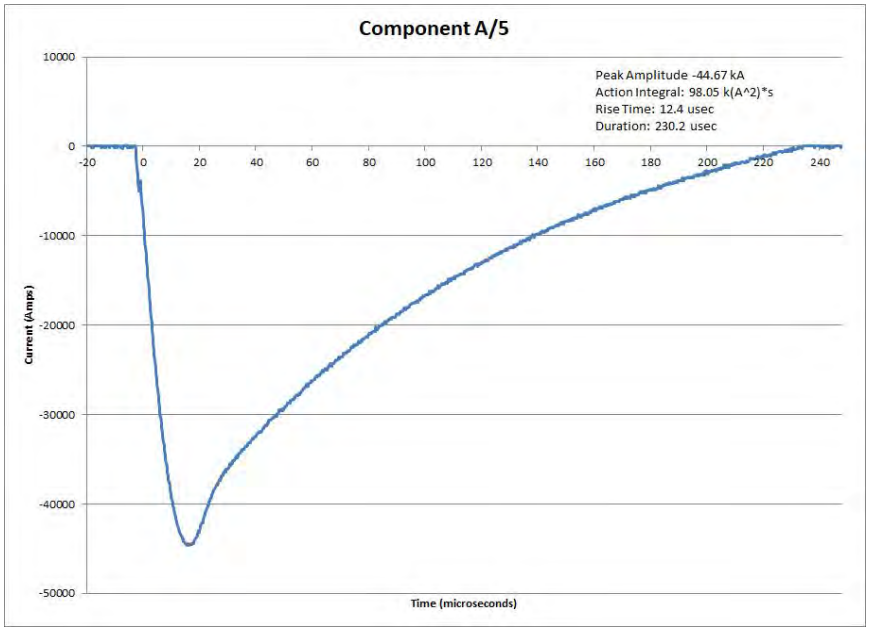


Figure 10: Arc Entry Test - 83387A - Zone 3 - TP1 - Component A5

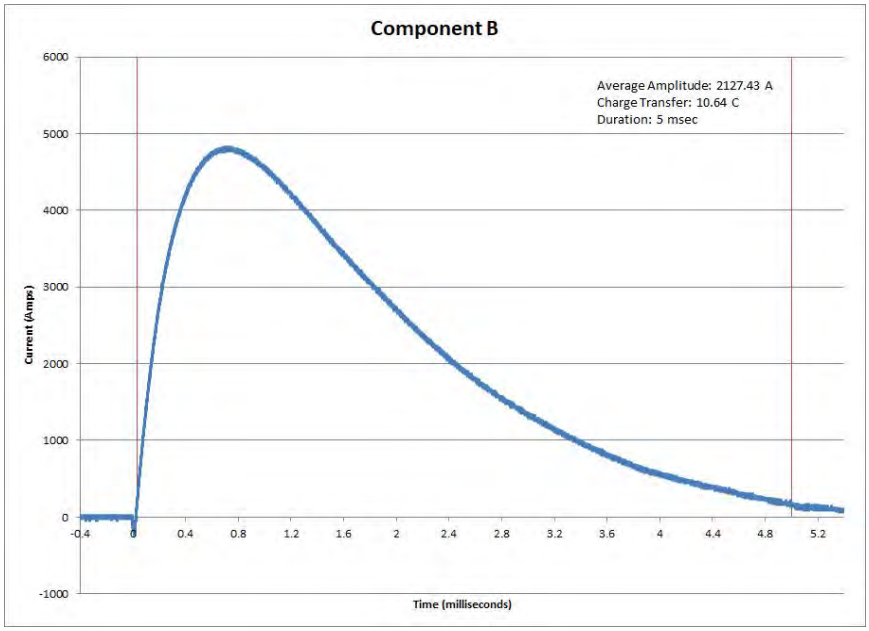


Figure 11: Arc Entry Test - 83387A - Zone 3 - TP1 - Component B

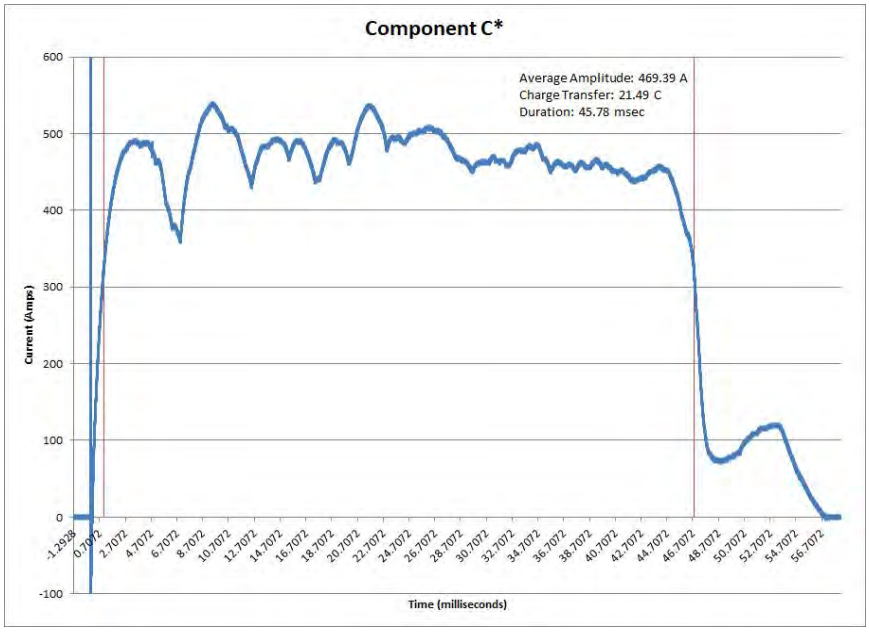


Figure 12: Arc Entry Test - 83387A - Zone 3 - TP1 - Component C*

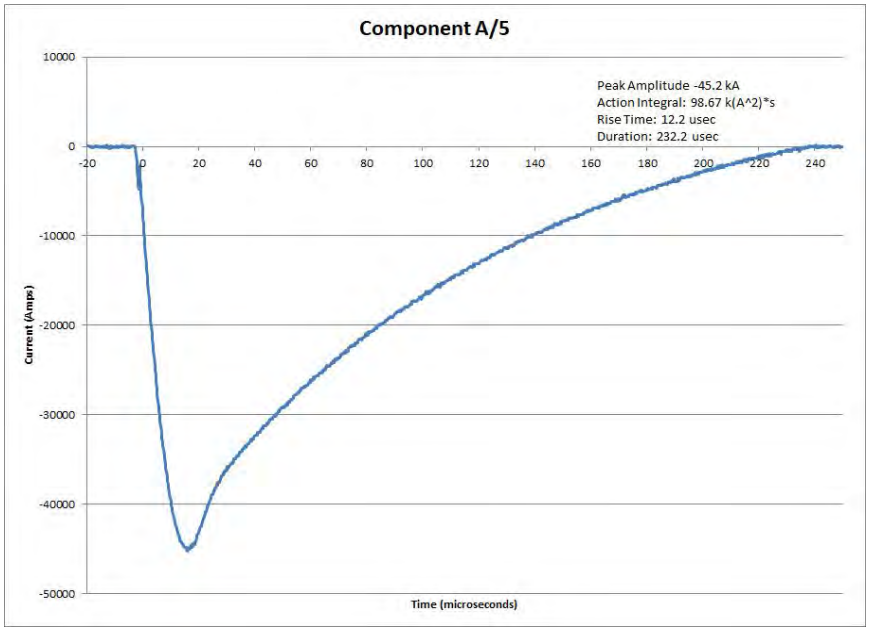


Figure 13: Arc Entry Test - 83387A - Zone 3 - TP2 - Component A5

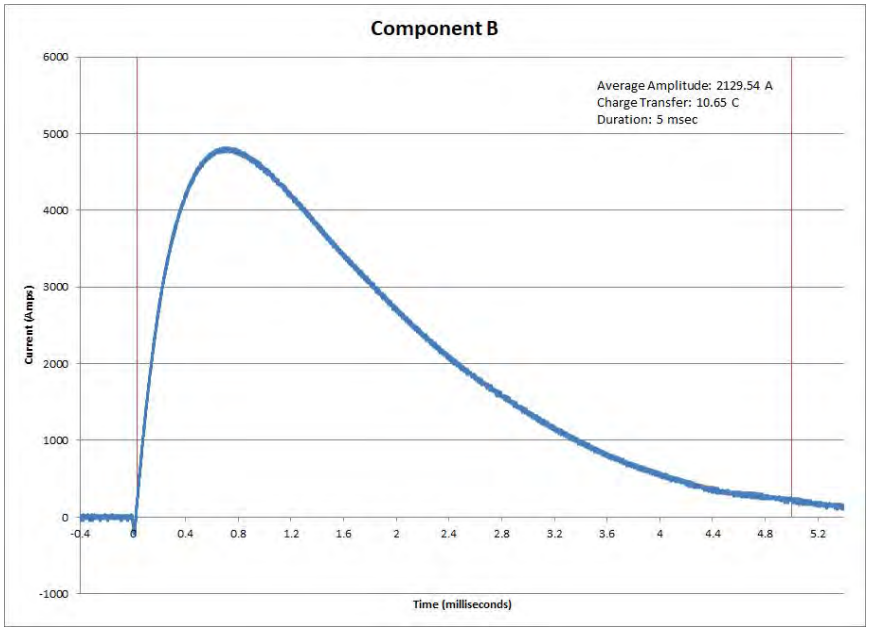


Figure 14: Arc Entry Test - 83387A - Zone 3 - TP2 - Component B

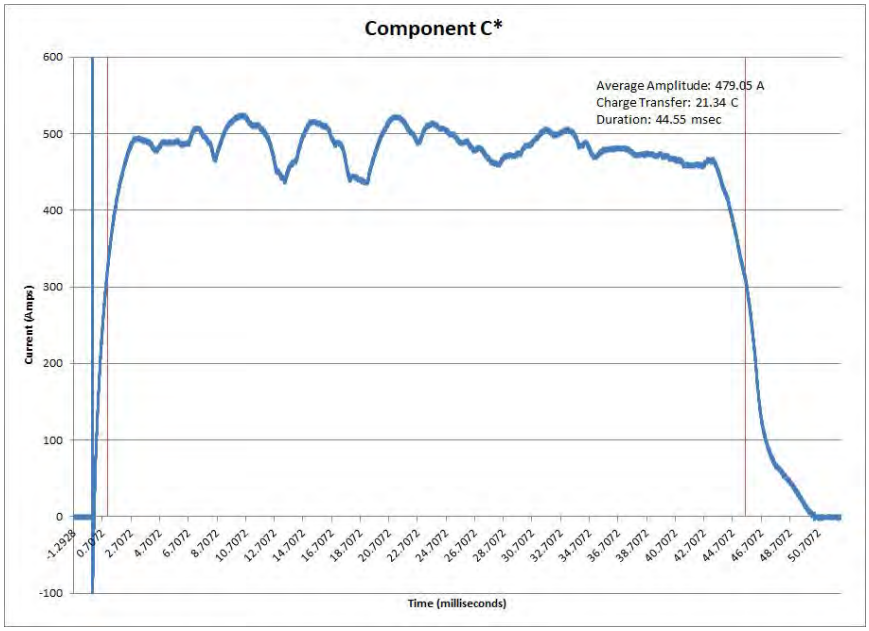


Figure 15: Arc Entry Test - 83387A - Zone 3 - TP2 - Component C*

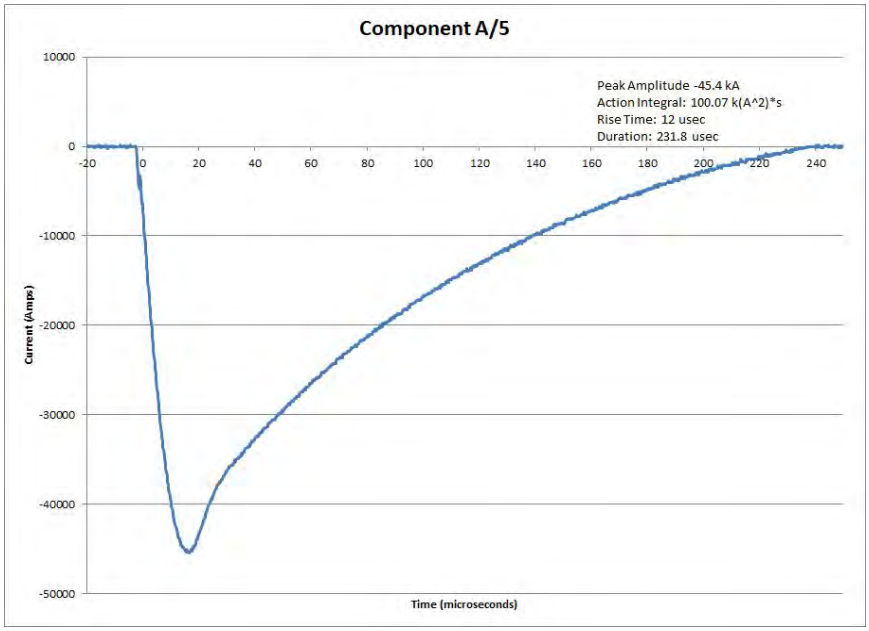


Figure 16: Arc Entry Test - 83387A - Zone 3 - TP3 - Component A5

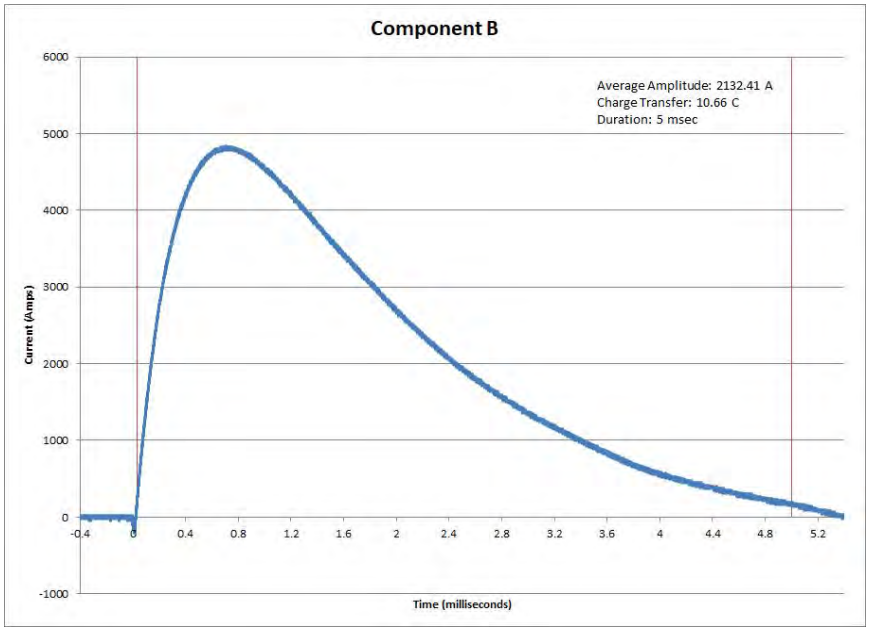


Figure 17: Arc Entry Test - 83387A - Zone 3 - TP3 - Component B

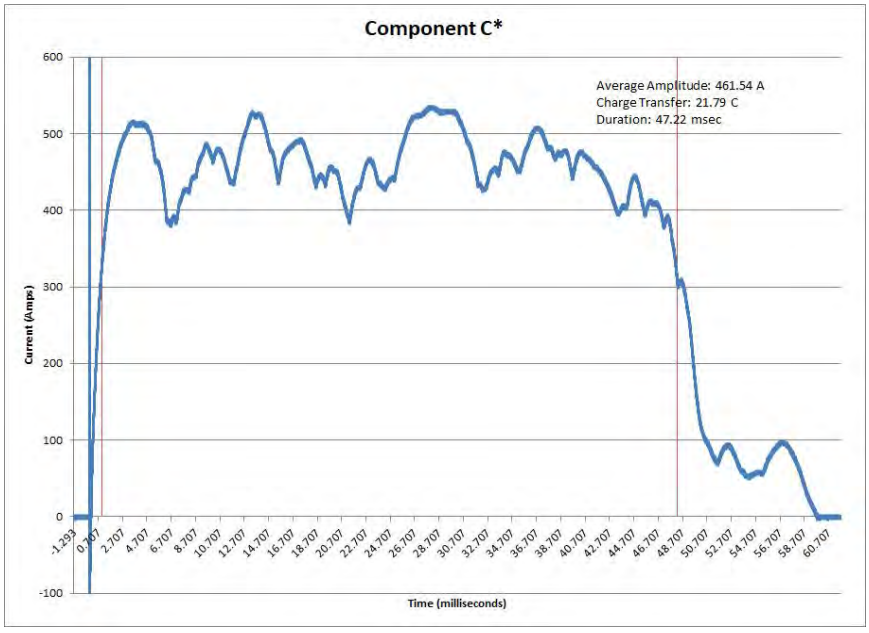


Figure 18: Arc Entry Test - 83387A - Zone 3 - TP3 - Component C*

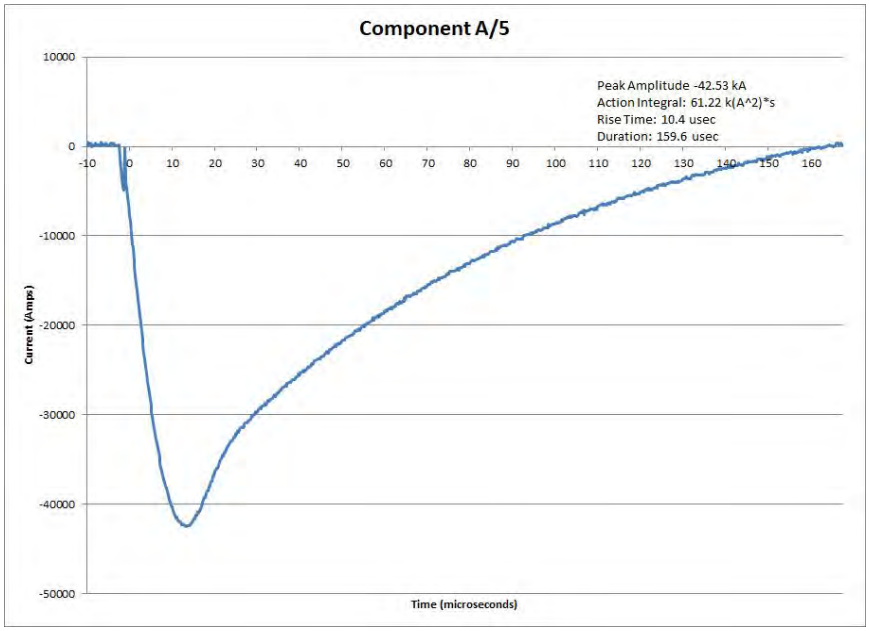


Figure 19: Arc Entry Test - 83388A - Zone 3 - TP1 - Component A5

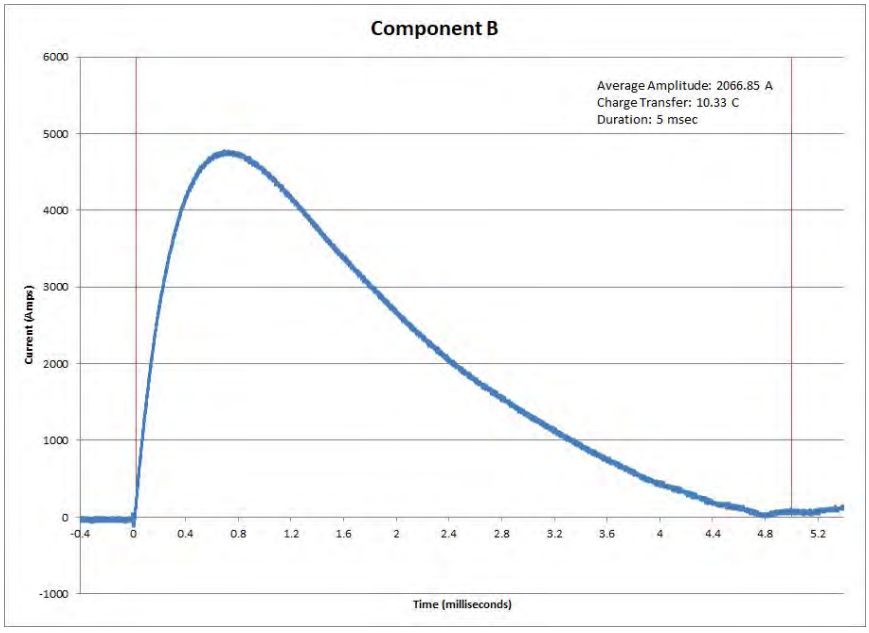


Figure 20: Arc Entry Test - 83388A - Zone 3 - TP1 - Component B

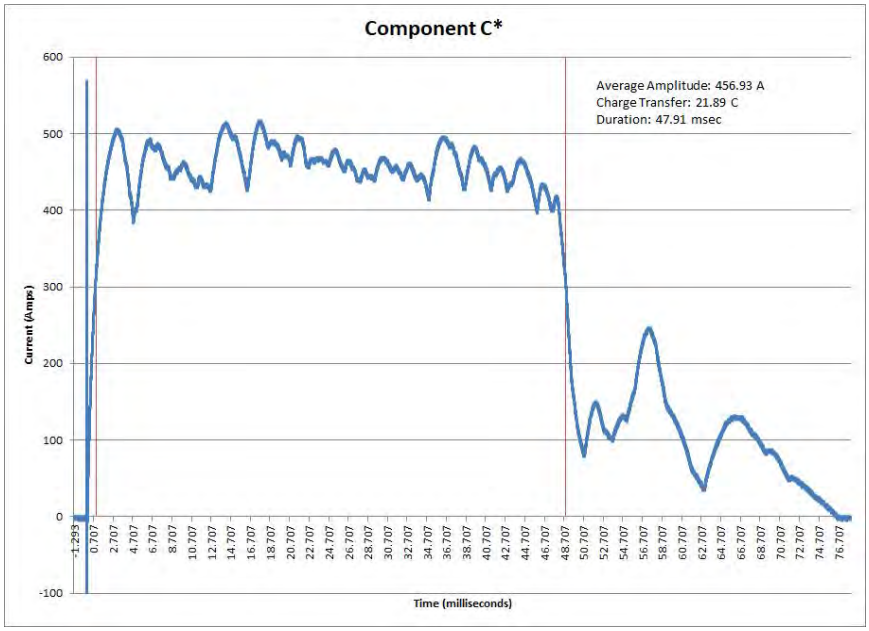


Figure 21: Arc Entry Test - 83388A - Zone 3 - TP1 - Component C*

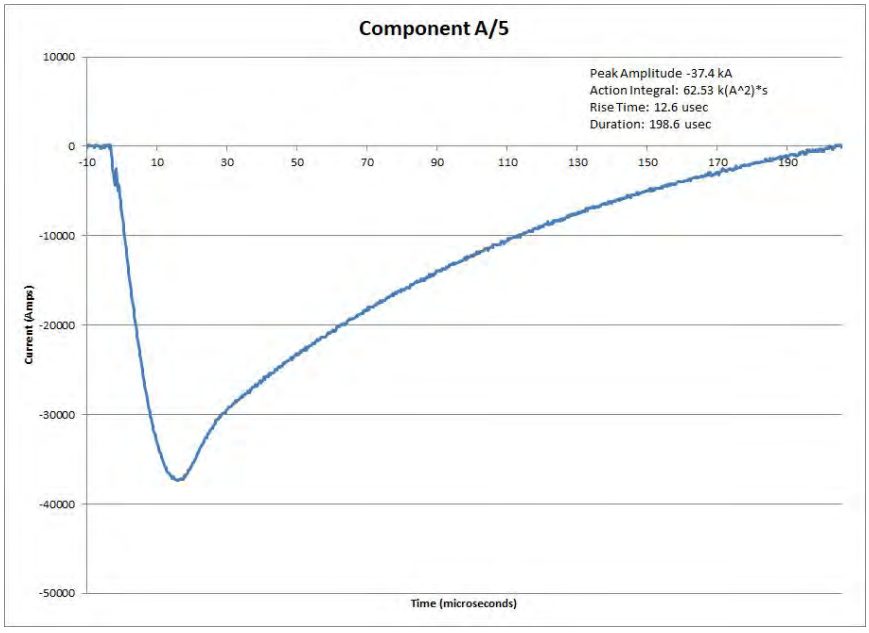


Figure 22: Arc Entry Test - 83388A - Zone 3 - TP2 - Component A5

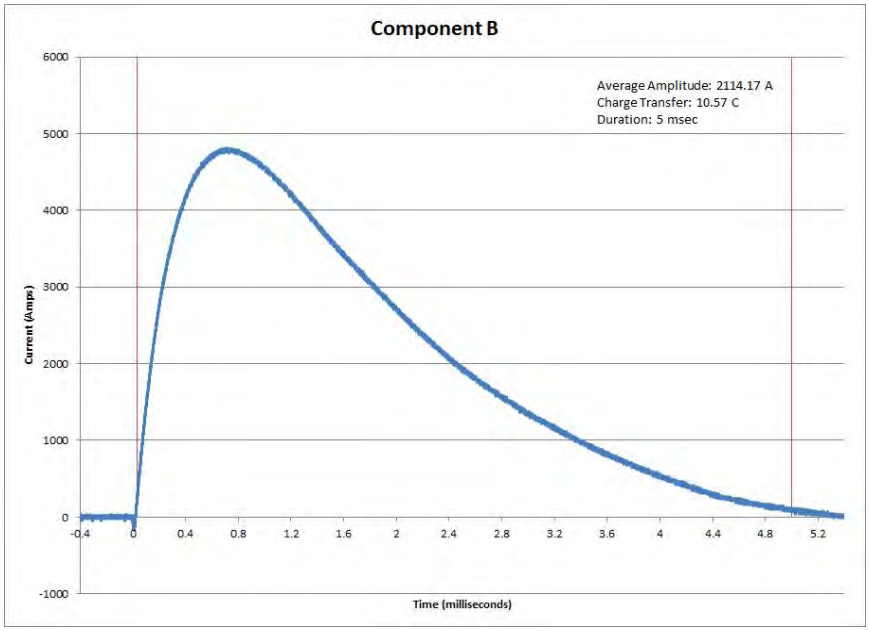


Figure 23: Arc Entry Test - 83388A - Zone 3 - TP2 - Component B

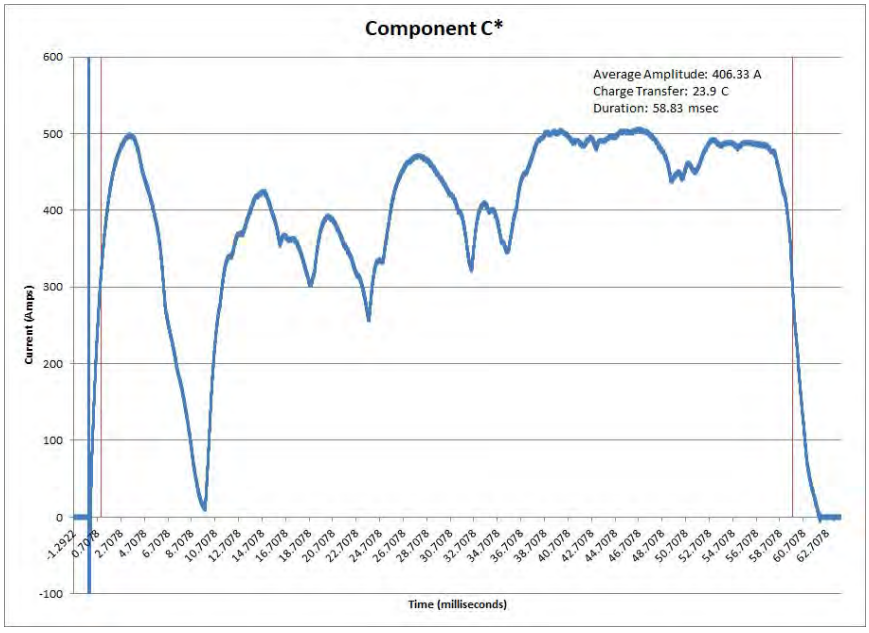


Figure 24: Arc Entry Test - 83388A - Zone 3 - TP2 - Component C*

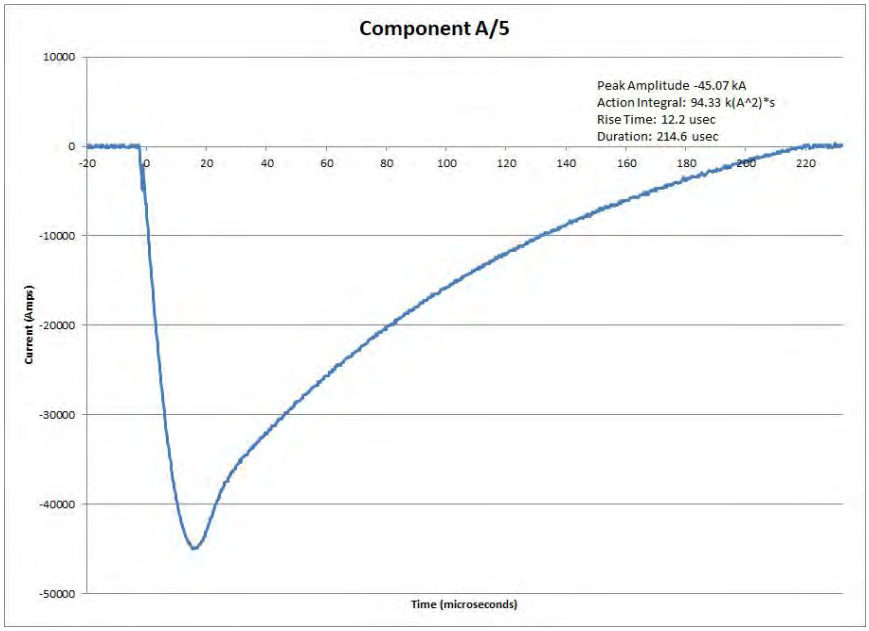


Figure 25: Arc Entry Test - 83388A - Zone 3 - TP3 - Component A5

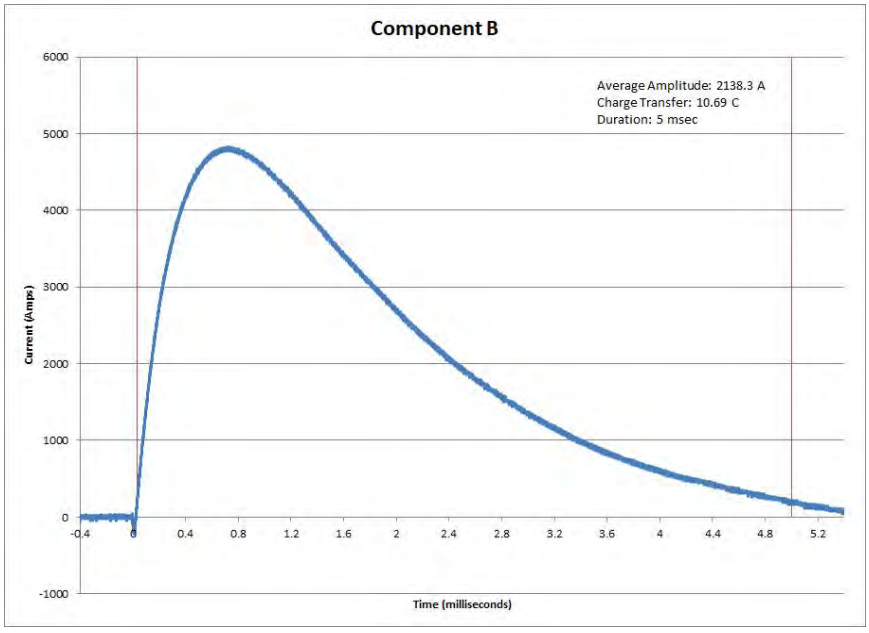


Figure 26: Arc Entry Test - 83388A - Zone 3 - TP3 - Component B

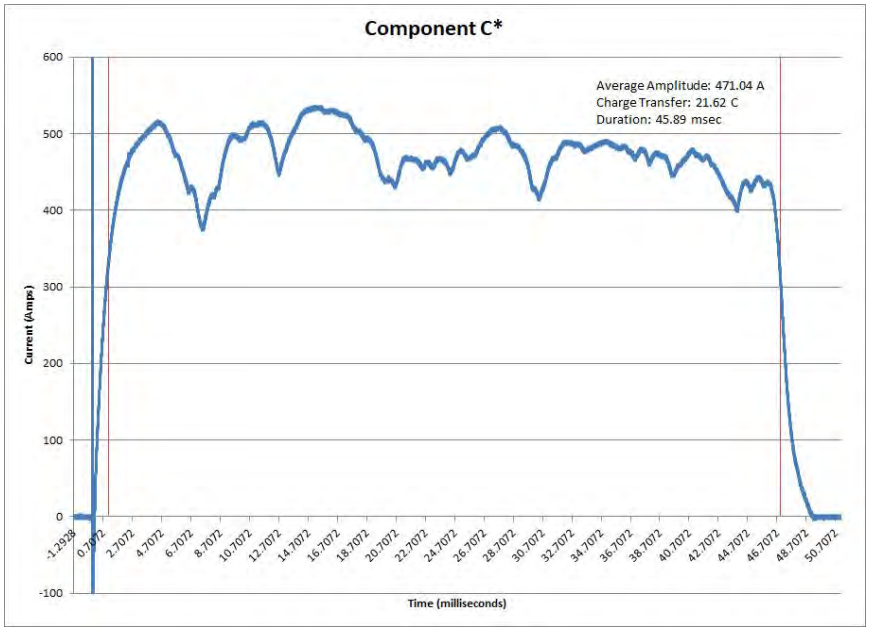


Figure 27: Arc Entry Test - 83388A - Zone 3 - TP3 - Component C*

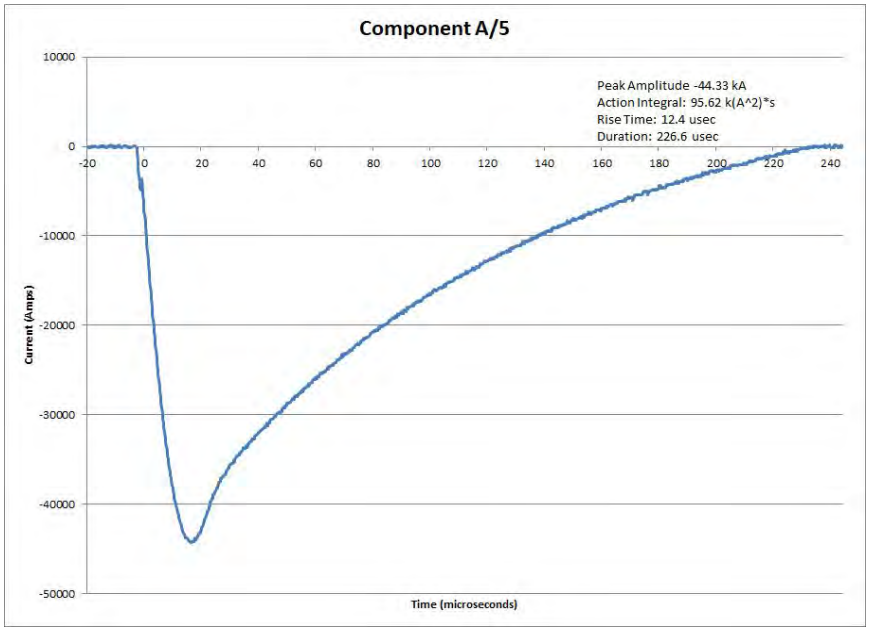


Figure 28: Arc Entry Test - 83388A - Zone 3 - TP4 - Component A5

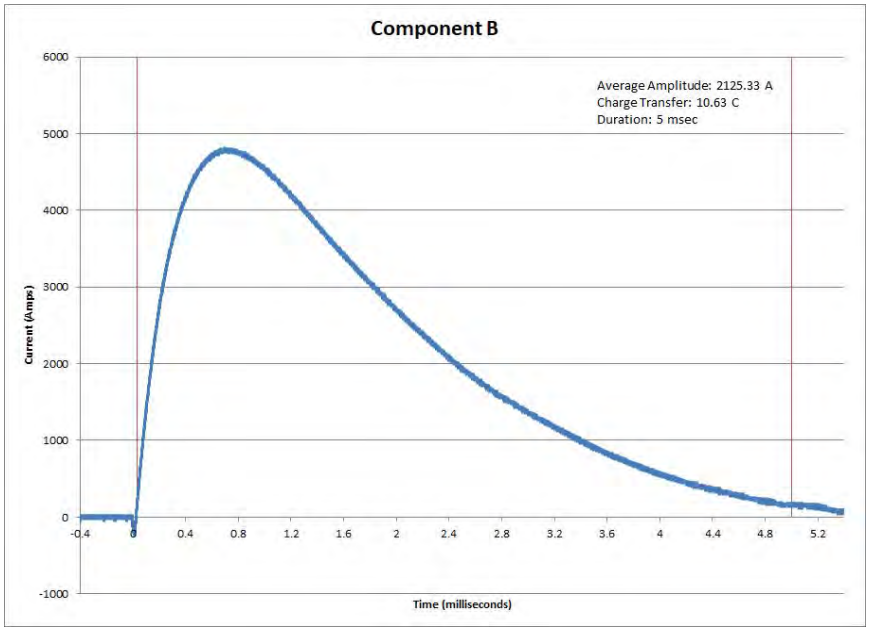


Figure 29: Arc Entry Test - 83388A - Zone 3 - TP4 - Component B

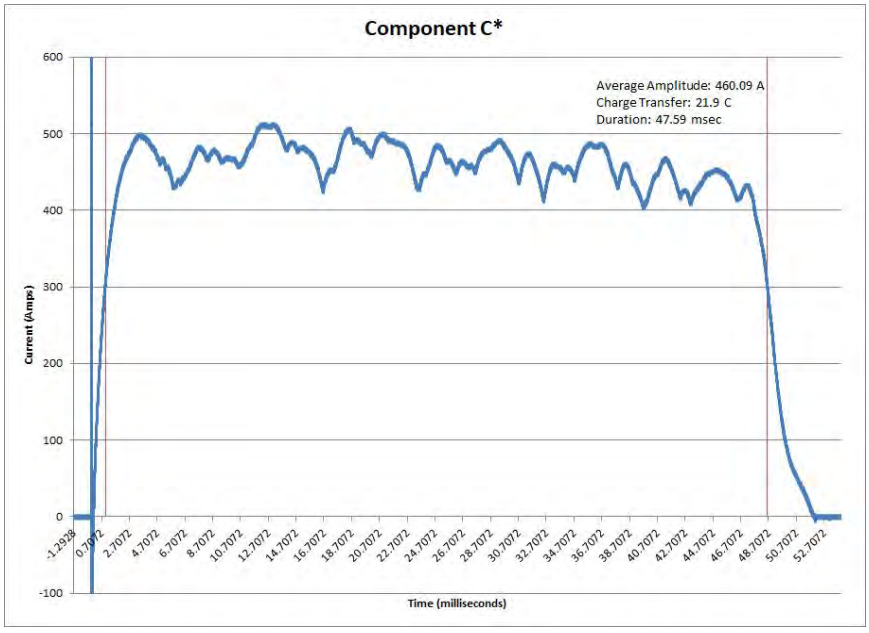


Figure 30: Arc Entry Test - 83388A - Zone 3 - TP4 - Component C*

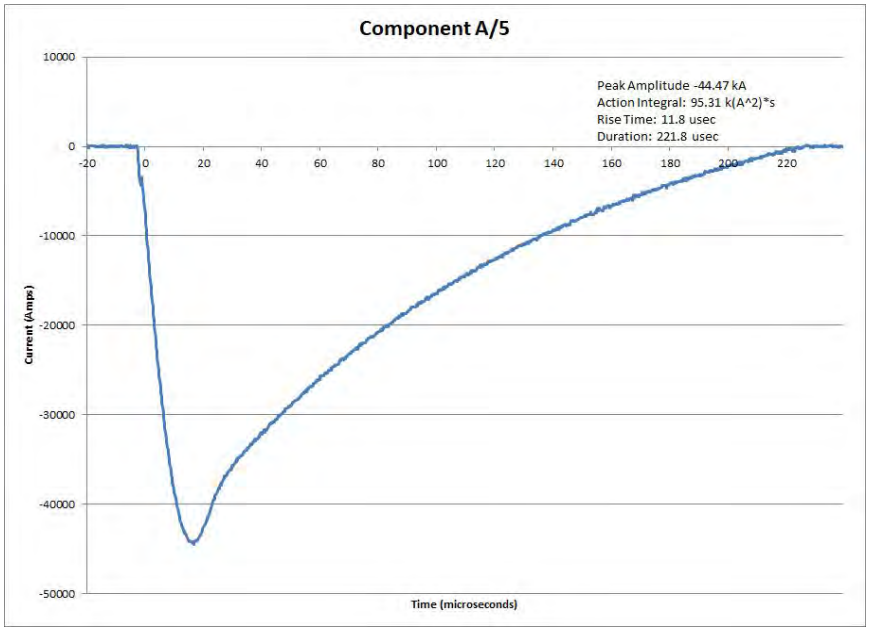


Figure 31: Arc Entry Test - 83388B - Zone 3 - TP1 - Component A5

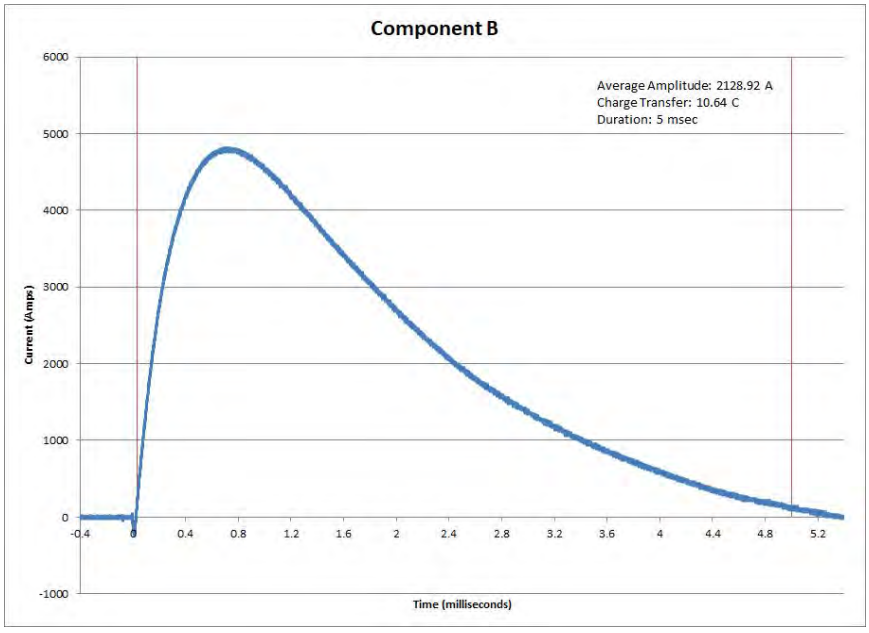


Figure 32: Arc Entry Test - 83388B - Zone 3 - TP1 - Component B

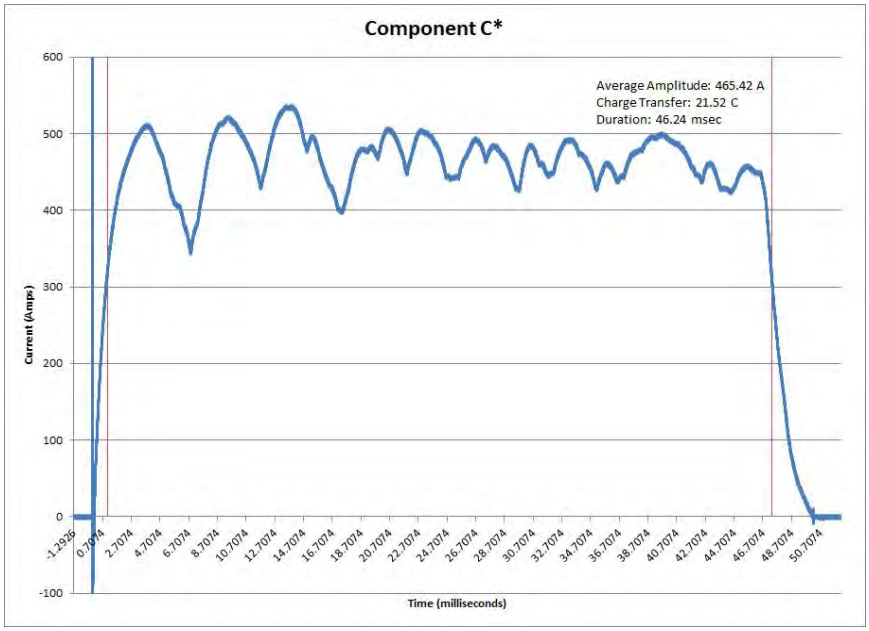


Figure 33: Arc Entry Test - 83388B - Zone 3 - TP1 - Component C*

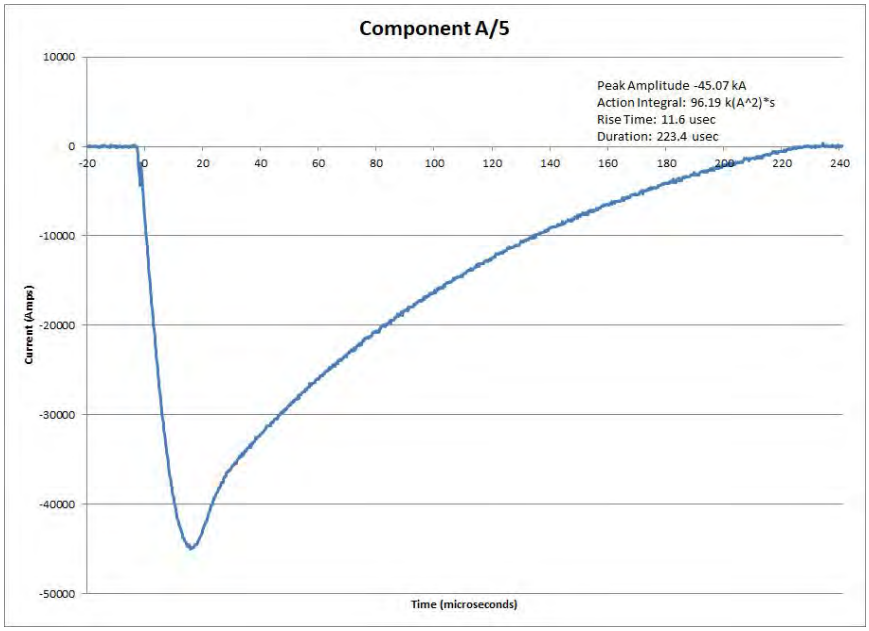


Figure 34: Arc Entry Test - 83388B - Zone 3 - TP2 - Component A5

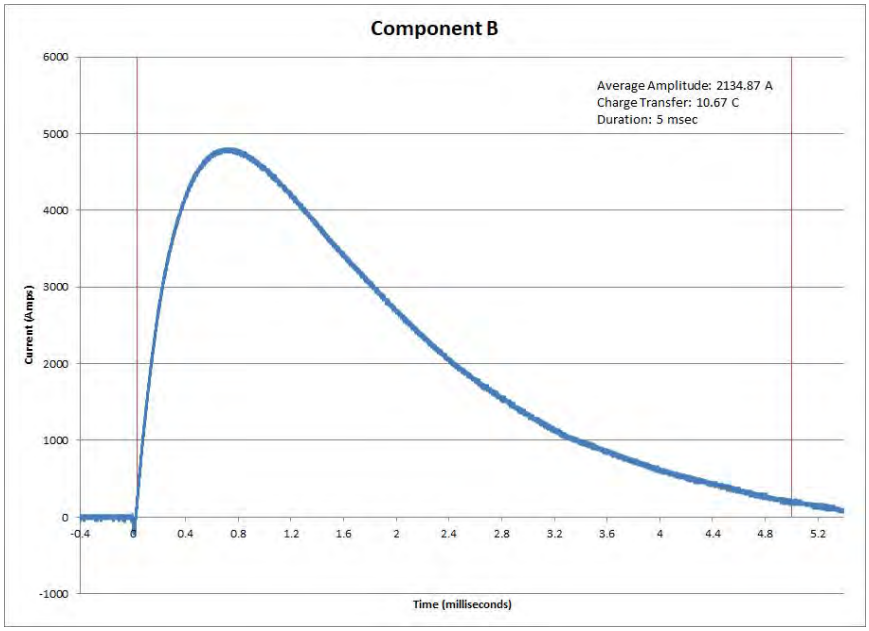


Figure 35: Arc Entry Test - 83388B - Zone 3 - TP2 - Component B

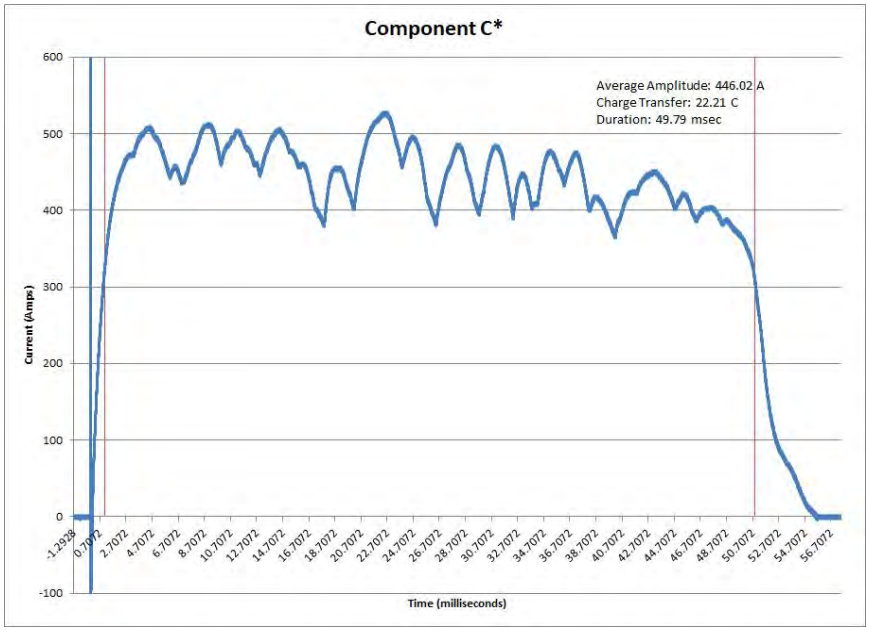


Figure 36: Arc Entry Test - 83388B - Zone 3 - TP2 - Component C*

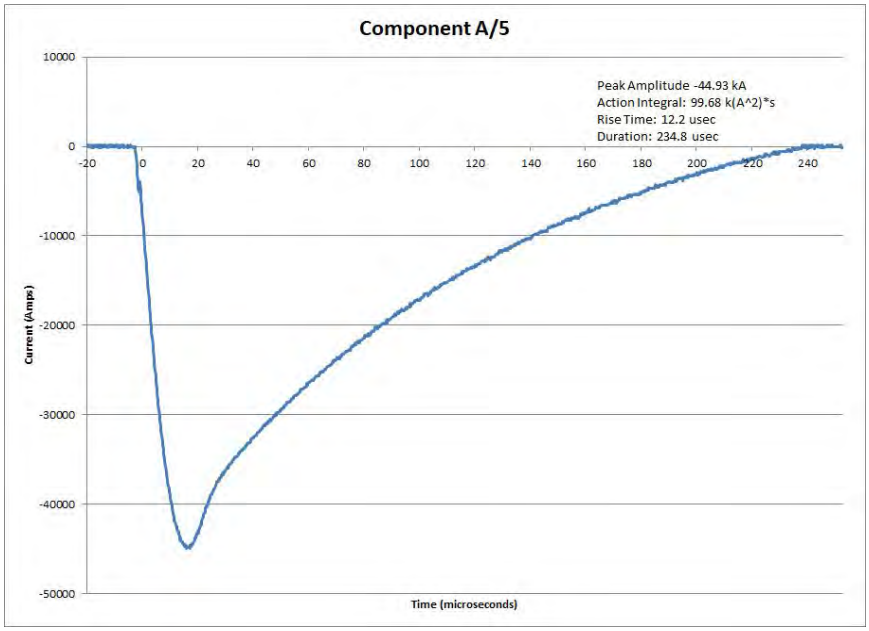


Figure 37: Arc Entry Test - 83389A - Zone 3 - TP1 - Component A5

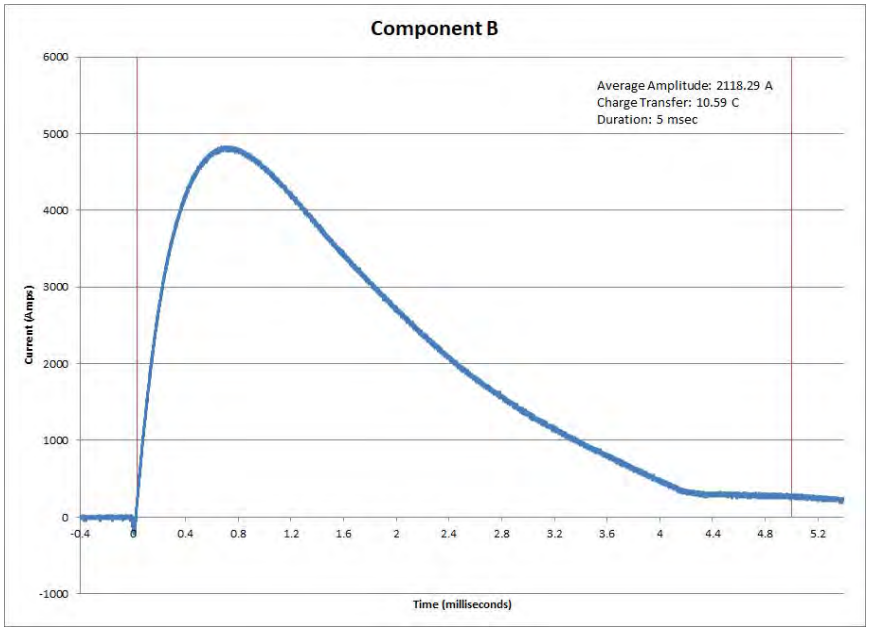


Figure 38: Arc Entry Test - 83389A - Zone 3 - TP1 - Component B

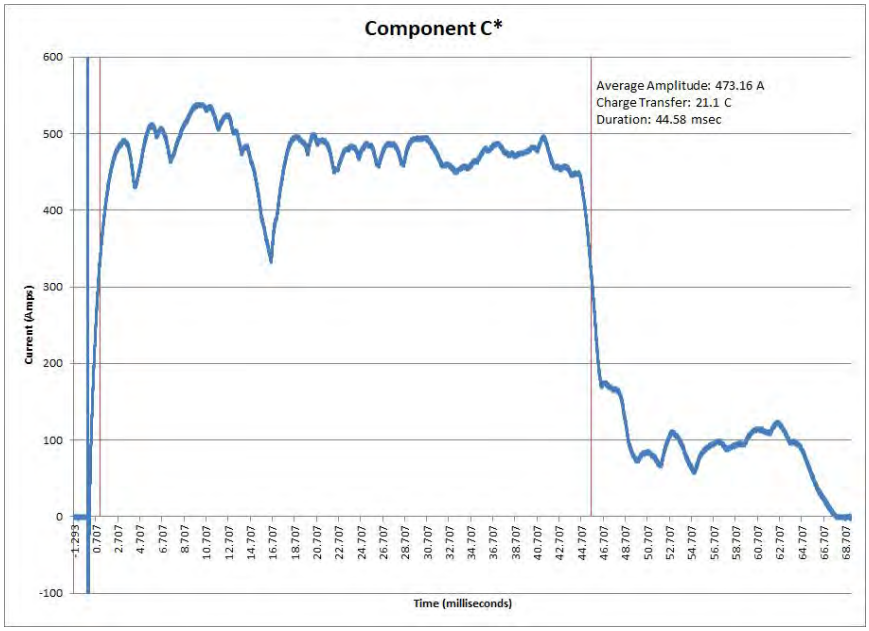


Figure 39: Arc Entry Test - 83389A - Zone 3 - TP1 - Component C*

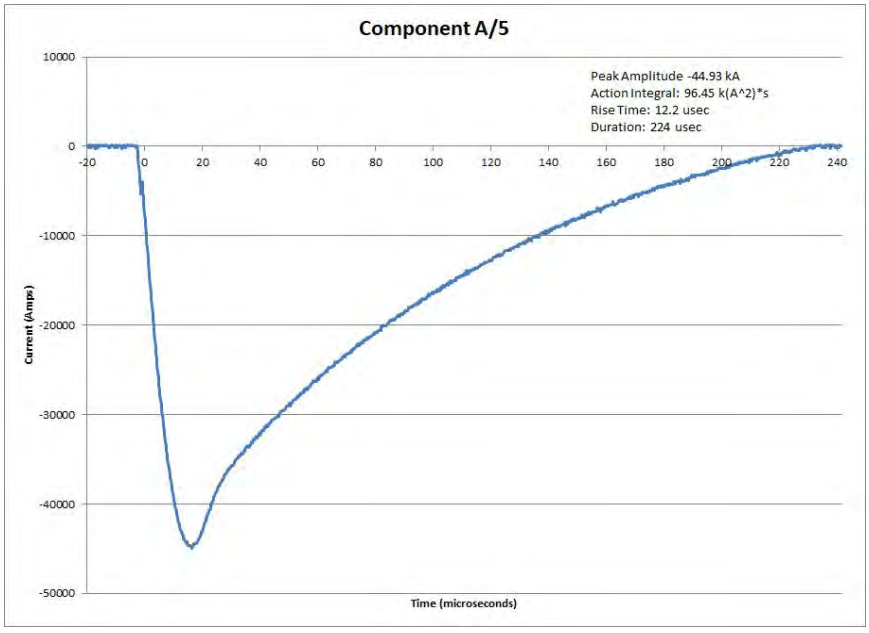


Figure 40: Arc Entry Test - 83389A - Zone 3 - TP2 - Component A5

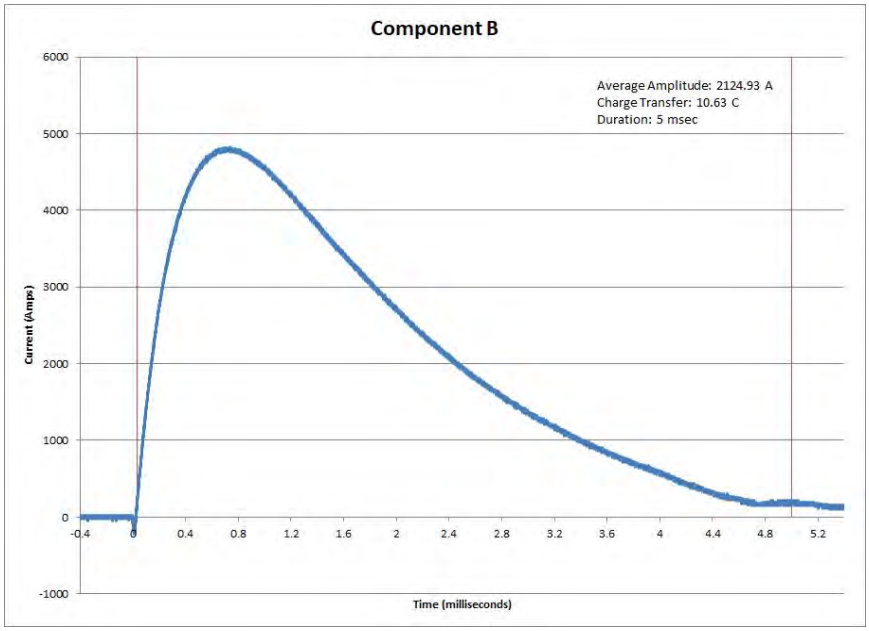


Figure 41: Arc Entry Test - 83389A - Zone 3 - TP2 - Component B

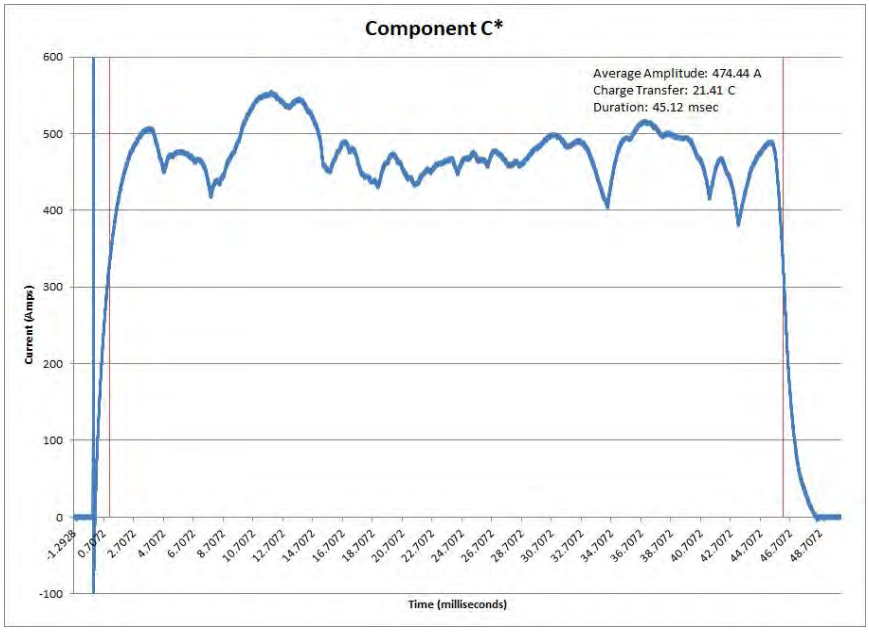


Figure 42: Arc Entry Test - 83389A - Zone 3 - TP2 - Component C*

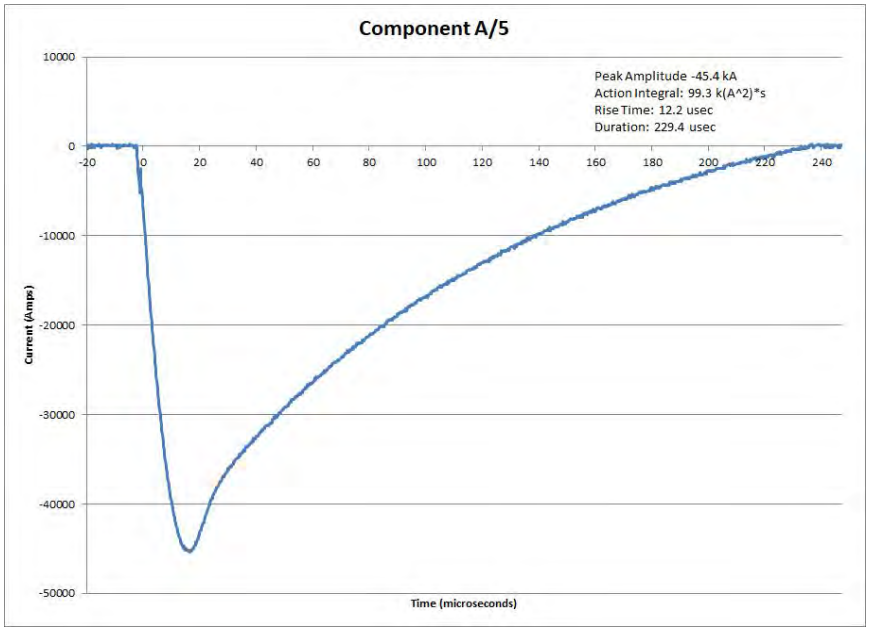


Figure 43: Arc Entry Test - 83389A - Zone 3 - TP3 - Component A5

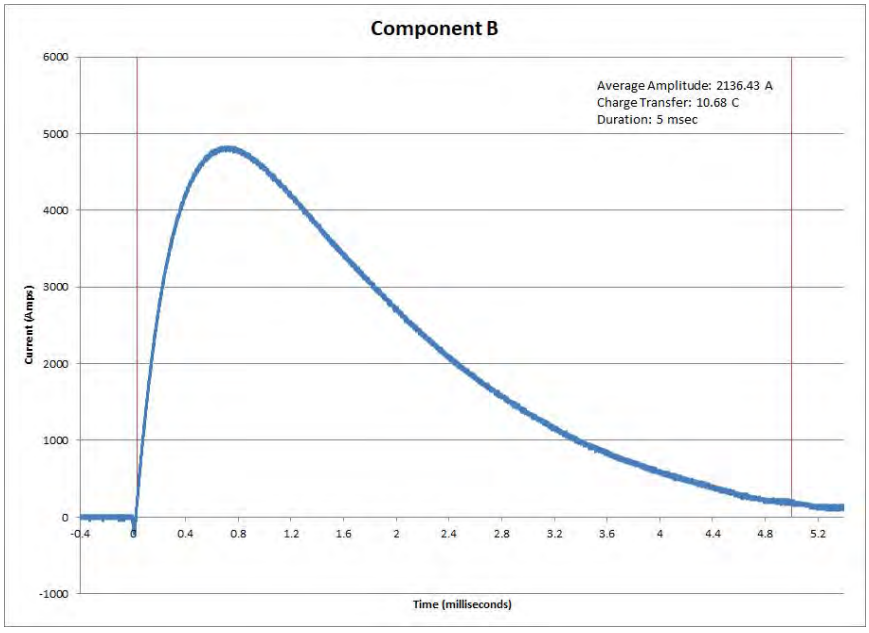


Figure 44: Arc Entry Test - 83389A - Zone 3 - TP3 - Component B

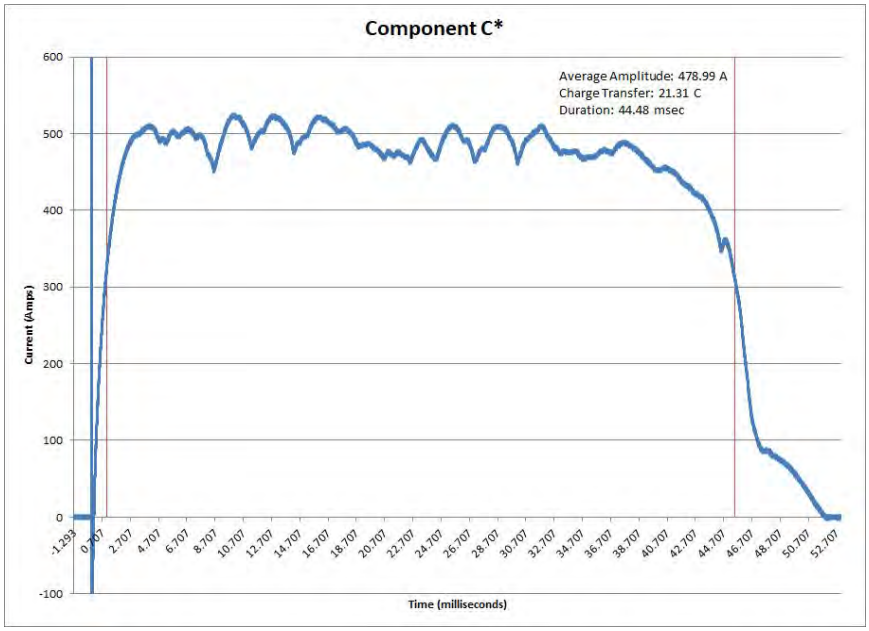


Figure 45: Arc Entry Test - 83389A - Zone 3 - TP3 - Component C*

Figure 46: Arc Entry Test - 83390A - TP1 - Component A5

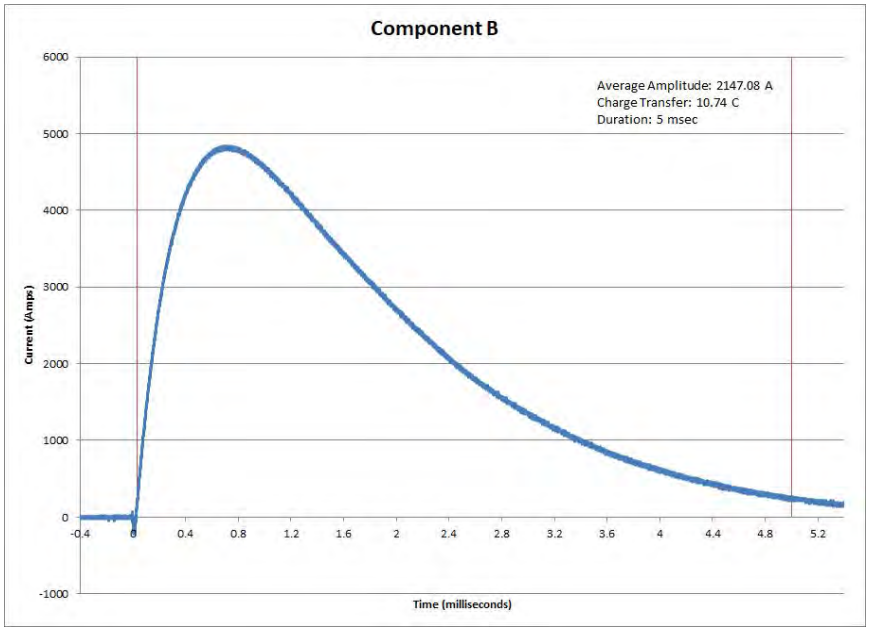


Figure 47: Arc Entry Test - 83390A - TP1 - Component B

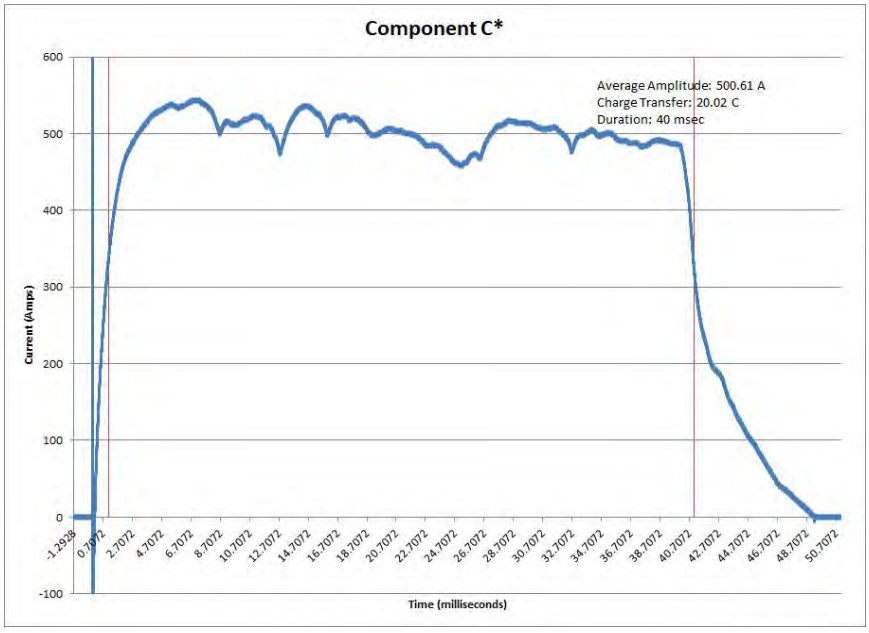


Figure 48: Arc Entry Test - 83390A - TP1 - Component C*

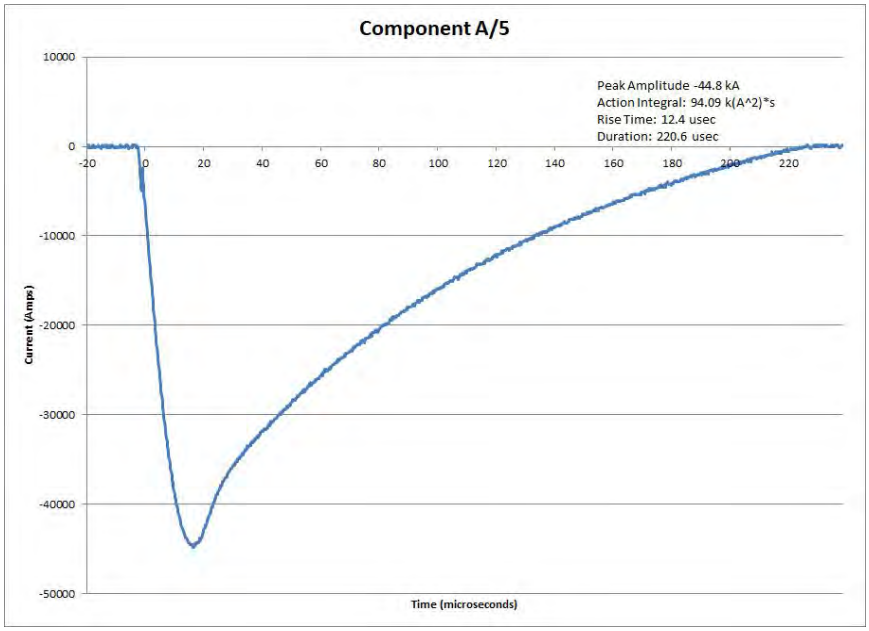


Figure 49: Arc Entry Test - 83390A - TP2 - Component A5

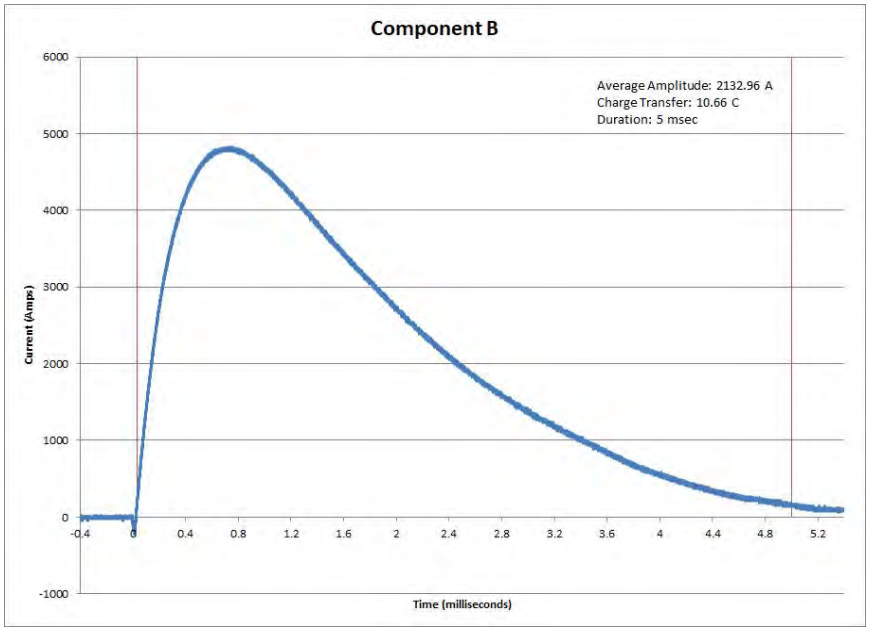


Figure 50: Arc Entry Test - 83390A - TP2 - Component B

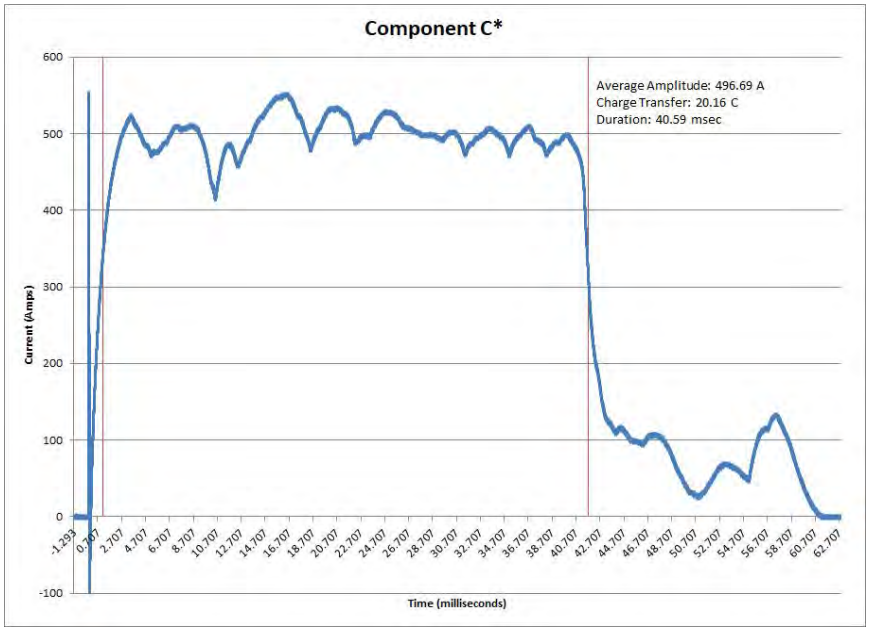


Figure 51: Arc Entry Test - 83390A - TP2 - Component C*

Figure 52: Arc Entry Test - 83390A - TP3 - Component A5

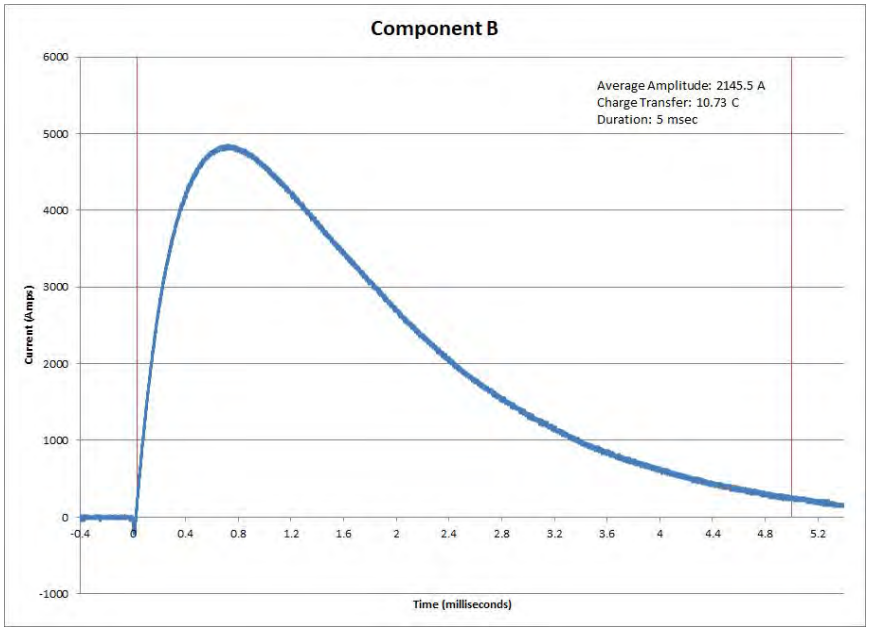


Figure 53: Arc Entry Test - 83390A - TP3 - Component B

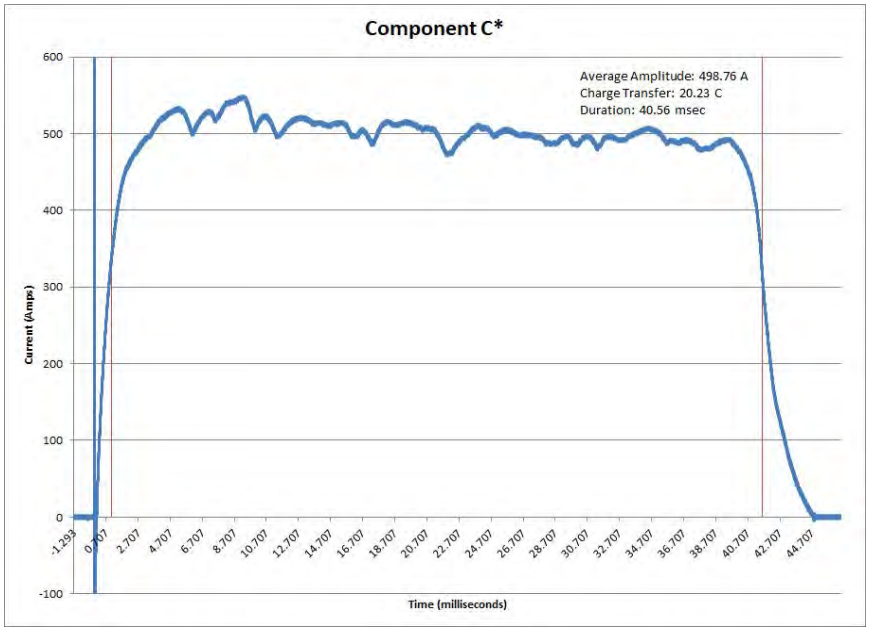


Figure 54: Arc Entry Test - 83390A - TP3 - Component C*

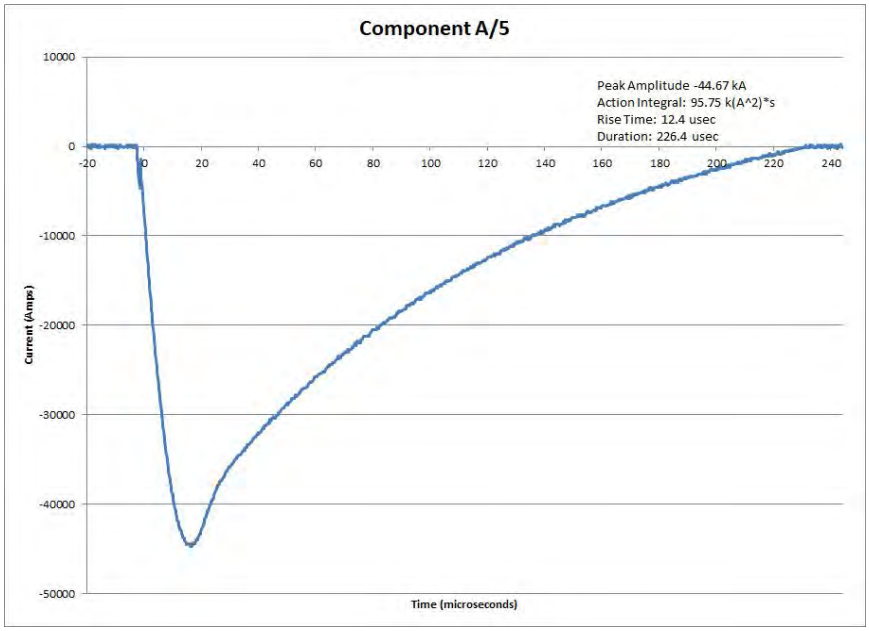


Figure 55: Arc Entry Test - 83391A - Zone 3 - TP1 - Component A5

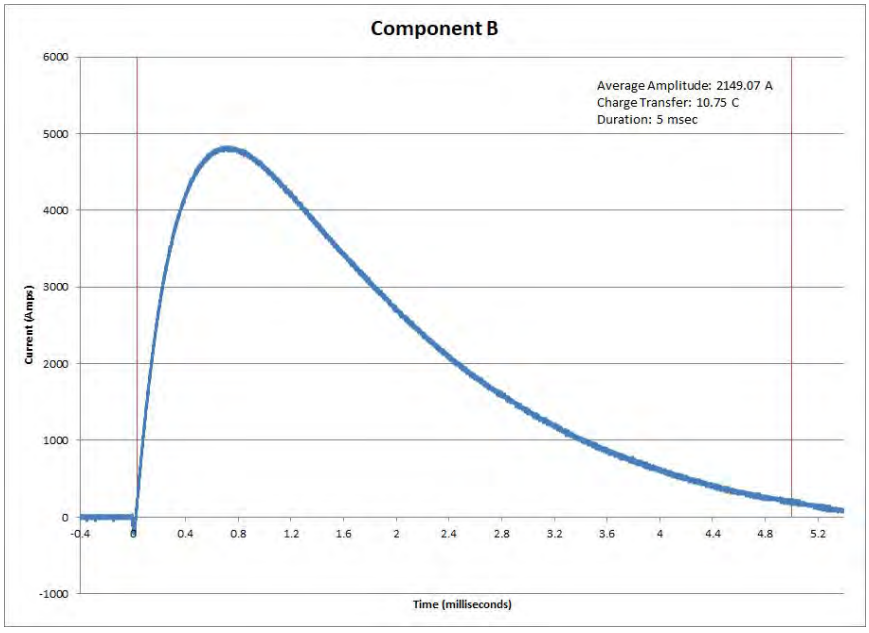


Figure 56: Arc Entry Test - 83391A - Zone 3 - TP1 - Component B

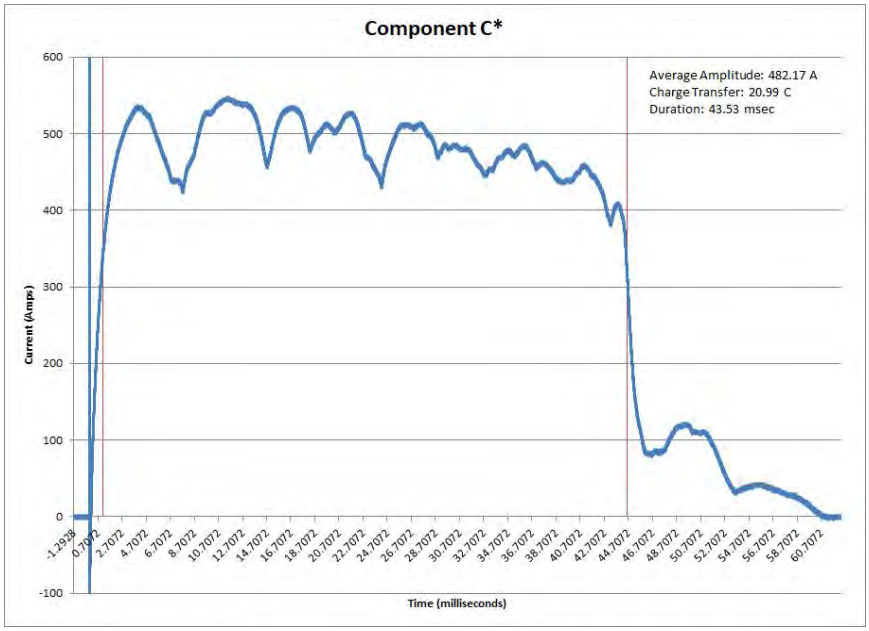


Figure 57: Arc Entry Test - 83391A - Zone 3 - TP1 - Component C*

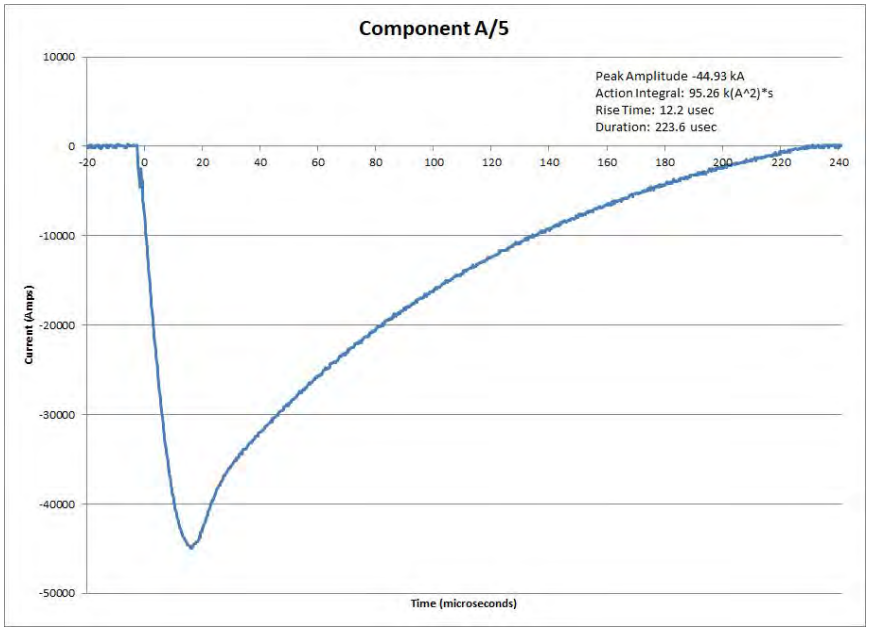


Figure 58: Arc Entry Test - 83391A - Zone 3 - TP2 - Component A5

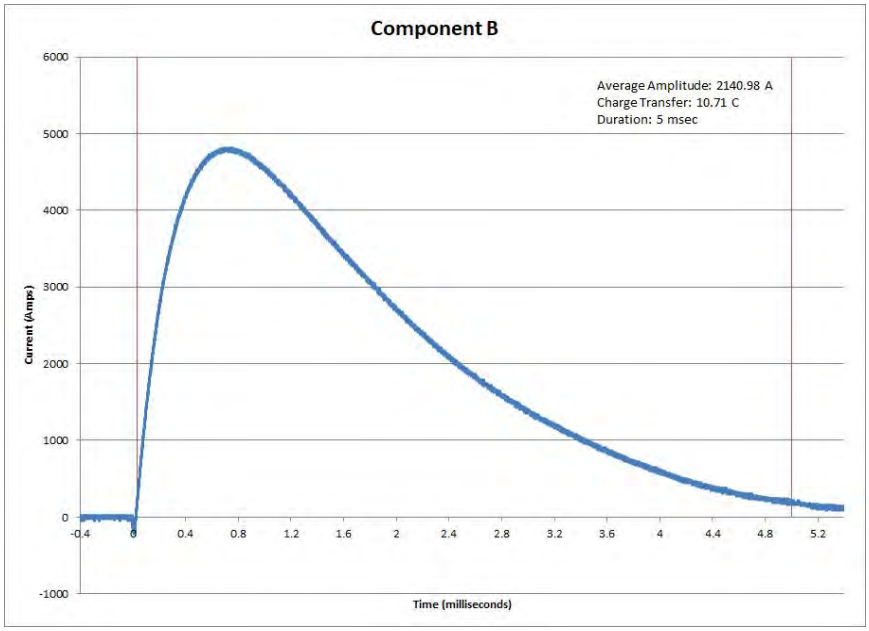


Figure 59: Arc Entry Test - 83391A - Zone 3 - TP2 - Component B

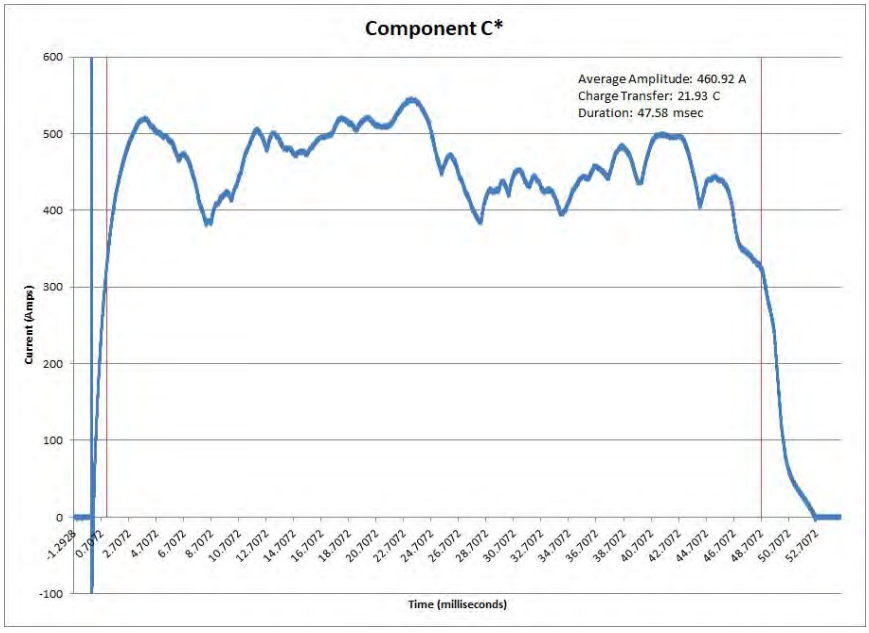


Figure 60: Arc Entry Test - 83391A - Zone 3 - TP2 - Component C*

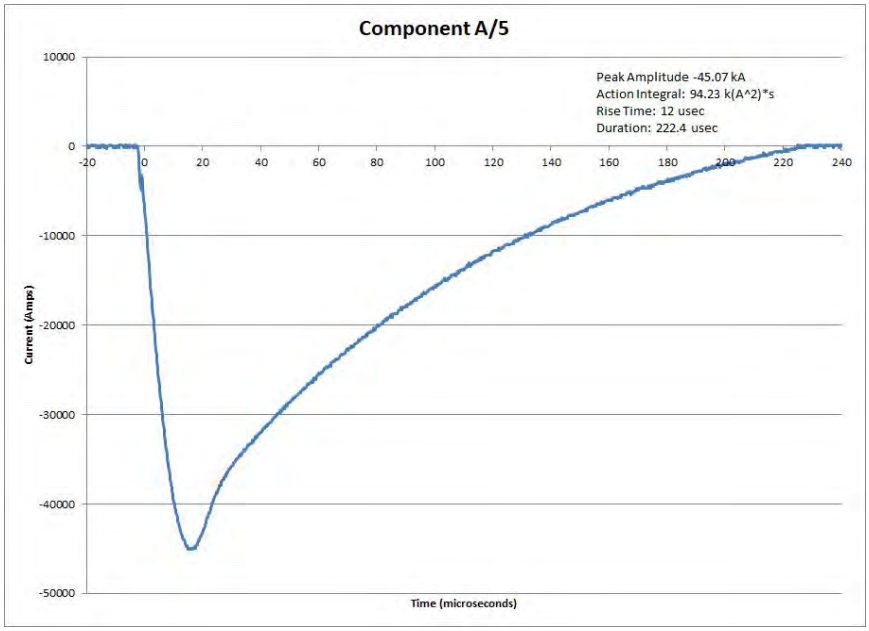


Figure 61: Arc Entry Test - 83391A - Zone 3 - TP3 - Component A5

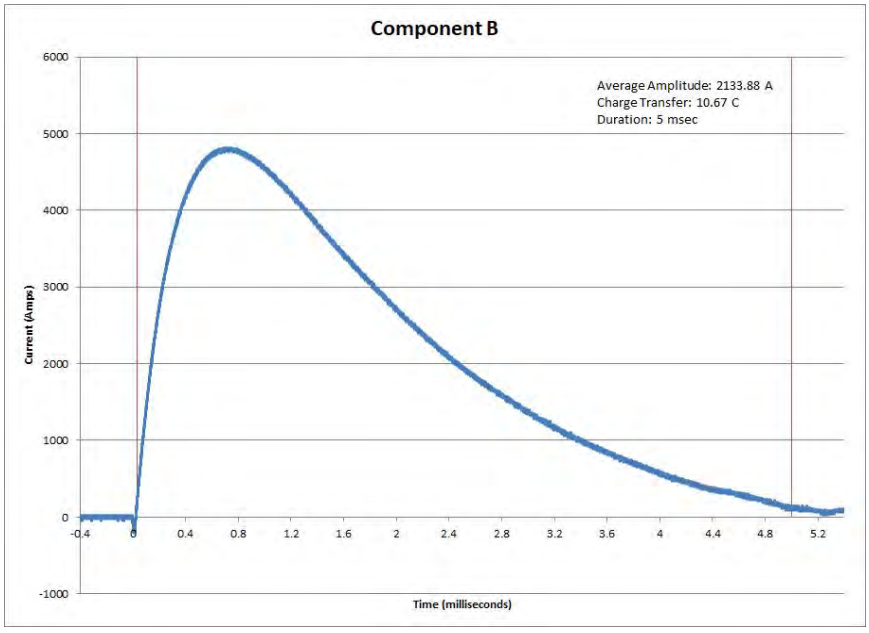


Figure 62: Arc Entry Test - 83391A - Zone 3 - TP3 - Component B

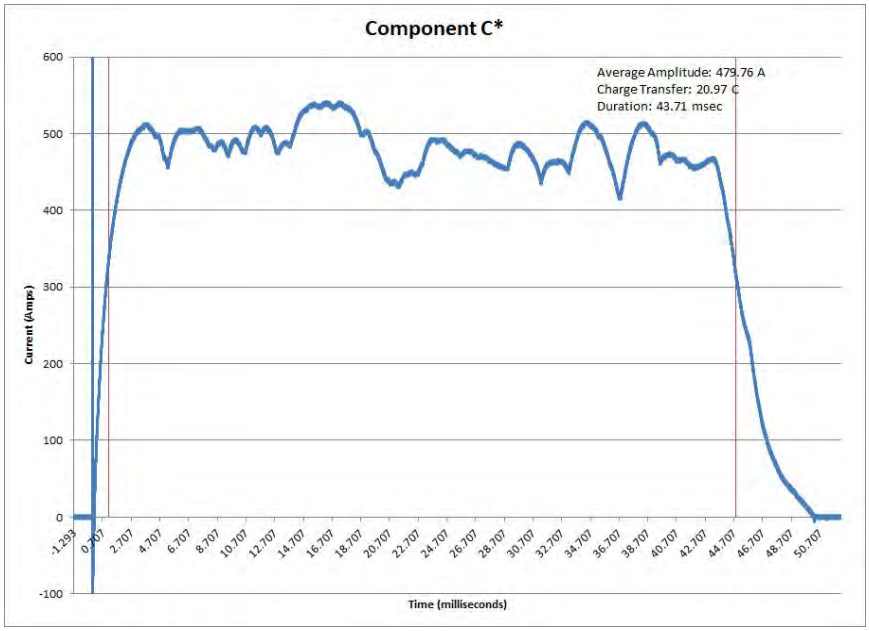


Figure 63: Arc Entry Test - 83391A - Zone 3 - TP3 - Component C*

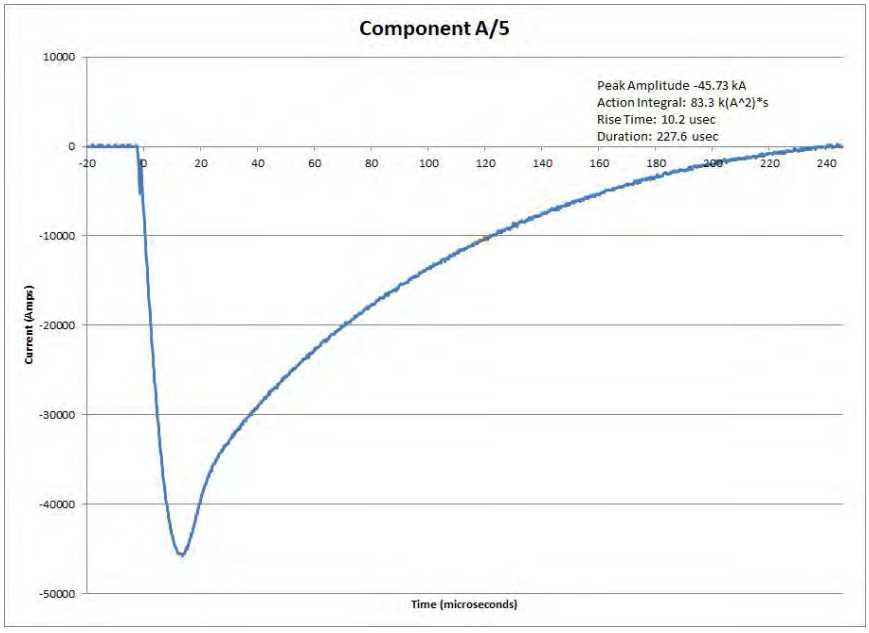


Figure 64: Arc Entry Test - Al Panel - Zone 3 - 1st Attempt - Component A5

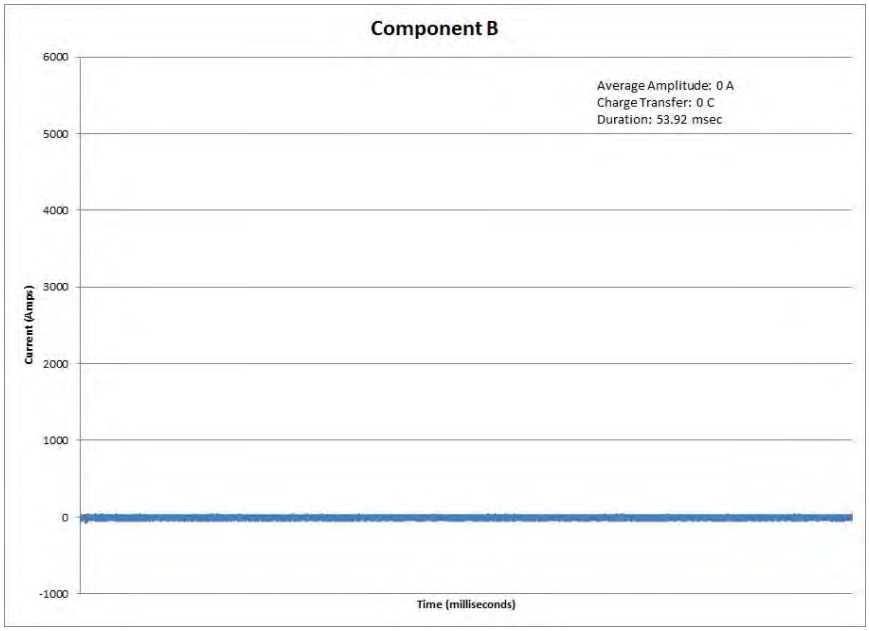


Figure 65: Arc Entry Test - Al Panel - Zone 3 - 1st Attempt - Component B

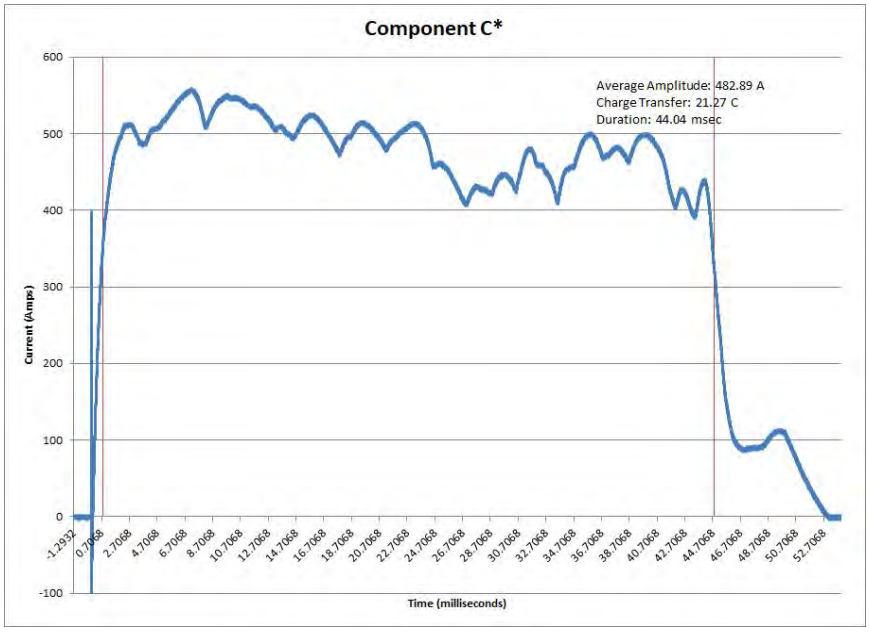


Figure 66: Arc Entry Test - Al Panel - Zone 3 - 1st Attempt - Component C*

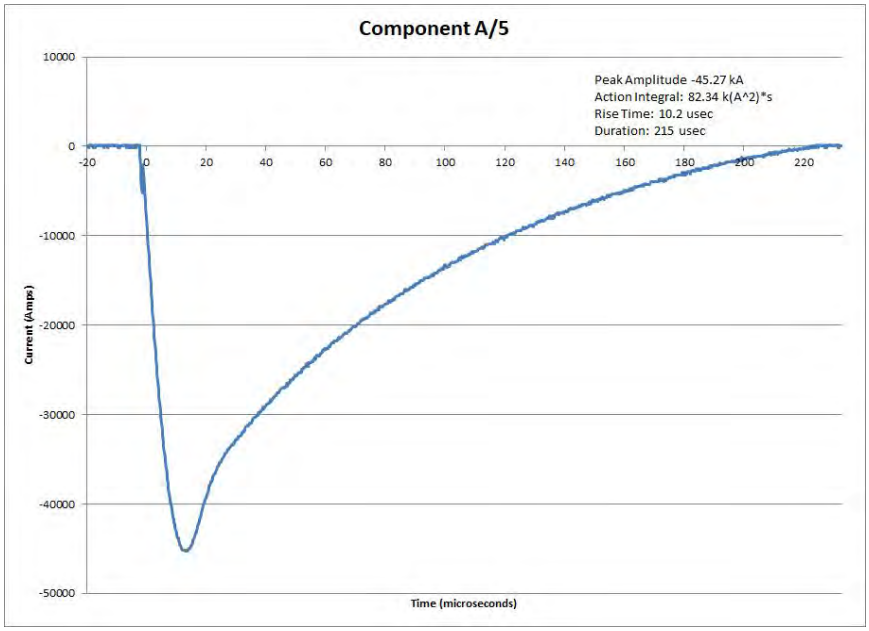


Figure 67: Arc Entry Test - Al Panel - Zone 3 - 2nd Attempt - Component A5

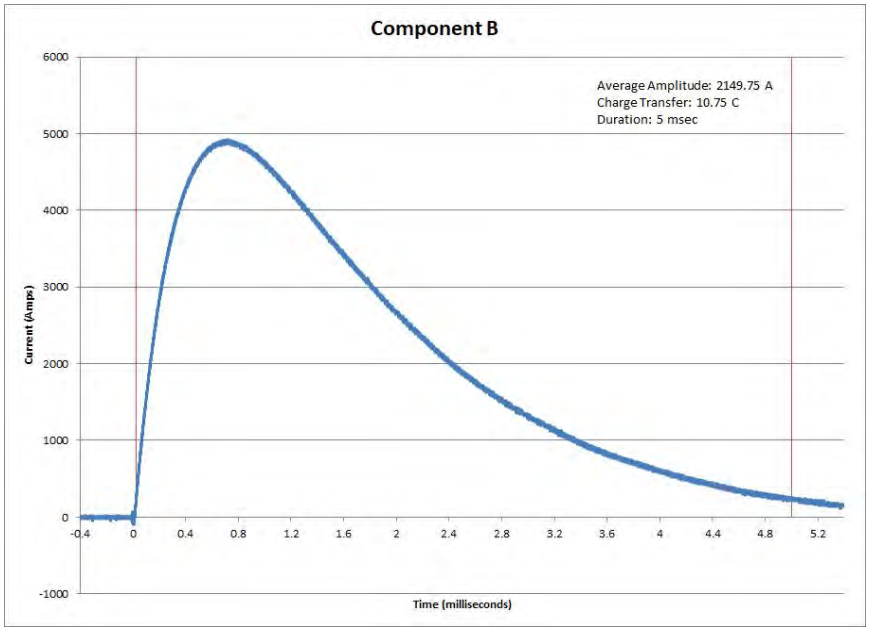


Figure 68: Arc Entry Test - Al Panel - Zone 3 - 2nd Attempt - Component B

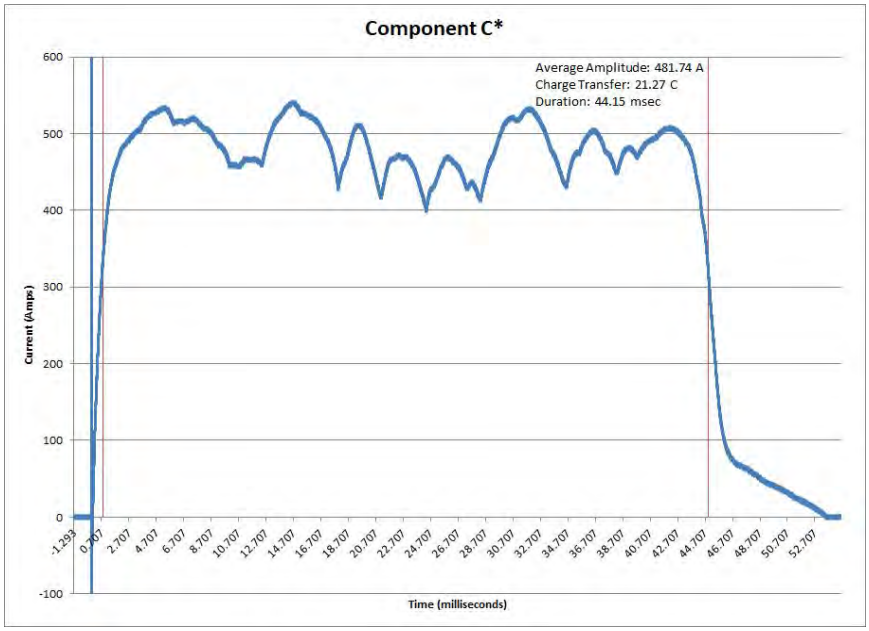


Figure 69: Arc Entry Test - Al Panel - Zone 3 - 2nd Attempt - Component C*

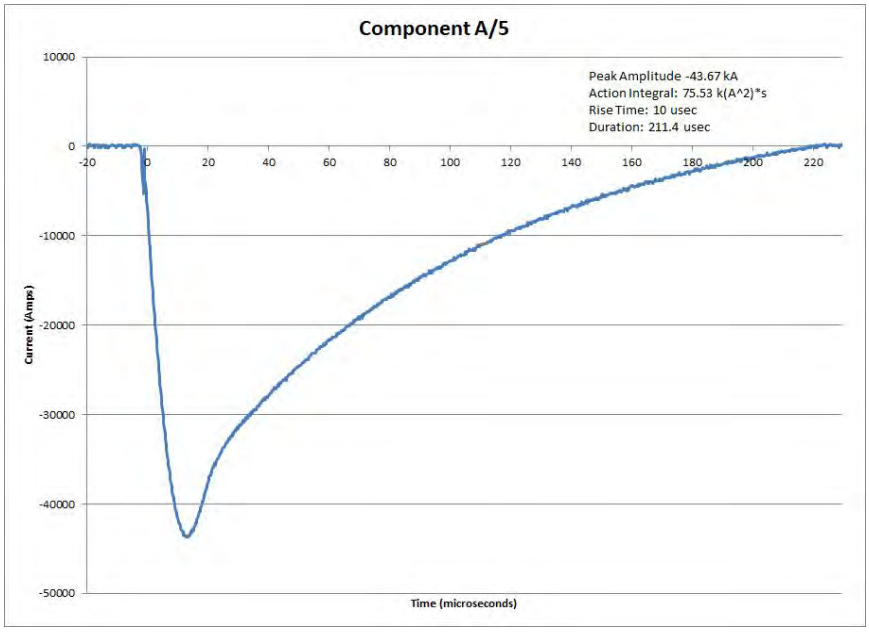


Figure 70: Arc Entry Test - Al Panel - Zone 3 - 3rd Attempt - Component A5

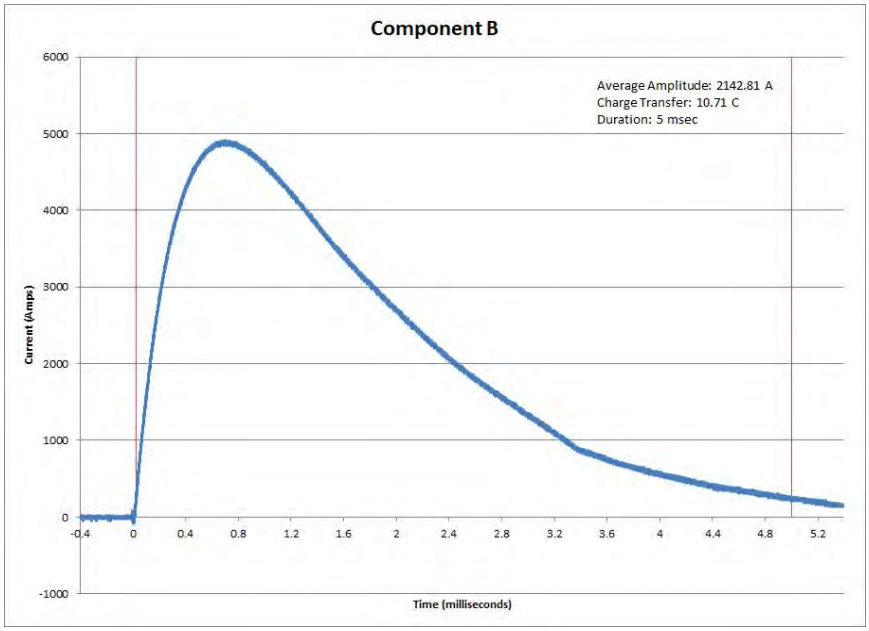


Figure 71: Arc Entry Test - Al Panel - Zone 3 - 3rd Attempt - Component B

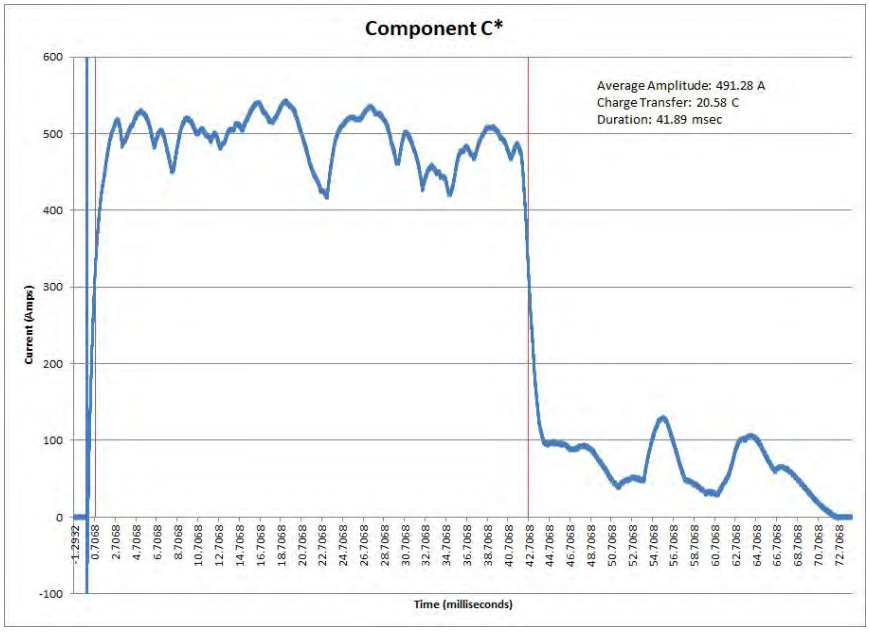


Figure 72: Arc Entry Test - Al Panel - Zone 3 - 3rd Attempt - Component C*

Appendix B - Test Photos

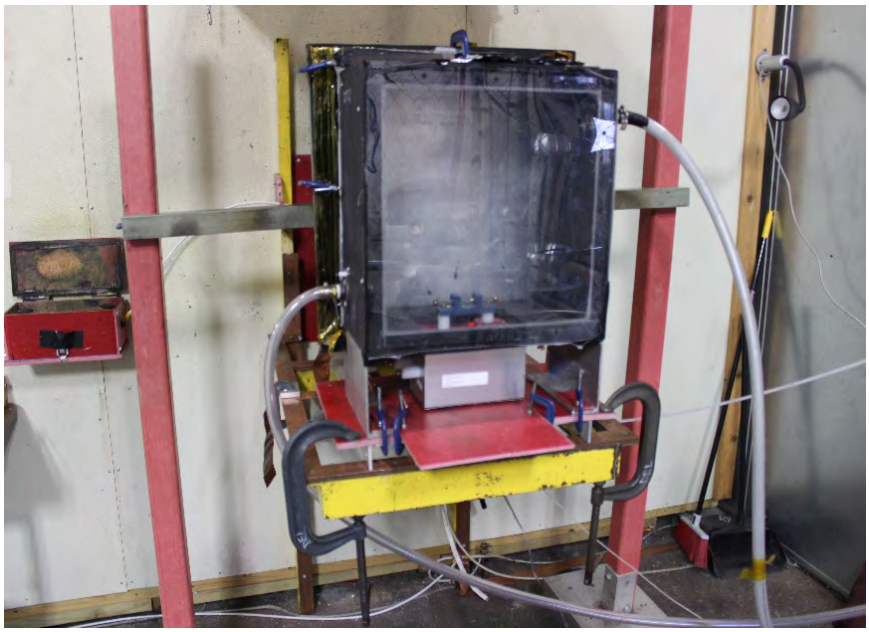


Figure 1: Arc Entry Test - 001-General Test Setup-1

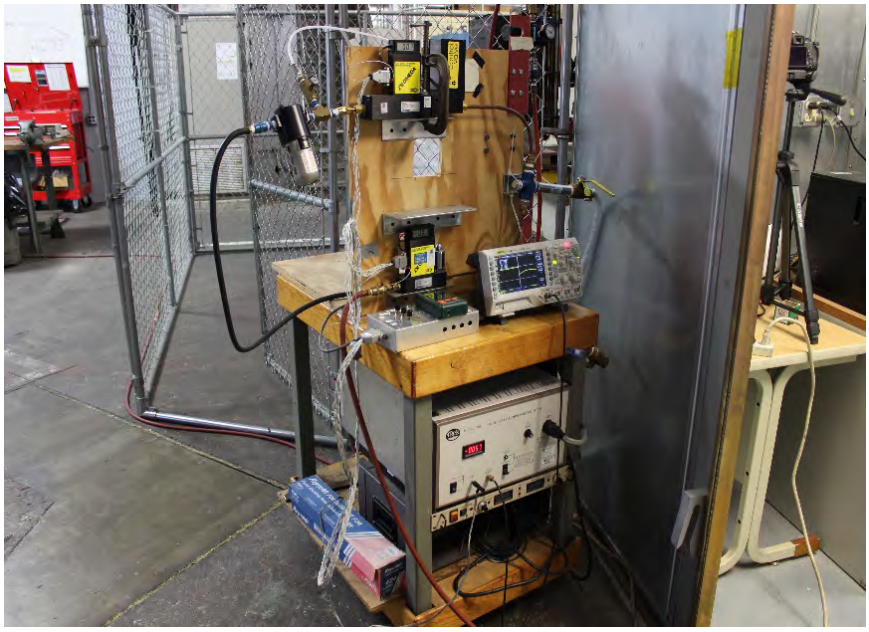


Figure 2: Arc Entry Test - 002-General Test Setup-2

Figure 3: Arc Entry Test - 003-Waveform Verification-Zone 3

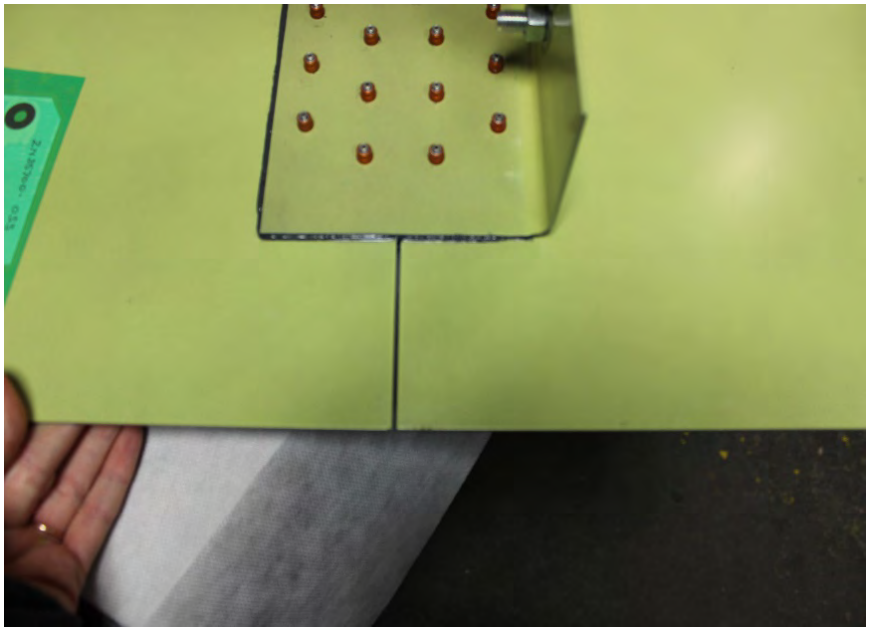


Figure 4: Arc Entry Test - 004-83388A-2N35700-055-Pre-Test-1

Figure 5: Arc Entry Test - 005-83388A-2N35700-055-Pre-Test-2

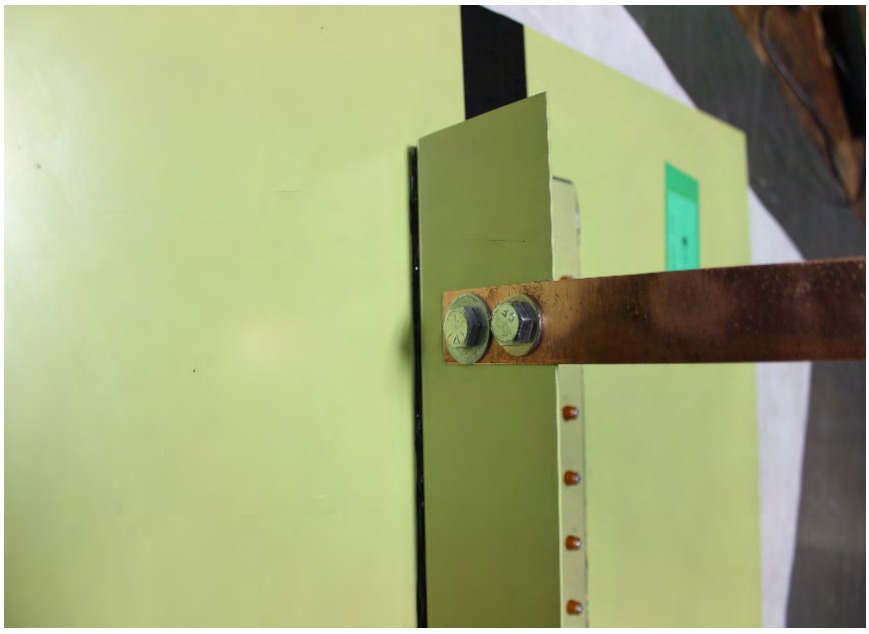


Figure 6: Arc Entry Test - 006-83388A-2N35700-055-Pre-Test-3

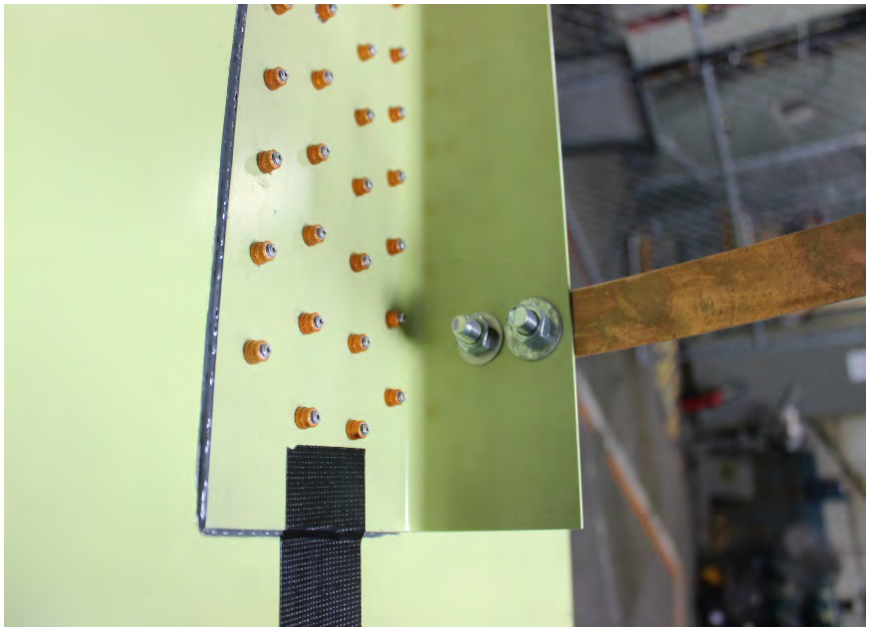


Figure 7: Arc Entry Test - 007-83388A-2N35700-055-Pre-Test-4

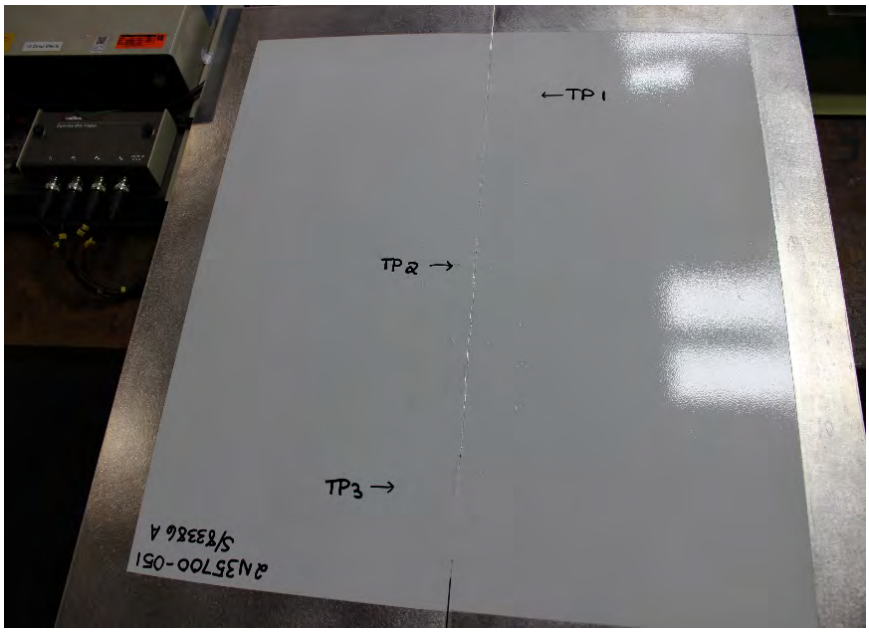


Figure 8: Arc Entry Test - 008-83386A-2N35700-051-Pre-Test

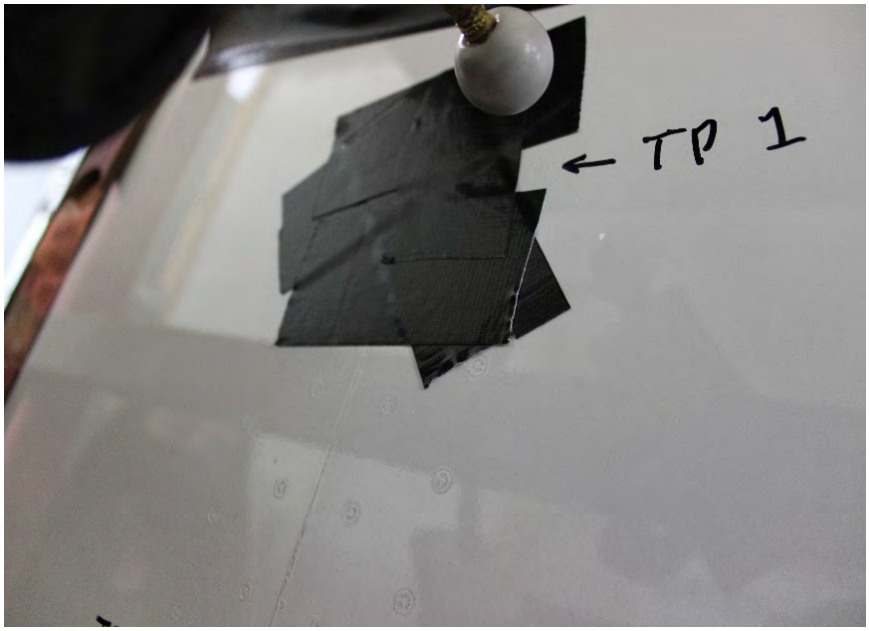


Figure 9: Arc Entry Test - 009-83388A-2N35700-055-Installation-Zone 3-TP1-Pre-Test-1

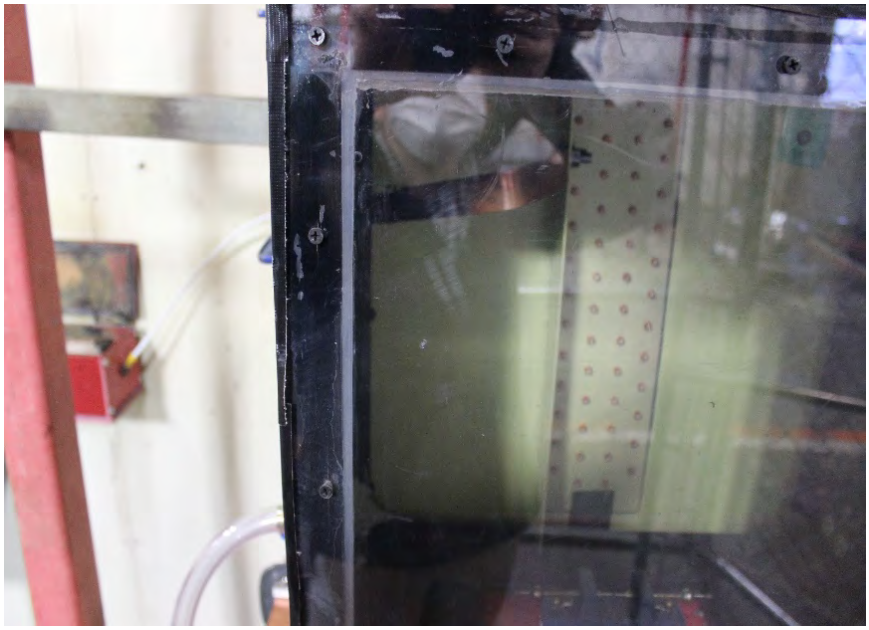


Figure 10: Arc Entry Test - 010-83388A-2N35700-055-Installation-Zone 3-TP1-Pre-Test-2

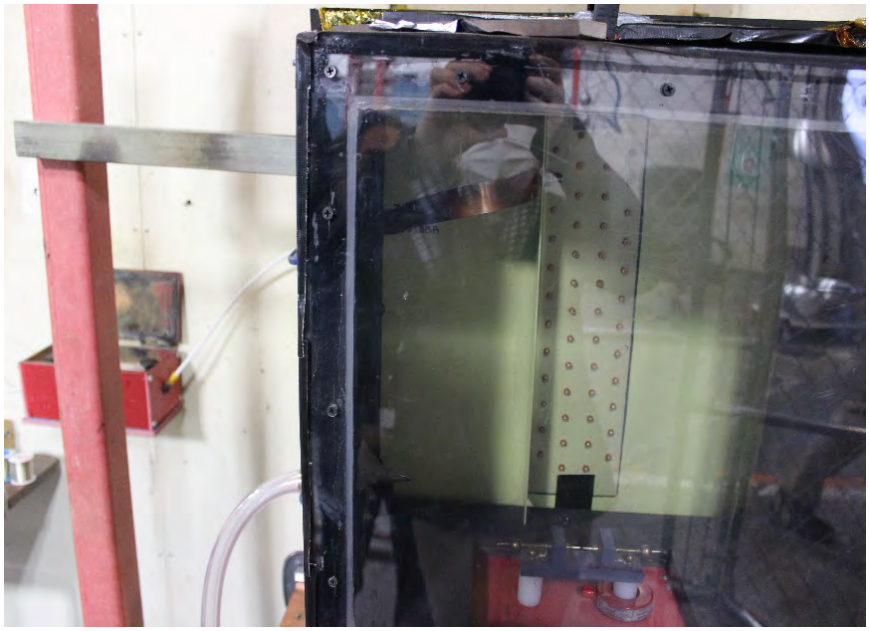


Figure 11: Arc Entry Test - 011-83388A-2N35700-055-Installation-Zone 3-TP1-Pre-Test-3

Figure 12: Arc Entry Test - 012-83388A-2N35700-055-Installation-Zone 3-TP1-Pre-Test-4

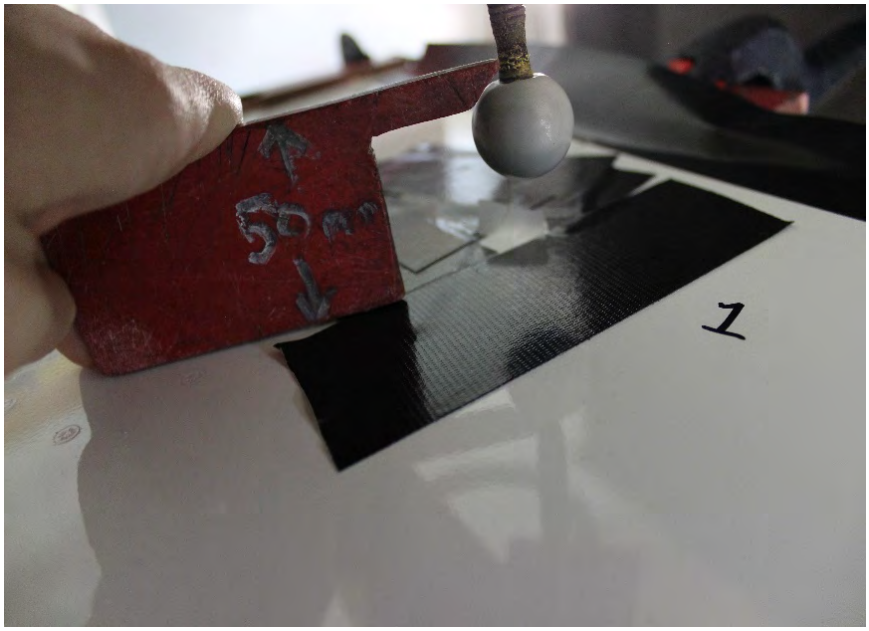


Figure 13: Arc Entry Test - 013-83388A-2N35700-055-Installation-Zone 3-TP1-Pre-Test-5

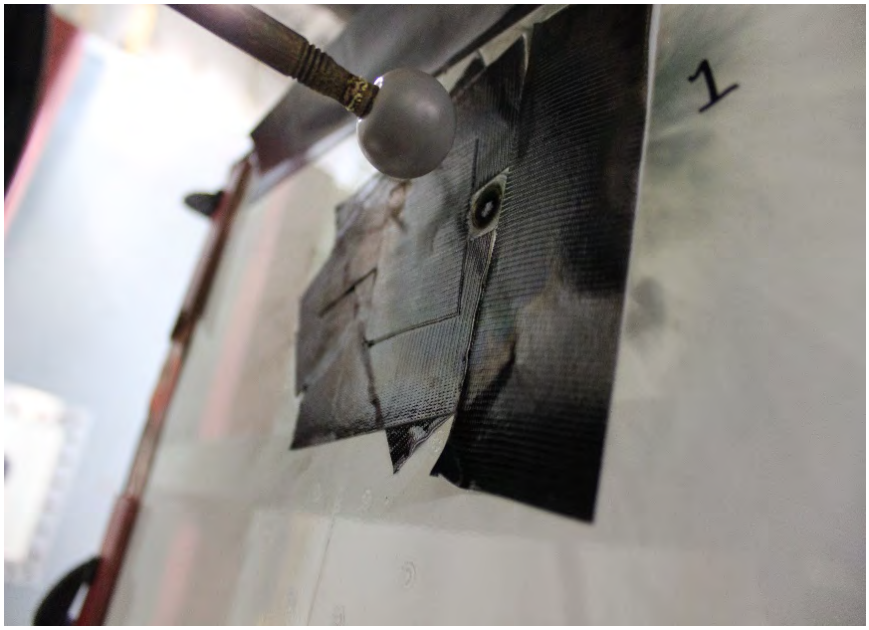


Figure 14: Arc Entry Test - 014-83388A-2N35700-055-Installation-Zone 3-TP1-Post-Test

Figure 15: Arc Entry Test - 015-83388A-2N35700-055-Installation-Zone 3-TP2-Pre-Test

Figure 16: Arc Entry Test - 016-83388A-2N35700-055-Installation-Zone 3-TP2-Post-Test

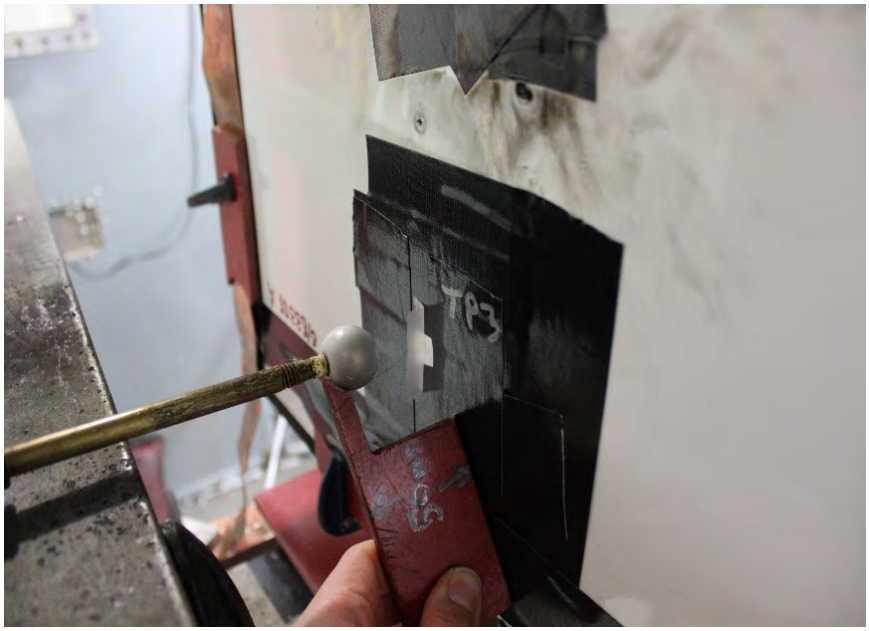


Figure 17: Arc Entry Test - 017-83388A-2N35700-055-Installation-Zone 3-TP3-Pre-Test

Figure 18: Arc Entry Test - 018-83388A-2N35700-055-Installation-Zone 3-TP3-Post-Test

Figure 19: Arc Entry Test - 019-83388A-2N35700-055-Installation-Zone 3-TP4-Pre-Test

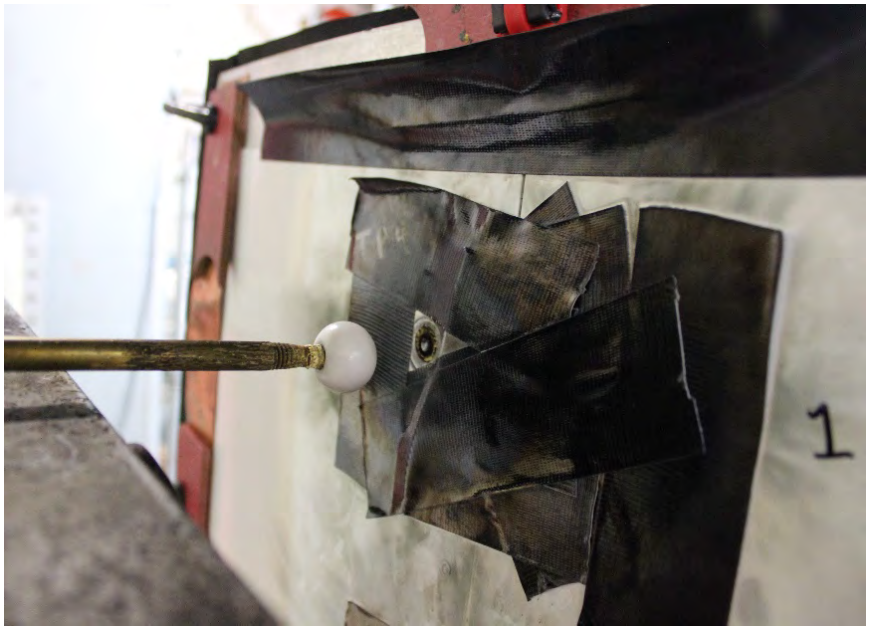


Figure 20: Arc Entry Test - 020-83388A-2N35700-055-Installation-Zone 3-TP4-Pre-Test

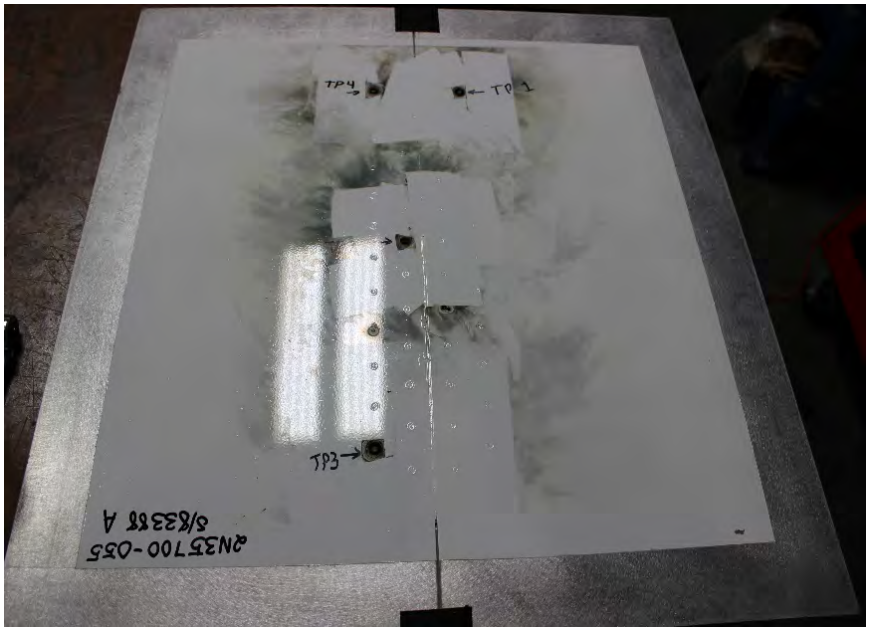


Figure 21: Arc Entry Test - 021-83388A-2N35700-055-Post-Test-1

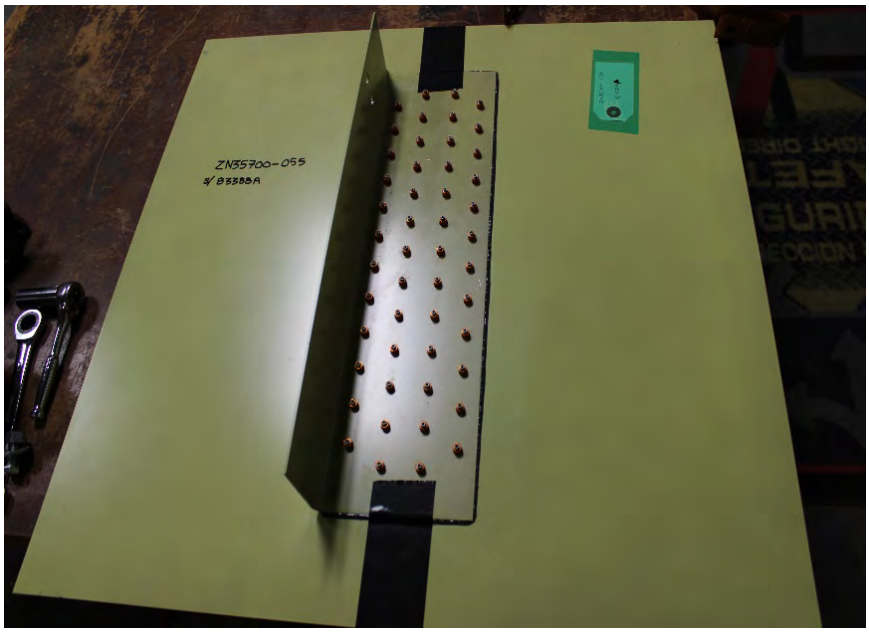


Figure 22: Arc Entry Test - 022-83388A-2N35700-055-Post-Test-2

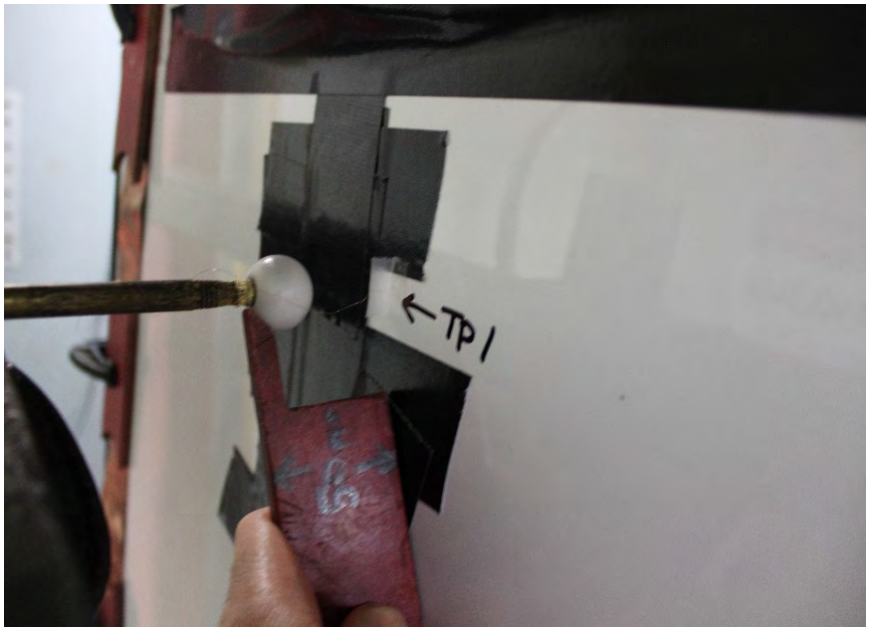


Figure 23: Arc Entry Test - 023-83388B-2N35700-055-Installation-Zone 3-TP1-Pre-Test

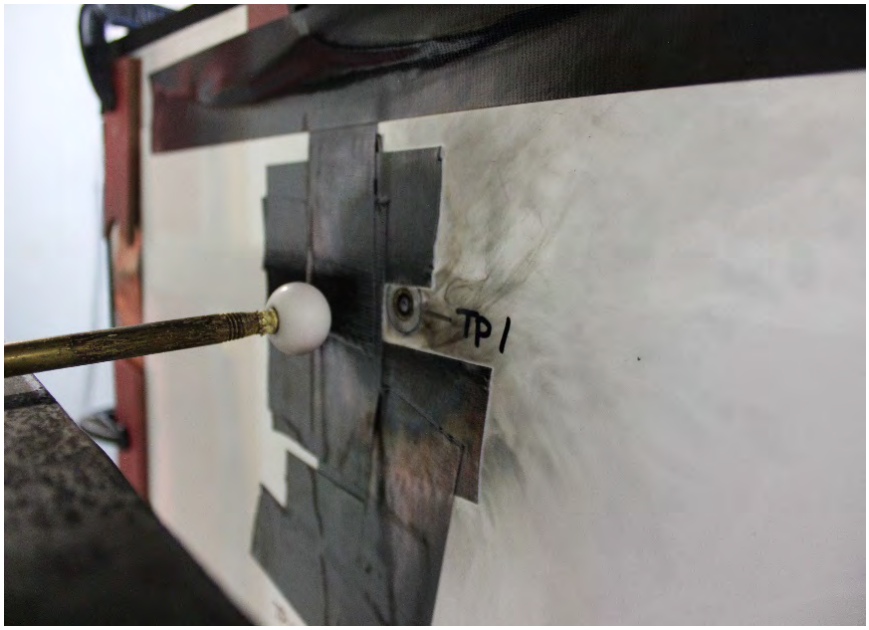


Figure 24: Arc Entry Test - 024-83388B-2N35700-055-Installation-Zone 3-TP1-Post-Test

Figure 25: Arc Entry Test - 025-83388B-2N35700-055-Installation-Zone 3-TP2-Pre-Test

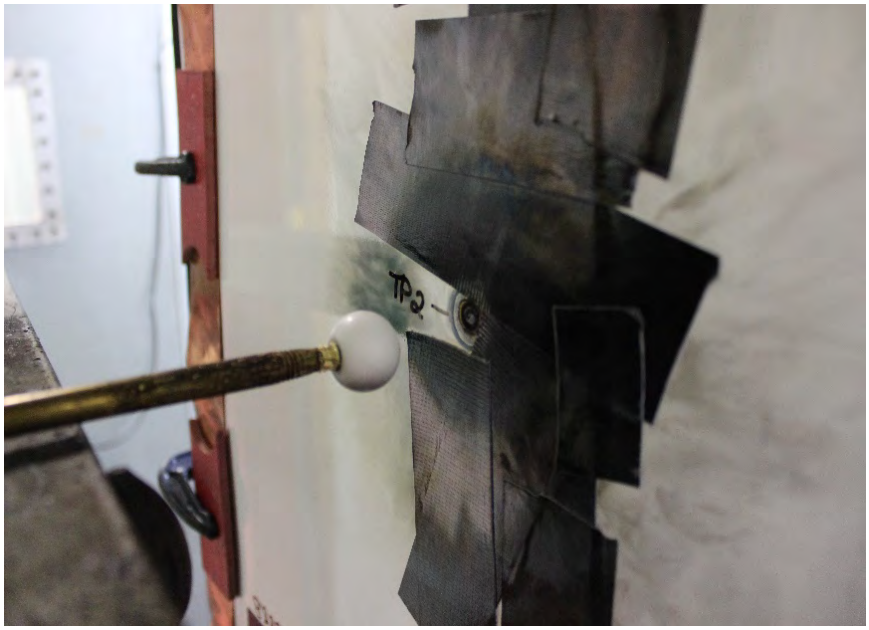


Figure 26: Arc Entry Test - 026-83388B-2N35700-055-Installation-Zone 3-TP2-Post-Test

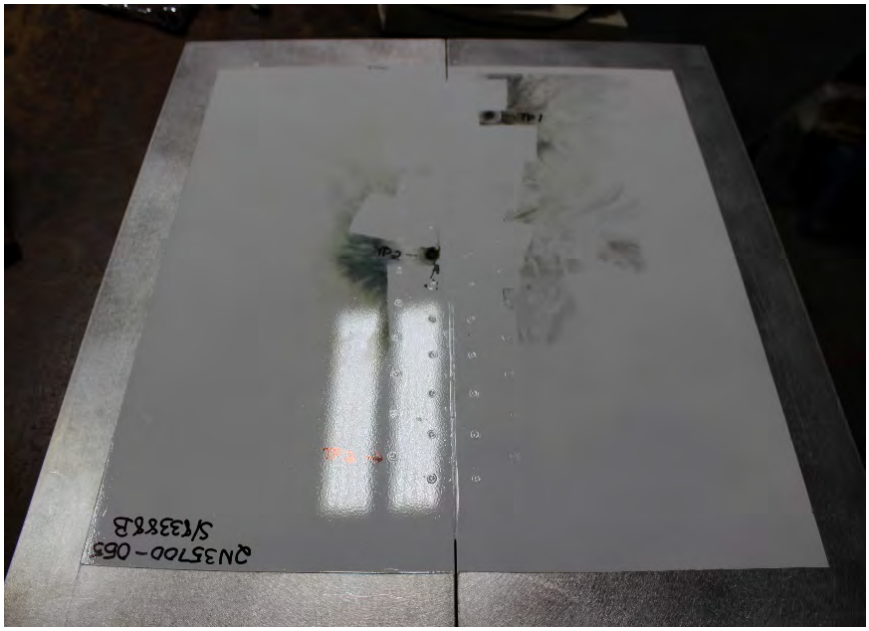


Figure 27: Arc Entry Test - 027-83388B-2N35700-055-Post-Test-1

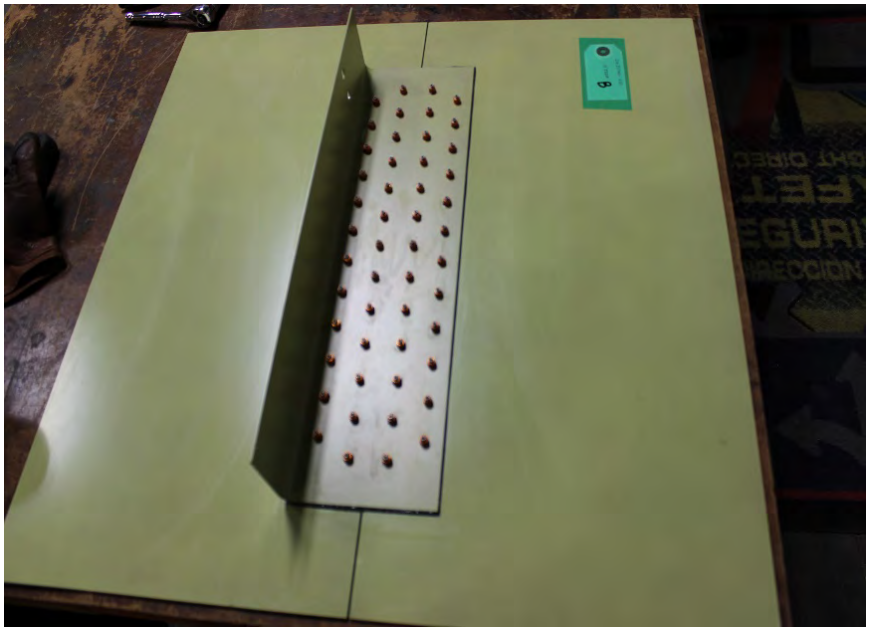


Figure 28: Arc Entry Test - 028-83388B-2N35700-055-Post-Test-2

Figure 29: Arc Entry Test - 029-83387A-2N35700-053-Installation-Zone 3-TP1-Pre-Test

Figure 30: Arc Entry Test - 030-83387A-2N35700-053-Installation-Zone 3-TP1-Post-Test

Figure 31: Arc Entry Test - 031-83387A-2N35700-053-Installation-Zone 3-TP2-Pre-Test

Figure 32: Arc Entry Test - 032-83387A-2N35700-053-Installation-Zone 3-TP2-Post-Test

Figure 33: Arc Entry Test - 033-83387A-2N35700-053-Installation-Zone 3-TP3-Pre-Test

Figure 34: Arc Entry Test - 034-83387A-2N35700-053-Installation-Zone 3-TP3-Post-Test

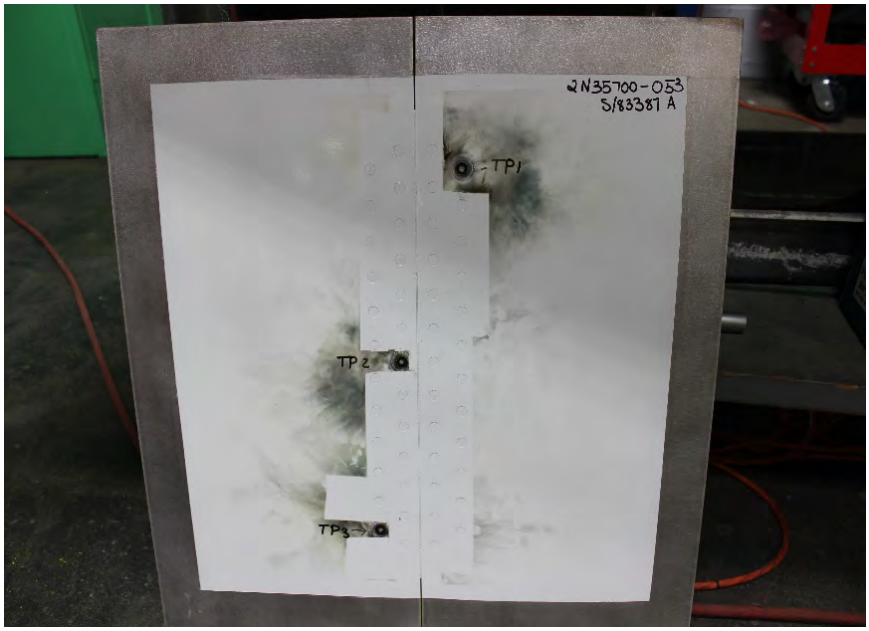


Figure 35: Arc Entry Test - 035-83387A-2N35700-053-Post-Test-1

Figure 36: Arc Entry Test - 036-83387A-2N35700-053-Post-Test-2

Figure 37: Arc Entry Test - 037-83386A-2N35700-051-Installation-Zone 3-TP1-Pre-Test

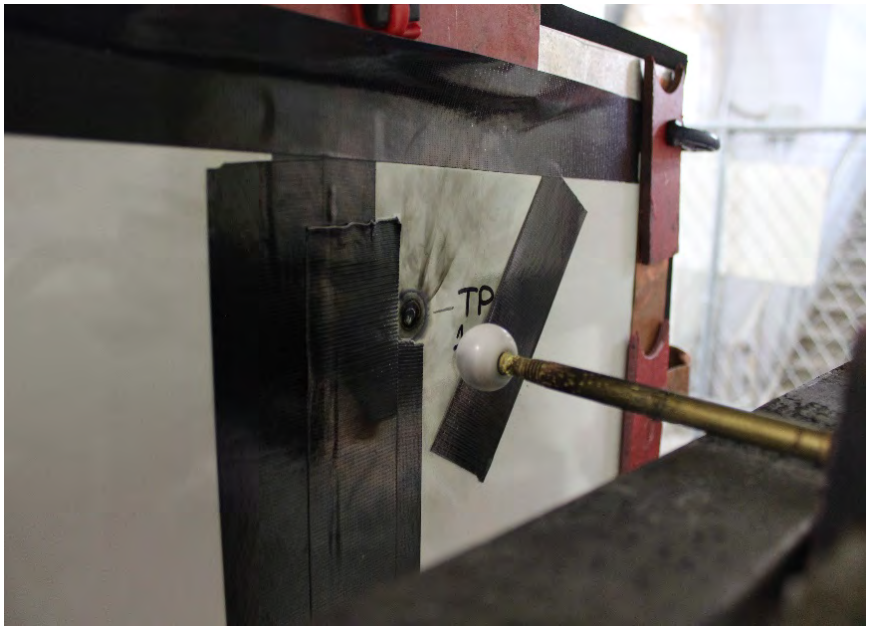


Figure 38: Arc Entry Test - 038-83386A-2N35700-051-Installation-Zone 3-TP1-Post-Test

Figure 39: Arc Entry Test - 039-83386A-2N35700-051-Installation-Zone 3-TP2-Pre-Test

Figure 40: Arc Entry Test - 040-83386A-2N35700-051-Installation-Zone 3-TP2-Post-Test

Figure 41: Arc Entry Test - 041-83386A-2N35700-051-Installation-Zone 3-TP3-Pre-Test

Figure 42: Arc Entry Test - 042-83386A-2N35700-051-Installation-Zone 3-TP3-Post-Test

Figure 43: Arc Entry Test - 043-83386A-2N35700-051-Pre-Test-1

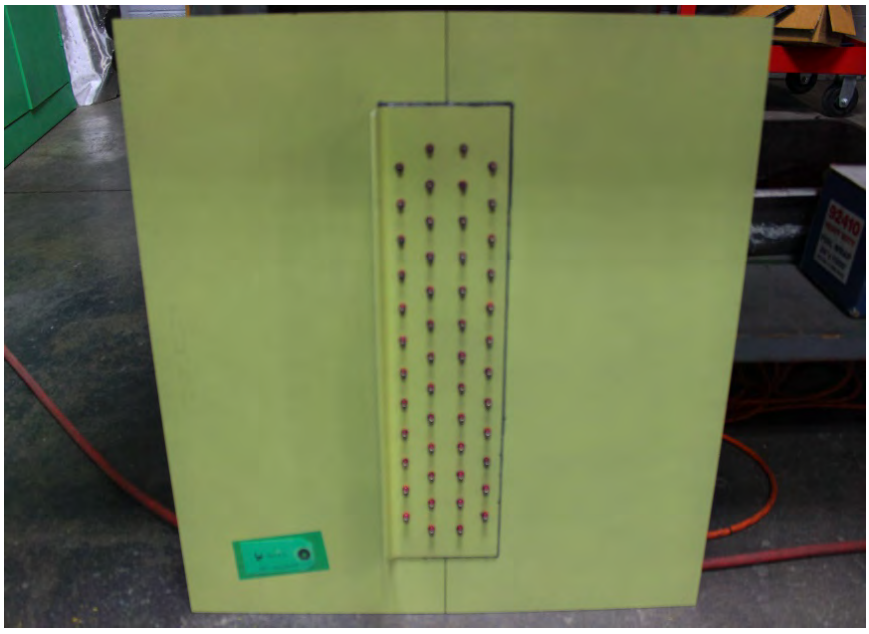


Figure 44: Arc Entry Test - 044-83386A-2N35700-051-Post-Test-2

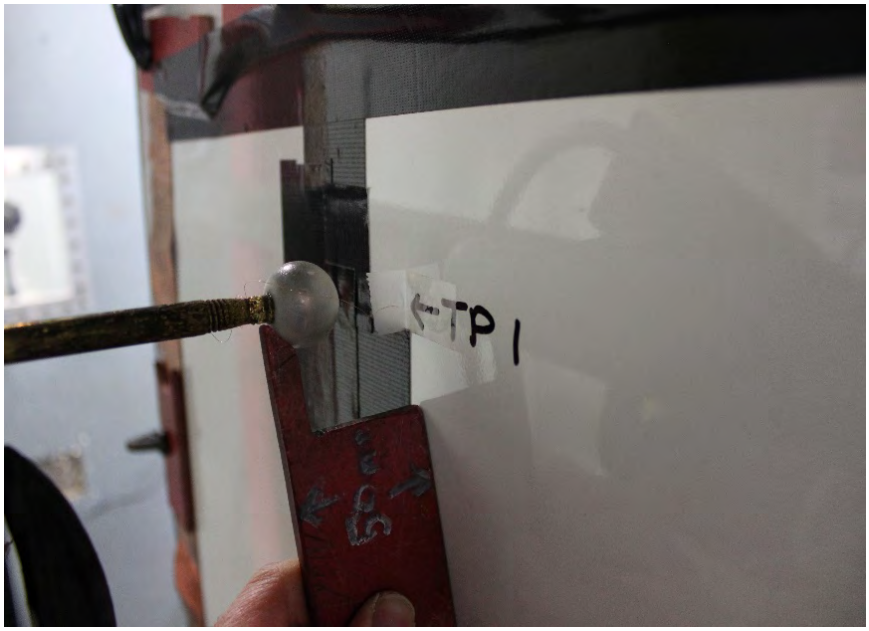


Figure 45: Arc Entry Test - 045-83390A-2N35700-059-Installation-Zone 3-TP1-Pre-Test

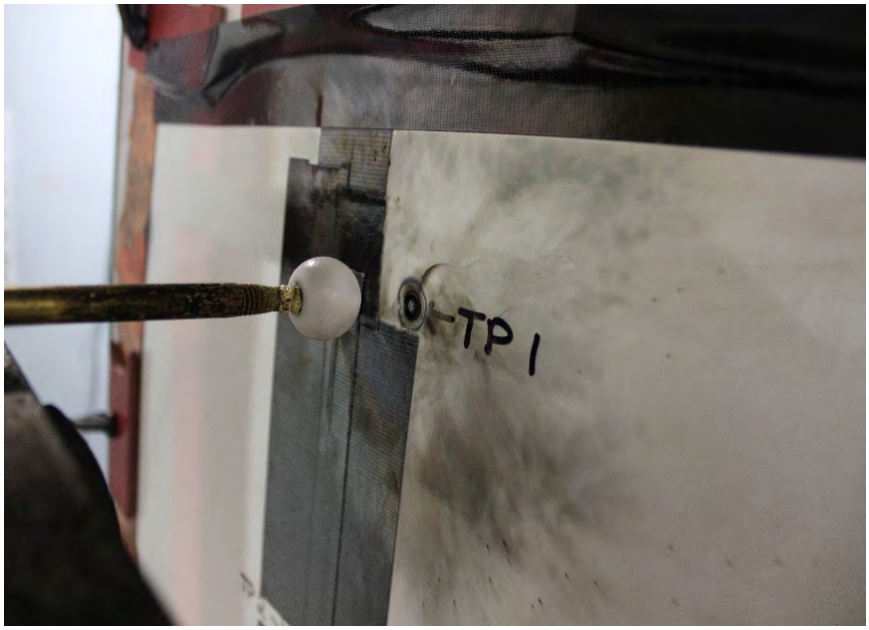


Figure 46: Arc Entry Test - 046-83390A-2N35700-059-Installation-Zone 3-TP1-Post-Test

Figure 47: Arc Entry Test - 047-83390A-2N35700-059-Installation-Zone 3-TP2-Pre-Test

Figure 48: Arc Entry Test - 048-83390A-2N35700-059-Installation-Zone 3-TP2-Post-Test

Figure 49: Arc Entry Test - 049-83390A-2N35700-059-Installation-Zone 3-TP3-Pre-Test

Figure 50: Arc Entry Test - 050-83390A-2N35700-059-Installation-Zone 3-TP3-Post-Test

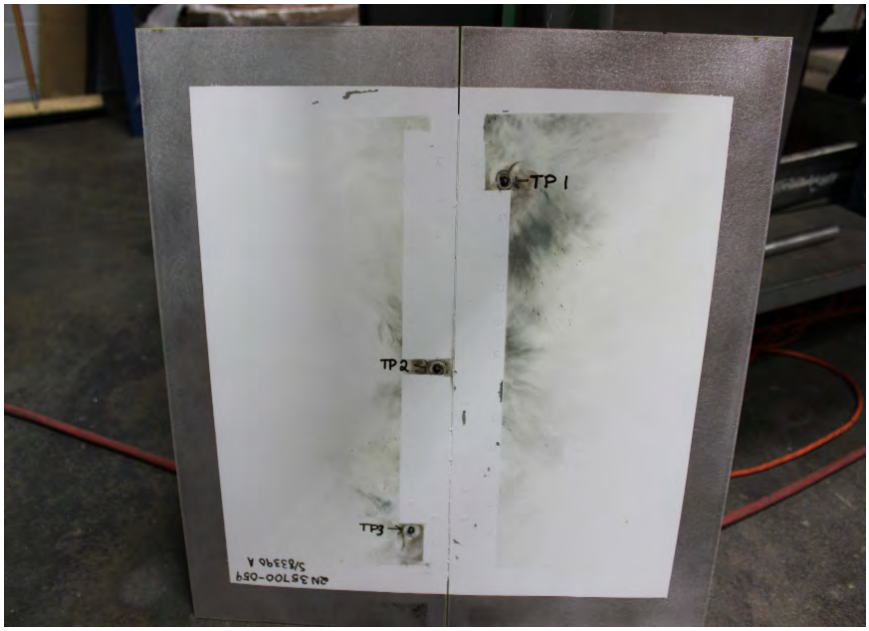


Figure 51: Arc Entry Test - 051-83390A-2N35700-059-Post-Test-1

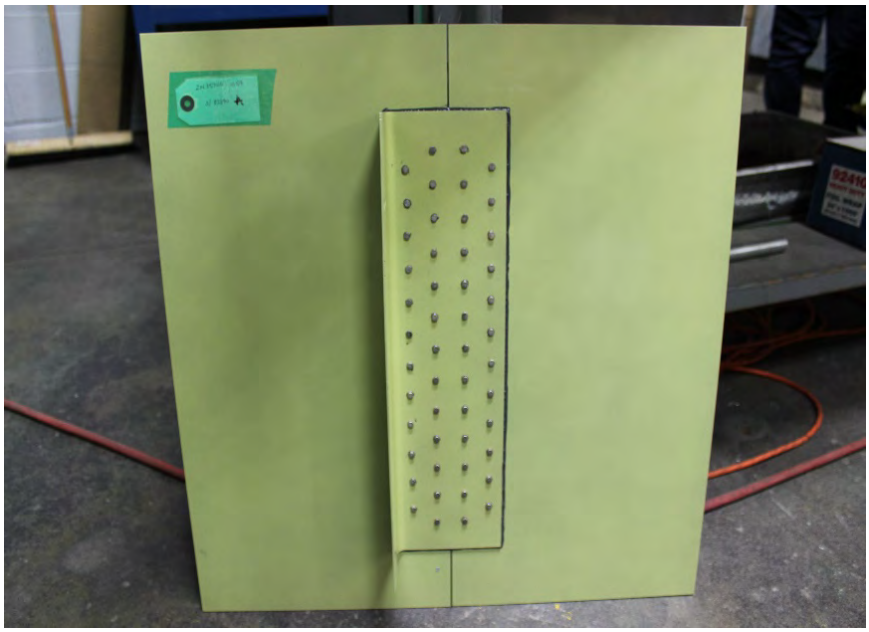


Figure 52: Arc Entry Test - 052-83390A-2N35700-059-Post-Test-2

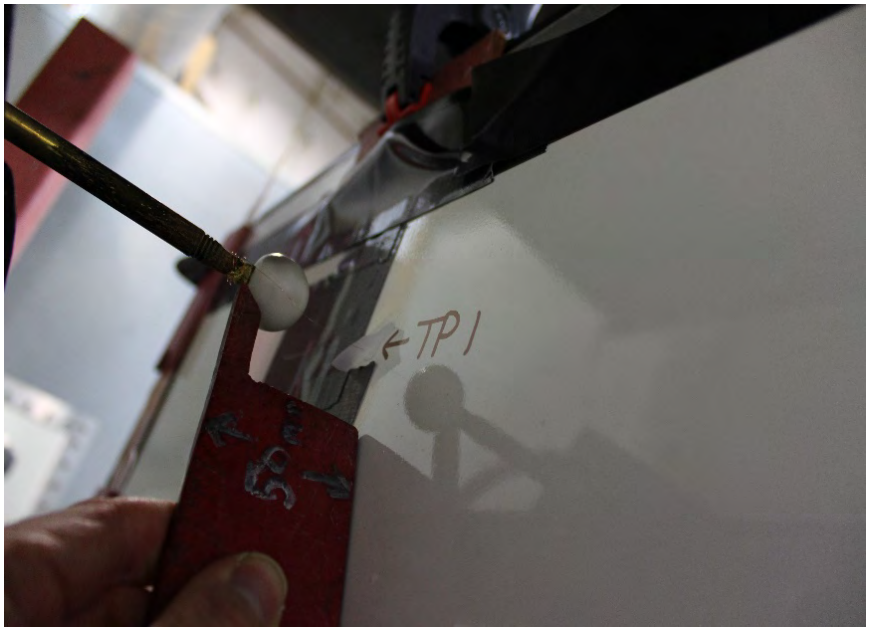


Figure 53: Arc Entry Test - 053-83389A-2N35700-057-Installation-Zone 3-TP1-Pre-Test

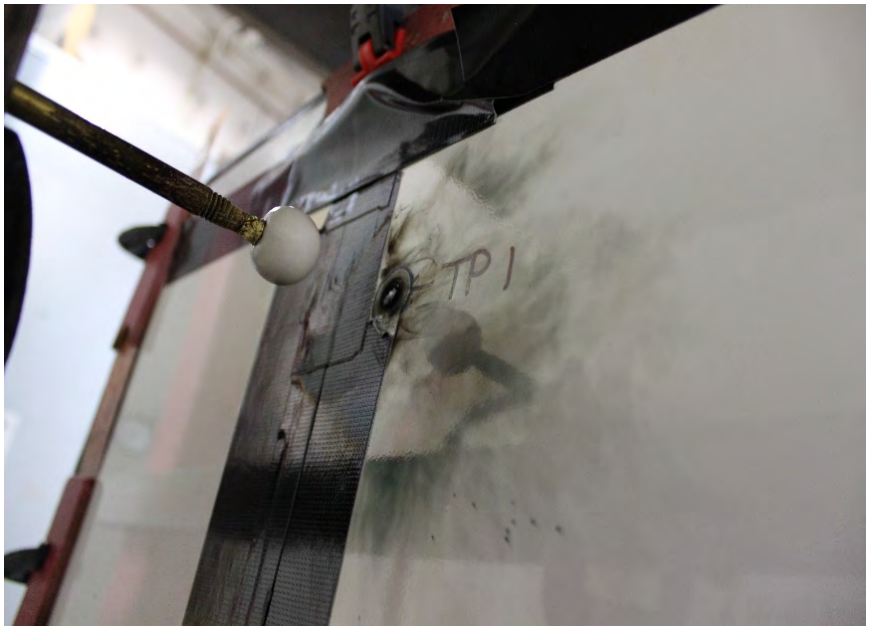


Figure 54: Arc Entry Test - 054-83389A-2N35700-057-Installation-Zone 3-TP1-Post-Test

Figure 55: Arc Entry Test - 055-83389A-2N35700-057-Installation-Zone 3-TP2-Pre-Test

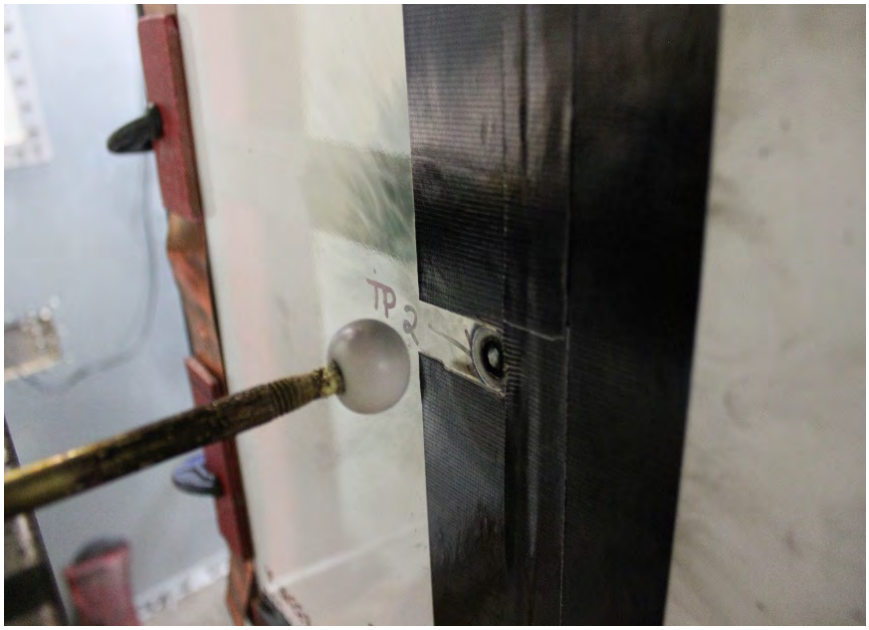


Figure 56: Arc Entry Test - 056-83389A-2N35700-057-Installation-Zone 3-TP2-Post-Test

Figure 57: Arc Entry Test - 057-83389A-2N35700-057-Installation-Zone 3-TP3-Pre-Test

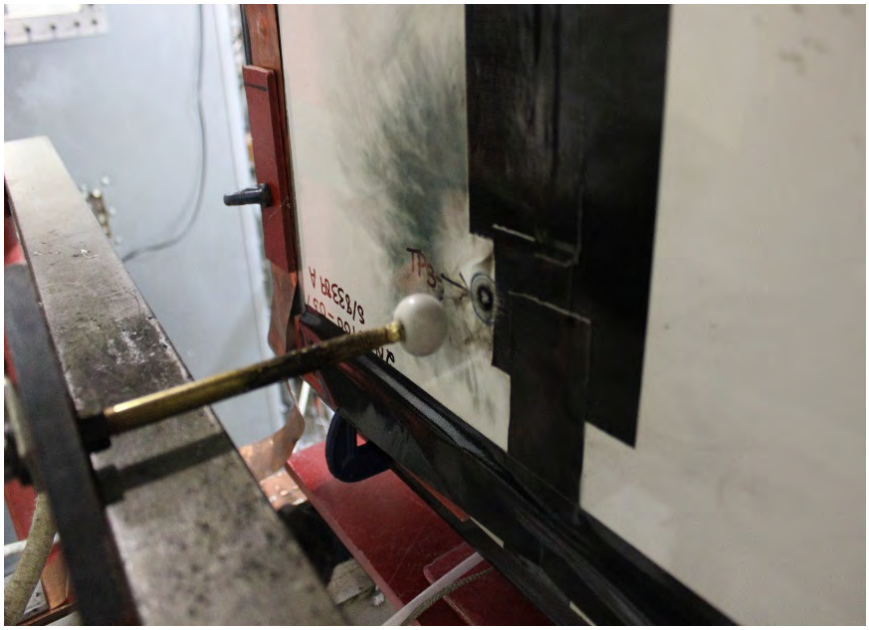


Figure 58: Arc Entry Test - 058-83389A-2N35700-057-Installation-Zone 3-TP3-Post-Test

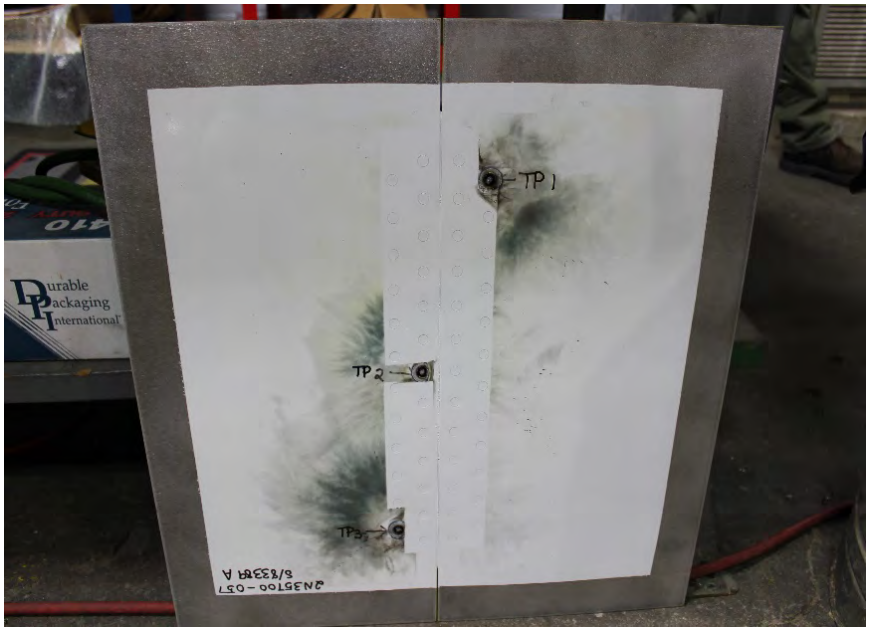


Figure 59: Arc Entry Test - 059-83389A-2N35700-057-Post-Test-1

Figure 60: Arc Entry Test - 060-83389A-2N35700-057-Post-Test-2

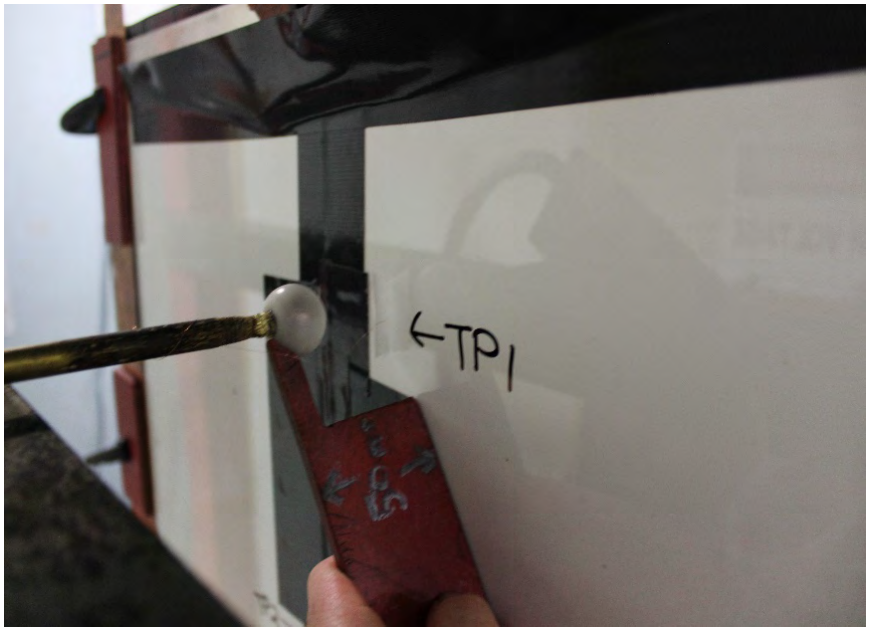


Figure 61: Arc Entry Test - 061-83391A-2N35700-061-Installation-Zone 3-TP1-Pre-Test

Figure 62: Arc Entry Test - 062-83391A-2N35700-061-Installation-Zone 3-TP1-Post-Test

Figure 63: Arc Entry Test - 063-83391A-2N35700-061-Installation-Zone 3-TP2-Pre-Test

Figure 64: Arc Entry Test - 064-83391A-2N35700-061-Installation-Zone 3-TP2-Post-Test

Figure 65: Arc Entry Test - 065-83391A-2N35700-061-Installation-Zone 3-TP3-Pre-Test

Figure 66: Arc Entry Test - 066-83391A-2N35700-061-Installation-Zone 3-TP3-Post-Test

Figure 67: Arc Entry Test - 067-83391A-2N35700-061-Post-Test-1

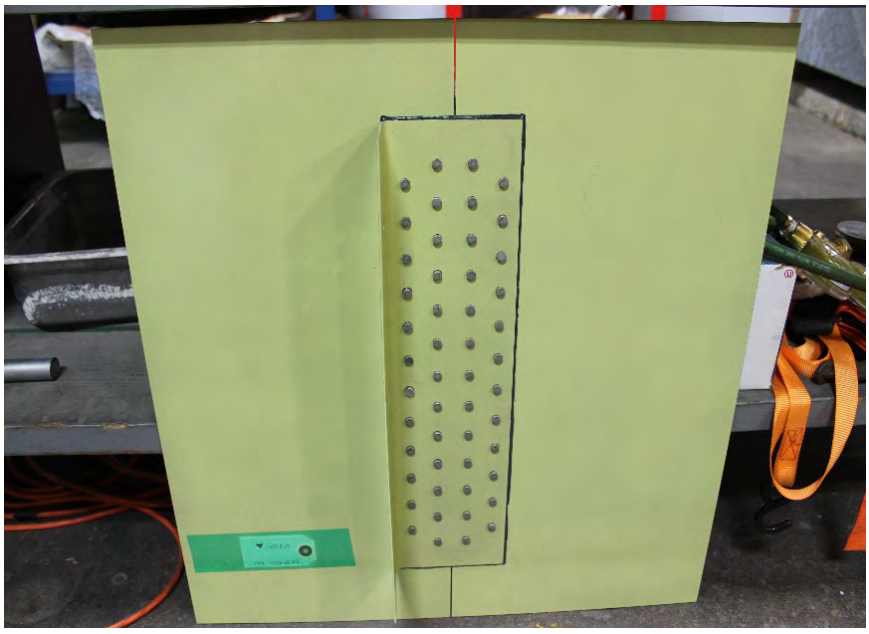


Figure 68: Arc Entry Test - 068-83391A-2N35700-061-Post-Test-2

Appendix C - Test Logs

Figure 1: Lightning Direct Effects Test Log

Customer	KART								
Workorder	ETL-R-009 / 21-PJ0014								
Tested To	DO160G Section 23								
EUT	Aluminum Panels								
Part Number	2N35700-055 S/N 83388A, 2N35700-055 S/N 83388B, 2N35700-053 S/N 83387A, 2N35700-051 S/N 83386A, 2N35700-059 S/N 83390A, 2N35700-057 S/N 83389A, 2N35700-061 S/N 83391A								
Serial Number	Noted								
Test Section	Lightning Direct Effects			**Category**	XX3N				
Tested By	Alyssa Gonzalez, Rebeka Khajehpour, Brian Mamaril								
Test Witness	N/A								
Start Date	1/5/2021								
End Date	1/7/2021								
Lab Conditions	**Date**	**Temp**	**Humidity**	**Date**	**Temp**	**Humidity**	**Date**	**Temp**	**Humidity**
	1/5/21	63.2°F	28.4%RH						
	1/6/21	65.7°F	26.4%RH						
	1/7/21	65.0°F	33.8%RH						

Test Log Data		
Date	**Time**	**Notes**
1/5/2021	10:00 AM	Gas verification completed, 9 detonations in a row, 7% hydrogen, less than 200µJ arc.
	10:50 AM	First verification completed. Component B did not fire, Component A peak amplitude high; all other components meet requirement.
	11:16 AM	Second verification completed. Component A peak amplitude high; all other components meet requirement.
	11:39 AM	Third verification completed. All components meet requirement.
1/5/2021	4:20PM	Testing to resume tomorrow.
1/6/2021	8:35AM	Gas verification completed.
	9:30AM	Bonding Panel 83388A to generator return: 0.2453mΩ
	9:37AM	Panel 83388A TP1 completed; gas didn't ignite. Component A/5 action integral below requirement; all other component requirements met.

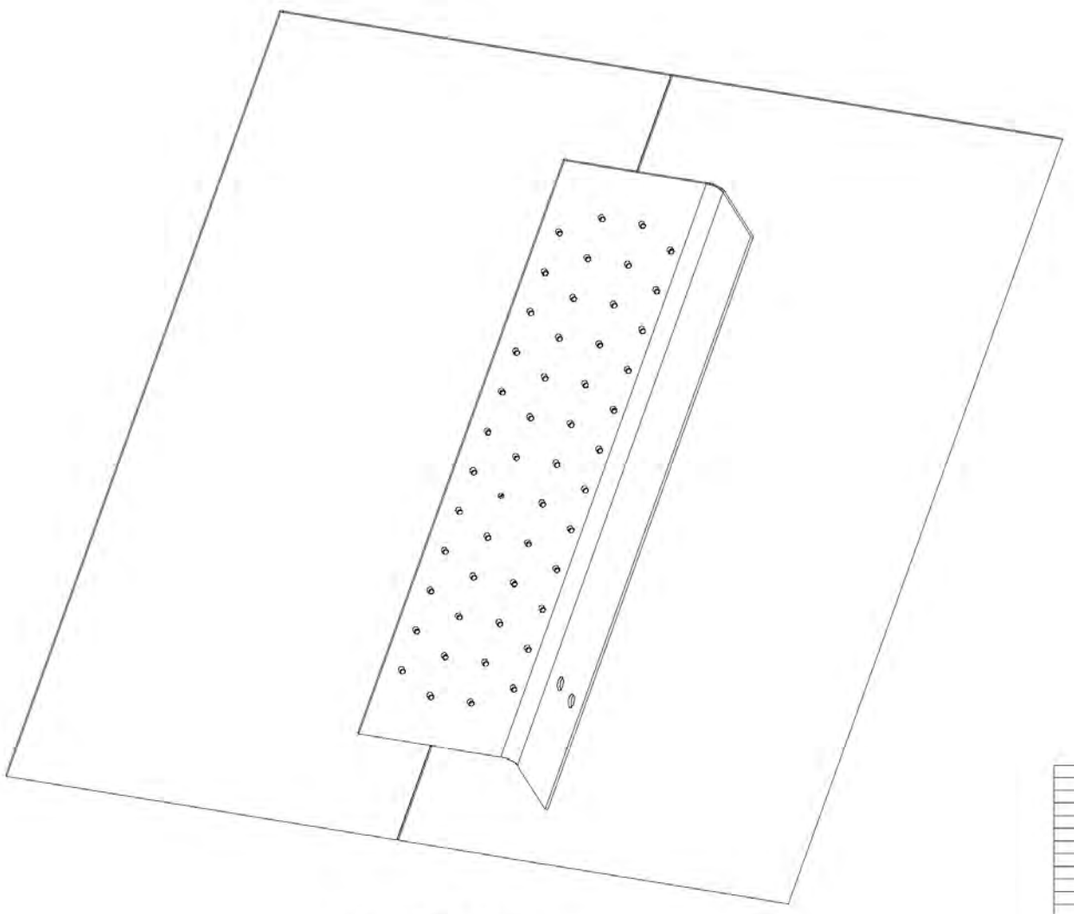
Test Log Data		
Date	**Time**	**Notes**
	9:38AM	Gas ignited with 166µJ arc.
		Panel 83388A TP2 will be used for generator verification. Winding added at generator output to adjust Component A/5.
	10:29 AM	Panel 83388A TP2 completed; gas didn't ignite. Component A/5 action integral below requirement; all other component requirements met.
	10:30 AM	Gas ignited with 157µJ arc.
		Panel 83388A TP3 will be used for generator verification. A-Bank charge voltage increased.
	10:57 AM	Panel 83388A TP3 completed; gas didn't ignite. Component A/5 peak amplitude nominally above requirement; all other component requirements met.
	10:58 AM	Gas ignited with 184µJ arc.
		Panel 83388A TP4 (at top of panel) will be used for generator verification.
	11:27 AM	Panel 83388A TP4 completed; gas didn't ignite. Component requirements met.
	11:28 AM	Gas ignited with 175µJ arc.
		Setup for Panel 83388B TP1.
	1:17PM	Bonding Panel 83388B to generator return: 0.2574mΩ
	1:22PM	Panel 83388B TP1 completed; gas didn't ignite. Component requirements met.
	1:23PM	Gas ignited with 144µJ arc.
		Setup for Panel 83388B TP2.
	1:39PM	Panel 83388B TP2 completed; gas didn't ignite. Component requirements met.
	1:40PM	Gas ignited with 170µJ arc.
		Setup for Panel 83387A TP1.
	2:24PM	Bonding Panel 83387A to generator return: 0.2410mΩ
	2:31PM	Panel 83387A TP1 completed; gas didn't ignite. Component A/5 action integral nominally high; all other component requirements met.

Test Log Data		
Date	**Time**	**Notes**
	2:32PM	Gas ignited with 189µJ arc.
		Setup for Panel 83387A TP2.
	2:53PM	Panel 83387A TP2 completed; gas didn't ignite. Component A/5 peak amplitude and action integral nominally high; all other component requirements met.
	2:54PM	Gas ignited with 157µJ arc.
		Setup for Panel 83387A TP3.
	3:12PM	Panel 83387A TP3 completed; gas didn't ignite. Component A/5 peak amplitude and action integral nominally high; all other component requirements met.
	3:13PM	Gas ignited with 199µJ arc.
		Setup for Panel 83386A TP1.
	3:50PM	Bonding Panel 83386A to generator return: 0.2861mΩ
	3:58PM	Panel 83386A TP1 completed; gas didn't ignite. Component A/5 action integral nominally high; all other component requirements met.
	3:59PM	Gas ignited with 194µJ arc.
1/6/2021	4:30PM	Testing to resume tomorrow.
1/7/2021	9:00AM	Gas verification completed.
		Setup for Panel 83386A TP2.
	9:41AM	Panel 83386A TP2 completed; gas didn't ignite. Component requirements met.
	9:42AM	Gas ignited with 185µJ arc.
		Setup for Panel 83386A TP3.
	10:14 AM	Panel 83386A TP3 completed; gas didn't ignite. Component A/5 peak amplitude and action integral nominally high; all other component requirements met.
	10:15 AM	Gas ignited with 171µJ arc.
		Setup for Panel 83390A TP1.
		Bonding Panel 83390A to generator return: 0.2644mΩ

Test Log Data		
Date	**Time**	**Notes**
	11:21 AM	Panel 83390A TP1 completed; gas didn't ignite. Component requirements met.
	11:22 AM	Gas ignited with 162µJ arc.
	11:42 AM	Setup for Panel 83390A TP2.
	11:43 AM	Panel 83390A TP2 completed; gas didn't ignite. Component requirements met.
		Gas ignited with 190µJ arc.
		Setup for Panel 83390A TP3.
	11:58 AM	Panel 83390A TP3 completed; gas didn't ignite. Component requirements met.
	11:59 AM	Gas ignited with 190µJ arc.
		Setup for Panel 83389A TP1.
	1:50PM	Bonding Panel 83389A to generator return: 0.3595mΩ
	1:56PM	Panel 83389A TP1 completed; gas didn't ignite. Component A/5 action integral nominally high; all other requirements met.
	1:57PM	Gas ignited with 190µJ arc.
		Setup for Panel 83389A TP2.
	2:23PM	Panel 83389A TP2 completed; gas didn't ignite. Component requirements met.
	2:24PM	Gas ignited with 195µJ arc.
		Setup for Panel 83389A TP3.
	2:41PM	Panel 83389A TP3 completed; gas didn't ignite. Component A/5 peak amplitude and action integral nominally high; all other requirements met.
	2:42PM	Gas ignited with 195µJ arc.
		Setup for Panel 83391A TP1.
	3:15PM	Bonding Panel 83391A to generator return: 0.2686mΩ
	3:22PM	Panel 83391A TP1 completed; gas didn't ignite. Component requirements met.
	3:23PM	Gas ignited with 190µJ arc.
		Setup for Panel 83391A TP2.

Test Log Data		
Date	**Time**	**Notes**
	3:36PM	Panel 83391A TP2 completed; gas didn't ignite. Component requirements met.
	3:37PM	Gas ignited with 200µJ arc.
		Setup for Panel 83391A TP3.
	3:51PM	Panel 83391A TP3 completed; gas didn't ignite. Component A/5 peak amplitude nominally high.
	3:52PM	Gas ignited with 185µJ arc.
1/7/2020	4:30PM	Test completed.

Appendix D – Test Article Engineering Drawings



ZONE 3 TEST ARTICLE ASSY

NOTES:

1. INTERPRET THIS DATASET PER ASME Y14. 100 - 2017
2. DIMENSIONS AND TOLERANCES PER ASME Y14.5 - 2009
3. MASK OFF INDICATED AREA BEFORE APPLYING ANY COATINGS.
4. WET INSTALL ALL FASTENERS PER PPG PR-1440 CLASS B FUEL TANK SEALANT TECHNICAL DATA SHEET. APPLY PR-1440 CLASS B FUEL TANK SEALANT TO THE SHANK AND UNDER THE HEAD OF THE FASTENER ENSURING FULL COVERAGE PRIOR TO INSTALLATION. THREADS MUST BE FREE OF SEALANT BEFORE AND AFTER INSTALLATION. IF TRACES ARE VISIBLE AFTER INSTALLATION, WIPE OFF WITH CLEAN DRY CLOTH. DO NOT USE SOLVENT. DURING INSTALLATION, A BEAD OF SEALANT MUST BE FORCED OUT FROM THE HEAD OF THE FASTENER. USE A DRY CLOTH TO WIPE OFF EXCESS SEALANT BEFORE CURE.
5. FS = FASTENER MANUFACTURED HEAD FAR SIDE.
6. FINISH ALODINE PLUS ONE COAT OF FUEL TANK PRIMER.
7. FAY SEAL ALL MATING SURFACES. APPLY PR-1440 CLASS B SEALANT WITH A ROLLER TO ONE OR BOTH FAYING SURFACES. ENSURE ALL AREAS OF THE FAYING SURFACE HAVE A MINIMUM APPLIED FILM THICKNESS OF 0.005 INCH BEFORE ASSEMBLY. AFTER ASSEMBLY, A CONTINUOUS BEAD OF SEALANT MUST BE CLEARLY VISIBLE AT THE PERIFERY OF FAYING SURFACES AS EVIDENCE THAT THE JOINTS ARE FILLED. A CONTINUOUS BEAD OF SEALANT MUST REMAIN ALONG ALL EDGES. EXCESSIVE SEALANT SQUEEZE OUT MUST EITHER BE SMOOTHED INTO A FILLET SEAL OR CLEANED WITH A CLEAN DRY CLOTH.
8. TOP COAT (TBD) APPLIED EXCEPT WHERE NOTED ON FAR SIDE ONLY.

QTY PER ASSY						ITEM	PART NUMBER	DESCRIPTION	MATERIAL/SUPPLIER	SIZE	NOTES
-061	-059	-057	-055	-053	-051						
			50			22	HST79CY8				
				50		21	HST79CY5				
					50	20	HL70-8				
						19	HL70-5				
						18					
	50					17	NAS1097AD8-5				INSTALL IN ∅.247-.250 HOLE
		50				16	NAS1097AD5-5				INSTALL IN ∅.161-.164 HOLE
			50			15	HST11VBJ8-5				INSTALL IN ∅.247-.250 HOLE
				50		14	HST11VBJ5-5				INSTALL IN ∅.161-.164 HOLE
					50	13	HL11VBJ8-5				INSTALL IN ∅.247-.250 HOLE
						12	HL11VBJ5-5				INSTALL IN ∅.161-.164 HOLE
						11					
1	1	1	1	1	1	10	ZN35700-105	ANGLE	AL CLAD 2024-T3 (AMS-QQ-A-250/5)	0.080 THK	
2	2	2	2	2	2	9	ZN35700-103	PANEL	AL CLAD 2024-T3 (AMS-QQ-A-250/5)	0.080 THK	
						8					
						7					
						6	ZN35700-061	TEST ARTICLE ASSY			ASSY QTY = 2
						5	ZN35700-059	TEST ARTICLE ASSY			ASSY QTY = 2
						4	ZN35700-057	TEST ARTICLE ASSY			ASSY QTY = 2
						3	ZN35700-055	TEST ARTICLE ASSY			ASSY QTY = 2
						2	ZN35700-053	TEST ARTICLE ASSY			ASSY QTY = 2
						1	ZN35700-051	TEST ARTICLE ASSY			ASSY QTY = 2

PARTS LIST INFORMATION

C. Sparten	7/27/2020	
XXX	XX/XX/XXXX	
XXX	XX/XX/XXXX	

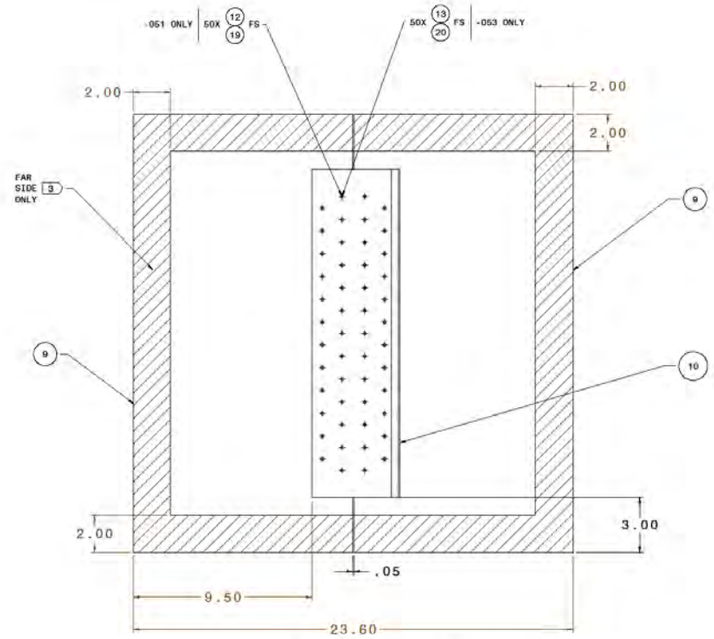
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES
TOLERANCES ON
DECIMALS .X = ±.1 .XX = ±.05 .XXX = ±.010
ANGLES ±30'

NATIONAL INSTITUTE FOR AVIATION RESEARCH, ETL

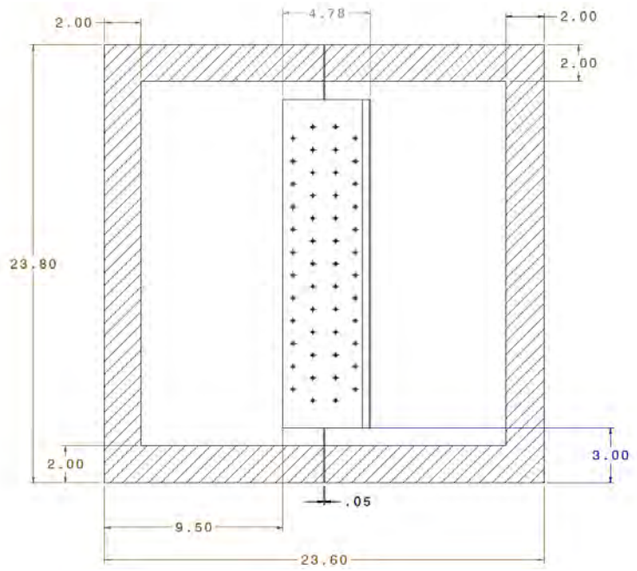
TITLE: ZONE 3 TEST ARTICLE ASSY

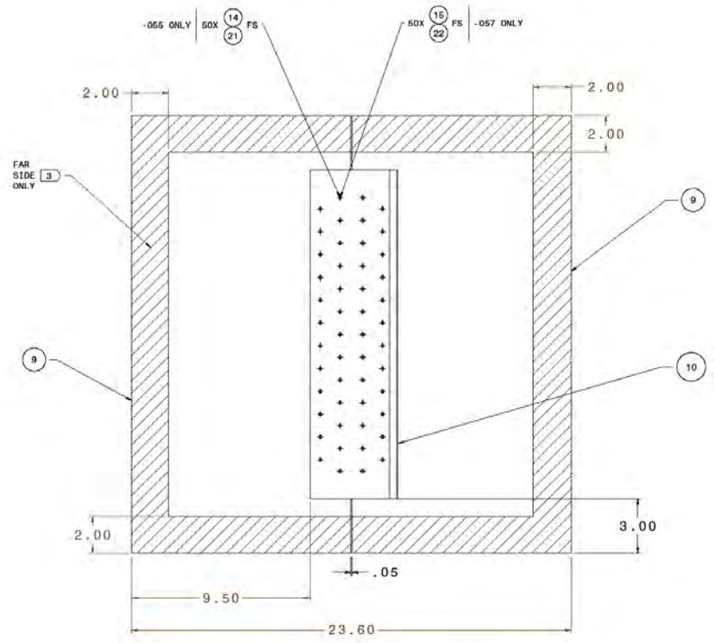
DESIGNG NO	REV
ZN35700	X

SCALE: NONE SHEET 1 OF 3



-051 TEST ARTICLE ASSEMBLY 8
-053 TEST ARTICLE ASSEMBLY 8





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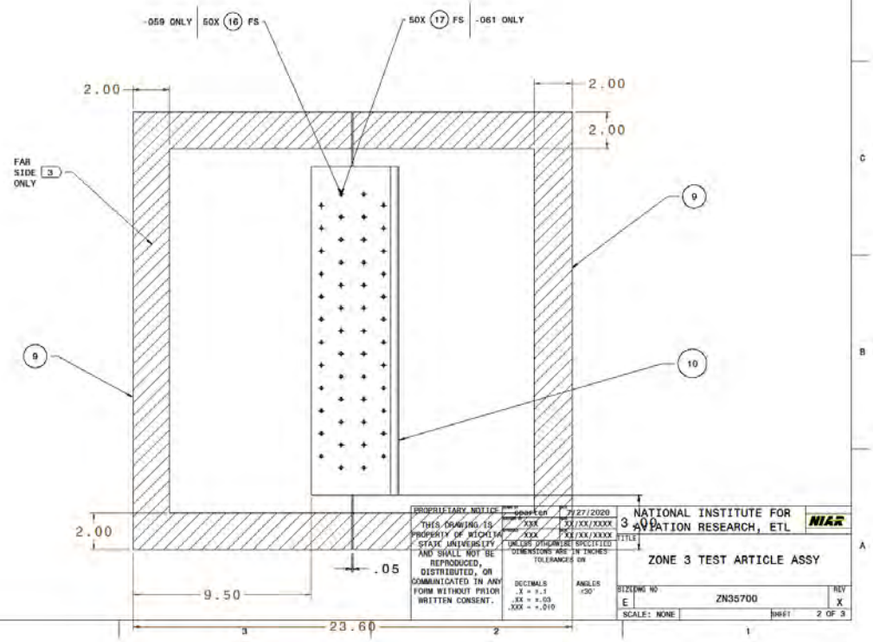
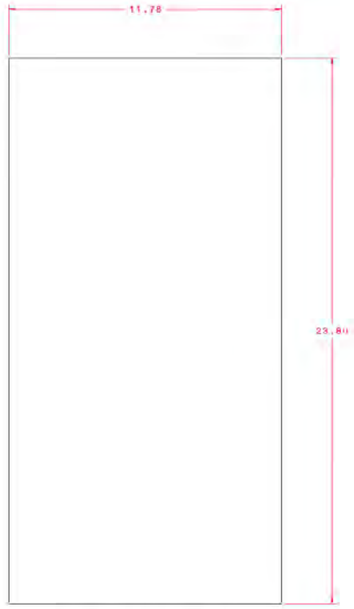
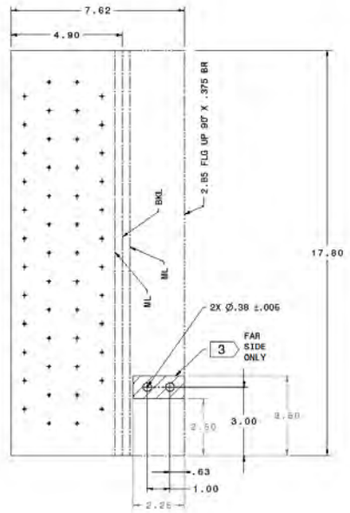
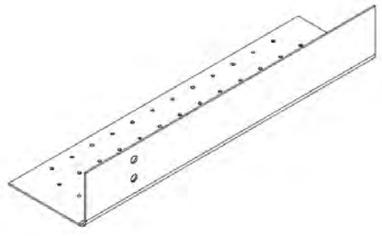


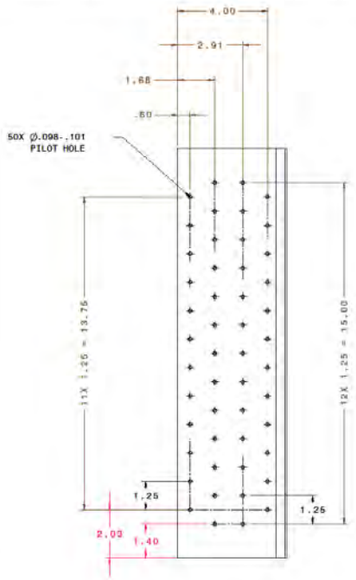


-103 PANEL 6

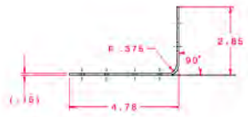


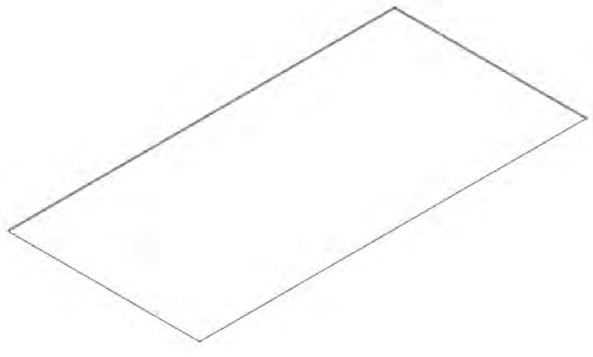
-105 ANGLE
FLAT PATTERN





-105 ANGLE 6





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	XXX	XX/XX/XXXX	
	XXX	XX/XX/XXXX	TITLE: ZONE 3 TEST ARTICLE ASSY
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ON: DECIMALS .X = ±.1 .XX = ±.03 .XXX = ±.010 ANGLES ±30'			SIZE: E; DWG NO: ZN35700; REV: X; SCALE: NONE; SHEET: 3 OF 3