National Institute for Aviation Research
Wichita State University

1845 N. Fairmount

Wichita, Kansas 67260-0093

23-2152-RR53206

Kansas Aviation Research and Technology (KART) Program

Direct Attachment to Fasteners in Metal Bonded Skins Test Report

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Written by: Bethany Dalton	Date: 05/05/2023
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Section	Description
All	Initial Release of Document

Revision A	
Written by: Rebeka Khajehpour	Date: 05/26/2023
Reviewed by: Nick Conquest	Date: 08/23/2023
Approved by: Reid Owens	Date: 08/31/2023

Section	Description
All	Page formatting was made more uniform
Table of Contents	Page numbers were updated
List of Tables	Page numbers were updated
List of Figures	Page numbers were updated
4.1.1	Table 2 was modified for added detail and to correct the total stack-up thickness column

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List of Abbreviations, Acronyms, and Symbols

A, Amp	Amperes
ARP	Aerospace Recommended Practice
C	Coulomb
DEL	Direct Effects of Lightning
ETL	Environmental Test Laboratory
EUT	Equipment Under Test
KART	Kansas Aviation Research and Technology
kA	Kilo amperes
kA^2s	Kilo amperes squared seconds (measure of action integral)
µJ	micro joules
µs	Microseconds
mm	Millimeters
mm^2	Millimeters squared
mΩ	Milliohms
ms	Milliseconds
NIAR	National Institute for Aviation Research
Ω	Ohms
RH	Relative humidity
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

Table 1: Applicable Documents

Document Number	Description
SAE Aerospace ARP 5412B Revised 2013	Aircraft Lightning Environment and Related Test Waveforms
SAE Aerospace ARP 5414B Revised 2018	Aircraft Lightning Zone
SAE Aerospace ARP 5416A Revised 2013	Aircraft Lighting Test Methods
NIAR Document ENV-WP-2016-001 2015	Test Articles Manufacturing and Fastener Installation Requirements in Application to Metal Fuel Tank Lightning Sparking Threshold Identification
Document No 23-2152-TP035	Direct Attachment to Fasteners in Metal Bonded Skins Test Plan
DOT/FAA/CT-94/74 1994	Aircraft Fuel System Lightning Protection Design and Qualification Test Procedures Development, Final Report

2.0 Scope

This document contains the test results for the environmental effects testing of the KART test articles 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 National Institute for Aviation Research (NIAR) Environmental Test Laboratory (ETL) located at 3800 S. Oliver Wichita, Kansas 67210 and from April 6, 2023 to April 29, 2023.

Test setups and testing procedures were verified to be in compliance with Document No 23-2152-TP035. The test shot log containing waveform data for each test point is provided in Appendix A. Pre-test and post-test photos of the test articles are provided in

Appendix B. Test logs are provided in Appendix C. Appendix D contains deviations from the test plan or approved procedures. Appendix E contains the test article engineering drawings.

2.1 Purpose

This test was designed to determine the minimum thickness of assemblies which will prevent fuel vapor ignition as a result of direct attachment lightning current. The test assembly configurations contained thin aluminum bonded skins fastened to representative internal structure. The test articles were evaluated in lightning Zones 1A, 1C, 2A and 3 using the flammable gas ignition source detection method from SAE ARP 5416A, section 7.7.2 to determine whether fasteners in a particular joint assembly will ignite a gas mixture at the established test level.

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 NIAR ETL on the KART test articles.

3.1 Test Witnessing

Test was conducted by NIAR's Rebeka Khajehpour, Alyssa Gonzalez, Beth Dalton, David Bruner, Mel St. John, and Ted Angleton.

4.0 Arc Entry

4.1 General Test Setup

General test setup figures can be found in Figure 1 through Figure 5.

4.1.1 Test Article Design

The test article design represented generic fuel tank structure of wing skins joined with fasteners to a rib/spar. The skin panels were made of two plies of aluminum of the same

thickness joined by an adhesive between them. The test article configurations are detailed in Table 2. The same fasteners were used for each configuration, while the thickness of the skin and internal structure was varied.

Multiple test points were performed on each panel but to avoid electrical conditioning of the subsequent test points, they were spaced far enough apart so that the damage from the test points did not visibly overlap. Appendix E contains the test article engineering drawings.

Table 2: Test Article Panel List

Zone	Fastener	Skin Thickness (in)	Spar/Rib Thickness (in)	Thickness of Adhesive (in)	Total Stack-up Thickness (in)	Test Points	Configuration
1A	HST11BJ5-2	0.016+0.016	0.08	0.01	0.122	5	-01
	HST11BJ5-3	0.025+0.025	0.08	0.01	0.14	5	-04
	HST11BJ5-3	0.032+0.032	0.08	0.01	0.154	5	-05
1C	HST11BJ5-2	0.008+0.008	0.063	0.01	0.089	5	-09
	HST11BJ5-2	0.012+0.012	0.063	0.01	0.097	5	-06
	HST11BJ5-2	0.016+0.016	0.063	0.01	0.105	5	-02
2A	HST11BJ5-2	0.008+0.008	0.05	0.01	0.076	5	-10
	HST11BJ5-2	0.012+0.012	0.05	0.01	0.084	5	-07
	HST11BJ5-2	0.016+0.016	0.05	0.01	0.092	5	-03
3	HST11BJ5-2	0.008+0.008	0.05	0.01	0.076	5	-11
	HST11BJ5-2	0.012+0.012	0.05	0.01	0.084	5	-08

4.1.2 High Current Generator

The test articles were installed near the output of the high current generator, which allowed the arc to be discharged into the test point via the jet-diverting electrode. The panels were electrically bonded to the generator return by clamping copper straps between the exposed bare aluminum boarder of the test article and the generator return. This test setup is depicted in Figure 1.

High current probes were used at the lightning generator output to record the applied waveforms, one each for current Component A (and all variations; A/5, A_H, and D), B, and C*. An oscilloscope recorded the output of the generator via the current probes.

The required parameters for each current component are listed in Table 3. Laboratory equipment utilized during testing is detailed in Table 4.

Waveform verification was performed by initiating a high-current discharge into an aluminum plate terminated to the generator return.

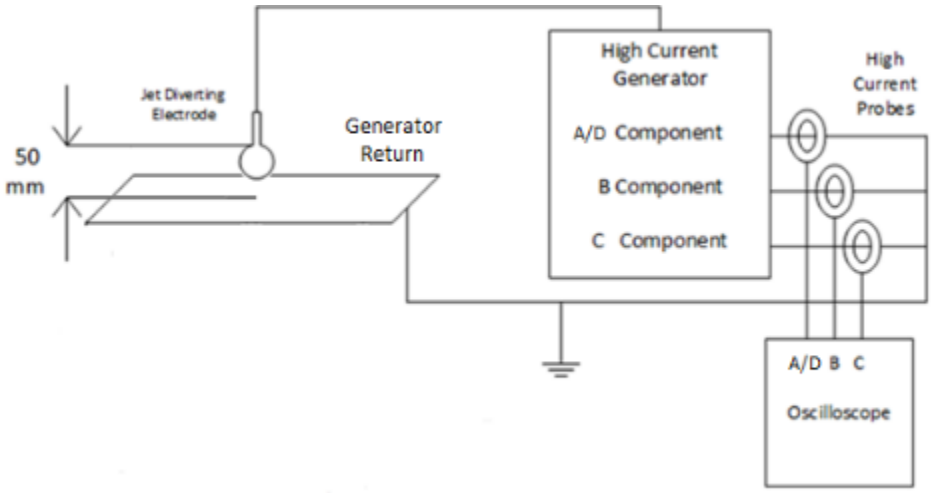

Figure 1: Waveform Verification Setup

The arc was directed toward each designated test point using an initiating wire extending from the jet-diverting electrode from a distance of 50 mm from the surface of the test article, as seen in Figure 2, and defined by ARP 5416A.

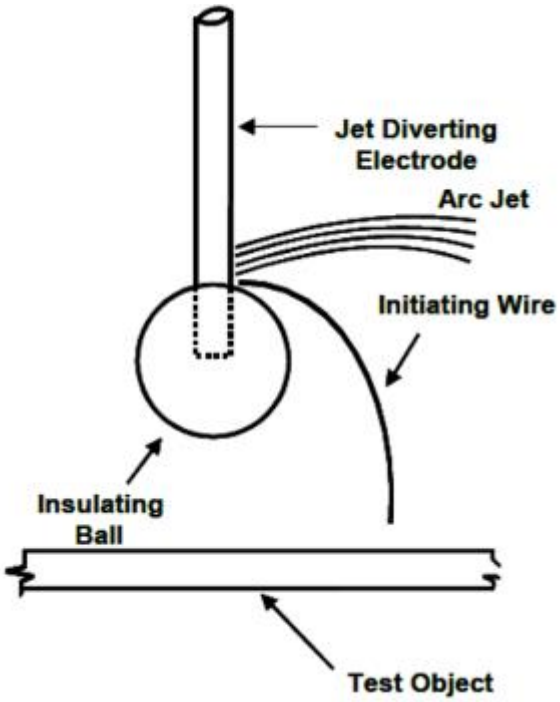

Figure 2: Jet-Diverting Electrode

The current Components described in were applied to the test article for each of the following lightning Zones:

- Zone 1A: Components A, B, C*
- Zone 1C: Components A_H, B, C*
- Zone 2A: Components B, C*, D
- Zone 3: Components A/5, B, C*

Table 3: Current Component Requirements

Component A	Peak Amplitude	200kA ± 10%
	Action Integral	$2MA^2s$ ± 20%
	Rise Time to 90% Peak	< 50µs
	Total Duration	< 500µs
Component A_H	Peak Amplitude	150kA ± 10%
	Action Integral	$800kA^2s$ ± 20%
	Rise Time to 90% Peak	< 50µs
	Total Duration	< 500µs
Component A/5	Peak Amplitude	40kA ± 10%
	Action Integral	$80kA^2s$ ± 20%
	Rise Time to 90% Peak	< 50µs
	Total Duration	< 500µs
Component B	Average Amplitude	2kA ± 20%
	Charge Transfer	10C ± 10%
	Total Duration	5ms ± 10%
Component C*	Average Amplitude	≥ 400A
	Charge Transfer	18C ± 20% or 6C ± 20%
	Total Duration	45ms ± 20% or 15ms ± 20%
Component D	Peak Amplitude	100kA ± 10%
	Action Integral	$250kA^2s$ ± 20%
	Rise Time to 90% Peak	< 25µs
	Total Duration	< 500µs

Table 4: Equipment Used For Lightning Direct Effects Testing

Description	Manufacturer	Model Number	Serial Number	Cal Due Date
Analog Voltage Input Module	Yokogawa	701250	91P321166	9/30/2023
Micro-Ohmmeter	Keithley	580	0685151	9/30/2023
High Current Generator	NIAR	HC1	001	N/A
Current Monitor Probe 100:1	Pearson Electronics Inc.	301X	147836	8/3/2023
Barometric Pressure and Humidity	Extech	SD700	Q774074	3/16/2024
Oscilloscope	Yokogawa	DL850E	91P313729	9/30/2023
HV Power Supply	Spellman	SL8PN2000X4874	102151349-A00001	N/A
Current Probe 1:1500	Danisense	DS600IDSA	14170020014	8/4/2023
Current Monitor Probe	Pearson Electronics Inc.	1423	147997	8/3/2023
HV Power Supply	Spellman	STR70N6/200/3PHASE	102186808-A00003	N/A

Description	Manufacturer	Model Number	Serial Number	Cal Due Date
Analog Voltage Input Module	Yokogawa	701250	91P321170	9/30/2023
Isolation Transformer 125-115-105V	Chicago Standard	P-6161	2152-IT-01-E-005	N/A
High-Voltage Electrostatic Voltmeter	Trek	341B-L-CE	304	2/13/2024
4 Channel 100MHz 1GSa/s	Rigol	DS1104Z	DS1ZA181305414	11/30/2023
Fuel Flow control	NIAR	FFC001	001	N/A
Mass Flow Controller 0-20 SKM H2	Omega	FMA5524A-H2	484161-1	11/15/2023
Massflow Controler Economical Gas	Omega	FMA5543	483712-1	11/15/2023
Digibridge	Gen Rad Inc.	1689	8243454004	10/31/2023
200uj Spark Circuit	NIAR	SS001	001	N/A
Single Stage Best Value Regulator Nitrogen	Harris	25GX-145-580	2152-RN-01-E-001	N/A
#5 EOS Rebel T6i Camera	Canon	DS126571	352072015527	N/A
#5 EOS Rebel 18-55mm Camera Lens	Canon	EFS 18-55mm	610204005413	N/A

General test setup photos are shown in Figure 3, Figure 4, and Figure 5.

Figure 3: General Test Setup

Figure 4: General Panel Installation

Figure 5: General Gas Test Setup

4.1.3 Flammable Gas Ignition Detection

The flammable gas ignition source detection method was used in accordance with SAE ARP 5416A section 7.7.2. A mixture of seven percent hydrogen and 93 percent air by volume was selected as the gas mixture.

The test setup consisted of a fuel flow setup and a voltage spark-source setup, as seen in Figure 6. The fuel flow setup included the hydrogen and air mass flow controllers, and

the associated tubing, hoses, and test chamber containing the flammable gas mixture, with the foil blowout panel. The spark source setup consisted of the spark source circuit, the high voltage power supply, the electrostatic voltmeter, and the oscilloscope for the electrostatic voltmeter. The spark source capacitance was measured with a capacitance bridge. During this test the electrostatic voltmeter required repair which is detailed in Appendix D

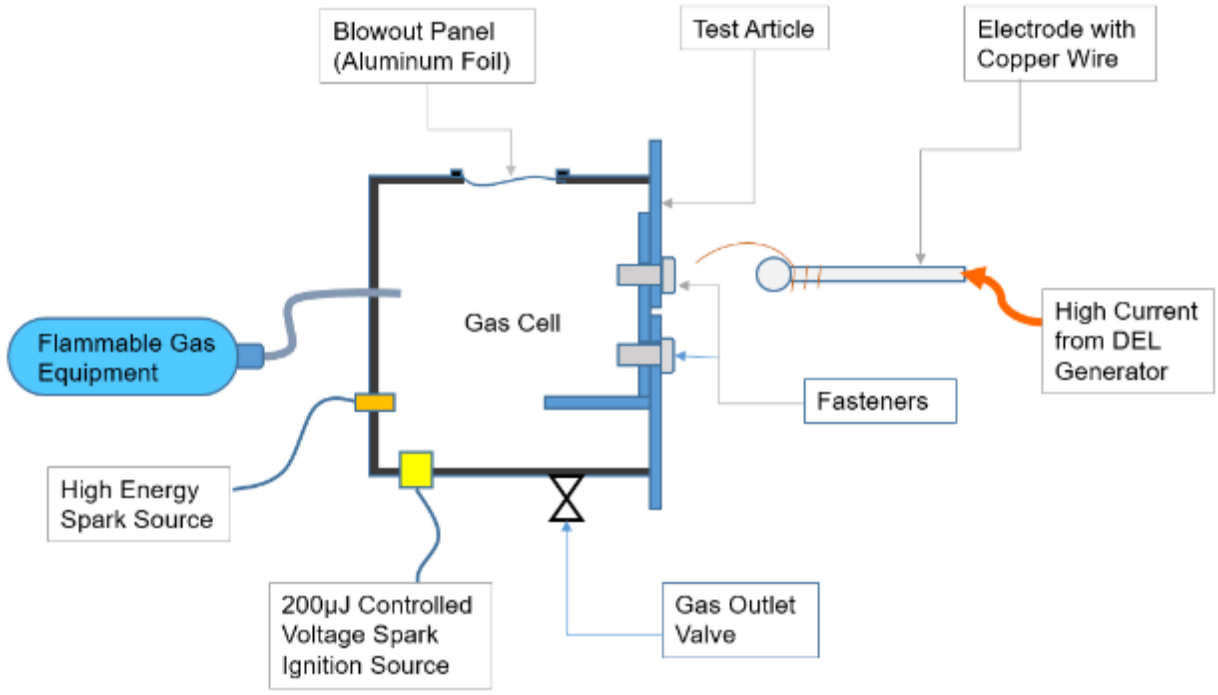

Figure 6: Test Setup Diagram

4.2 Results and Testing

Direct attachment lightning testing was performed for Zones 1A, 1C, 2A, and 3. For each of the test panels, five of the fasteners on the panel were selected as test points for direct attachment testing. If the gas ignited as a result of the lightning direct attachment test point, then the test is considered to have failed. Table 5 details the ignition results of the direct attachment testing. All waveform data associated with this test can be found in Appendix A of this report. Photographs of the test setup can be found in Appendix B.

Table 5: Ignition Results

Configuration	Zone	Ignition/Failure
-01	1A	**Yes** (1/5 test points ignited/failed)
-04		**Yes** (2/2 test points ignited/failed)
-05		N/A - Omitted from testing due to damage severity
-09	1C	**Yes** (1/5 test points ignited/failed)
-06		No
-02		No
-10	2A	No
-07		No
-03		No
-11	3	No
-08		No

There were no failures on any configuration in Zone 3 or Zone 2A. The -09 configuration had two out of five test points fail in Zone 1C. The -01 configuration had one out of five test points fail in Zone 1A. The -04 configuration had two out of two test points fail in Zone 1A.

The failures observed for the -04 configuration were considered to be unusual in nature due to the fastener being fully ejected from the panel as a result of lightning testing. This unusual failure for the -04 configuration was possibly attributed to the rework done to the panel, as well as its very thin skin. The -04 panels were first fabricated with protruding head fasteners, which were later removed and replaced with the correct countersunk fasteners. An example of the panels before and after being reworked can be seen in Figure 7 and Figure 8, while the fastener that was expelled from the panel can be seen in Figure 9.

The remaining test points on the -04 configuration were omitted due to the severity of damage that occurred on the first two test points. Extensive damage was expected to also occur on the -05 configuration in Zone 1A because it received the same rework as the -04 panel, so the -05 configuration was omitted from testing entirely.

Due to the unlikely nature of having fasteners installed in a metal bonded skin in a Zone 1A region of an aircraft, Zone 1A testing has been omitted from the upcoming Phase II of this work.

Any invalid test points that occurred throughout testing are listed in Appendix D. Invalid test points were not considered in the data analysis for this test.

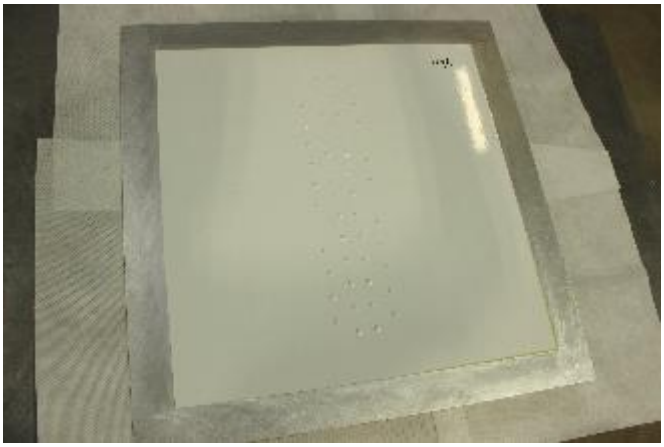

Figure 7: Example of Paint Appearance Before Rework (Panel -04A)

Figure 8: Example of Paint Appearance After Rework (Panel -04A)

Figure 9: Fastener after being expelled from panel (Panel -04A TP1)

5.0 Conclusions

Each of the panel configurations for each of the lighting Zones had differing skin and spar thicknesses. The thinnest configuration in which failure did not occur during testing in each Zone is detailed in Table 6.

Table 6: Minimum Configuration Thickness Threshold to Prevent Ignition

Zone	Configuration	Thickness Threshold to Prevent Ignition
1A	N/A	Not determined due to extensive damage
1C	-06	0.012”+0.012” skin w/ 0.063” spar
2A	-10	0.008”+0.008” skin w/ 0.05” spar
3	-11	0.008”+0.008” skin w/ 0.05” spar

Due to the cancelation of the Zone 1A testing, a minimum thickness threshold was not determined.

Since an ignition occurred on the -09 configuration in Zone 1C, the minimum thickness threshold was determined to be the -06 configuration which did not result in any ignitions during testing.

The minimum thickness configurations determined as the threshold thicknesses for Zones 2A and 3 were the -10 and -11 configurations respectively.

Appendix A - Waveform Test Data Shot Log

Figure A-1: Zone 3 Shot Log

EUT	Test Point	Components	Component A/5				Component B			Component C/C*			Notes
			Peak Amplitude (kA)	A/I (AAs)	Rise Time (µs)	Duration (µs)	Average Amplitude (A)	Charge Transfer (C)	Duration (ms)	Average Amplitude (A)	Charge Transfer (C)	Duration (ms)	
Al Cal Plate	WV01	A/5, B, C*	-37.73	7.02E+04	14	240	2.15E+03	10.73	5.002	465.78	20.40	43.78	23.4 kV D, 5.5 kV B, 24+28g C*
-11A	TP1	A/5, B, C*	-34.27	4.57E+04	16	168	2.12E+03	10.60	5.002	402.48	23.17	57.58	23.4 kV D, 5.5 kV B, 24+28g C*
-11A	TP2	A/5, B, C*	-40.93	6.73E+04	16	184	2.03E+03	10.17	5.002	344.68	7.74	22.46	27.3 kV D, 5.5 kV B, 24+28g C*
-11A	TP3	A/5, B, C*	-44.27	9.43E+04	14	230	2.14E+03	10.68	5	425.06	22.36	52.60	27.3 kV D, 5.5 kV B, 24+28g C*
-11A	TP4	A/5, B, C*	-39.80	7.56E+04	16	222	2.14E+03	10.68	5	435.23	21.30	48.94	24.8 kV D, 5.5 kV B, 24+28g C*
-11A	TP5	A/5, B, C*	-39.53	7.50E+04	14	228	2.14E+03	10.69	5.002	475.53	19.61	41.24	24.8 kV D, 5.5 kV B, 24+28g C*
-11B	TP1	A/5, B, C*	-40.00	7.53E+04	14	218	2.13E+03	10.67	5	455.81	20.74	45.49	24.8 kV D, 5.5 kV B, 24+28g C*
-11B	TP2	A/5, B, C*	-39.80	7.39E+04	16	212	2.14E+03	10.72	5	451.75	20.85	46.16	24.8 kV D, 5.5 kV B, 24+28g C*
-11B	TP3	A/5, B, C*	-39.80	7.71E+04	16	234	2.15E+03	10.75	5	438.24	21.48	49.01	24.8 kV D, 5.5 kV B, 24+28g C*

EUT	Test Point	Components	Component A/5				Component B			Component C/C*			Notes
			Peak Amplitude (kA)	A/I (AAs)	Rise Time (µs)	Duration (µs)	Average Amplitude (A)	Charge Transfer (C)	Duration (ms)	Average Amplitude (A)	Charge Transfer (C)	Duration (ms)	
-11B	TP4	A/5, B, C*	-39.80	7.68E+04	14	232	2.15E+03	10.74	5	462.49	19.89	43.00	24.8 kV D, 5.5 kV B, 24+28g C*
-08A	TP1	A/5, B, C*	-39.80	7.55E+04	16	224	2.15E+03	10.75	5	442.56	21.05	47.56	24.8 kV D, 5.5 kV B, 24+28g C*
-08A	TP2	A/5, B, C*	-39.67	7.32E+04	16	220	2.14E+03	10.70	5	461.17	20.27	43.95	24.8 kV D, 5.5 kV B, 24+28g C*
-08A	TP3	A/5, B, C*	-39.73	7.64E+04	14	228	2.15E+03	10.73	5	449.08	22.05	49.11	24.8 kV D, 5.5 kV B, 24+28g C*
-08A	TP4	A/5, B, C*	-39.73	7.58E+04	16	226	2.15E+03	10.73	5	444.04	22.21	50.02	24.8 kV D, 5.5 kV B, 24+28g C*
-08A	TP5	A/5, B, C*	-39.73	7.63E+04	14	228	2.15E+03	10.74	5	442.67	22.51	50.84	24.8 kV D, 5.5 kV B, 24+28g C*

Figure A-2: Zone 2A Shot Log

EUT	Test Point	Components	Component D				Component B			Component C/C*			Notes
			Peak Amplitude (kA)	A/I (AAs)	Rise Time (µs)	Duration (µs)	Average Amplitude (A)	Charge Transfer (C)	Duration (ms)	Average Amplitude (A)	Charge Transfer (C)	Duration (ms)	
Al Cal Plate	WV02	D, B, C*	-96.93	2.63E+05	8	174	2.14E+03	10.70	5	443.20	22.65	51.09	45.0 kV D, 5.5 kV B, 24+28g C*
-10A	TP1	D, B, C*	-96.53	2.42E+05	10	148	2.13E+03	10.64	5	452.75	21.80	48.16	45.0 kV D, 5.5 kV B, 24+28g C*
-10A	TP2	D, B, C*	-96.00	2.41E+05	8	144	2.07E+03	10.37	5	450.99	21.49	47.71	45.0 kV D, 5.5 kV B, 24+28g C*
-10A	TP3	D, B, C*	-96.00	2.45E+05	8	148	2.12E+03	10.59	5	446.05	22.18	49.73	45.0 kV D, 5.5 kV B, 24+28g C*
-10A	TP4	D, B, C*	-95.53	2.44E+05	10	148	2.14E+03	10.67	5	464.10	20.91	45.06	45.0 kV D, 5.5 kV B, 24+28g C*
-10A	TP5	D, B, C*	-95.20	2.47E+05	8	158	2.13E+03	10.67	5	455.45	20.99	46.08	45.0 kV D, 5.5 kV B, 24+28g C*
-07A	TP1	D, B, C*	-96.73	2.42E+05	8	146	2.13E+03	10.66	5	457.50	20.84	45.56	45.0 kV D, 5.5 kV B, 24+28g C*
-07A	TP2	D, B, C*	-96.53	2.43E+05	8	144	2.13E+03	10.65	5	452.80	21.55	47.60	45.0 kV D, 5.5 kV B, 24+28g C*
-07A	TP3	D, B, C*	-95.93	2.45E+05	8	152	2.12E+03	10.61	5	444.81	21.75	48.89	45.0 kV D, 5.5 kV B, 24+28g C*

EUT	Test Point	Components	Component D				Component B			Component C/C*			Notes
			Peak Amplitude (kA)	A/I (AAs)	Rise Time (µs)	Duration (µs)	Average Amplitude (A)	Charge Transfer (C)	Duration (ms)	Average Amplitude (A)	Charge Transfer (C)	Duration (ms)	
-07A	TP4	D, B, C*	-96.07	2.49E+05	8	154	2.13E+03	10.65	5	463.69	21.08	45.47	45.0 kV D, 5.5 kV B, 24+28g C*
-07A	TP5	D, B, C*	-95.33	2.46E+05	8	150	2.13E+03	10.64	5	461.13	21.67	47.00	45.0 kV D, 5.5 kV B, 24+28g C*
-07A	TP6	D, B, C*	-95.33	2.47E+05	8	150	2.12E+03	10.58	5	439.19	22.80	51.92	45.0 kV D, 5.5 kV B, 24+28g C*
-03A	TP1	D, B, C*	-97.27	2.45E+05	8	142	2.13E+03	10.65	5	456.63	22.06	48.31	45.0 kV D, 5.5 kV B, 24+28g C*
-03A	TP2	D, B, C*	-96.33	2.44E+05	8	146	2.14E+03	10.68	5	467.12	21.78	46.63	45.0 kV D, 5.5 kV B, 24+28g C*
-03A	TP3	D, B, C*	-95.80	2.47E+05	10	150	2.13E+03	10.66	5	376.54	24.91	66.14	45.0 kV D, 5.5 kV B, 24+28g C*
-03A	TP4	D, B, C*	-95.47	2.47E+05	8	154	2.13E+03	10.64	5	454.91	22.31	49.05	45.0 kV D, 5.5 kV B, 24+28g C*
-03A	TP5	D, B, C*	-95.13	2.47E+05	8	152	2.12E+03	10.60	5	455.18	22.14	48.65	45.0 kV D, 5.5 kV B, 24+28g C*
-09A	TP1	D, B, C*	-96.60	2.43E+05	10	142	2.10E+03	10.51	5	438.81	22.73	51.80	45.0 kV D, 5.5 kV B, 24+28g C*
-09A	TP2	D, B, C*	-95.60	2.41E+05	10	144	2.14E+03	10.70	5	454.18	21.88	48.16	45.0 kV D, 5.5 kV B, 24+28g C*

EUT	Test Point	Components	Component D				Component B			Component C/C*			Notes
			Peak Amplitude (kA)	A/I (AAs)	Rise Time (µs)	Duration (µs)	Average Amplitude (A)	Charge Transfer (C)	Duration (ms)	Average Amplitude (A)	Charge Transfer (C)	Duration (ms)	
-09A	TP3	D, B, C*	-96.07	2.44E+05	8	146	2.14E+03	10.68	5	452.16	22.19	49.08	45.0 kV D, 5.5 kV B, 24+28g C*
-09A	TP4	D, B, C*	-95.60	2.46E+05	10	152	2.12E+03	10.60	5	437.26	22.83	52.20	45.0 kV D, 5.5 kV B, 24+28g C*
-09A	TP5	D, B, C*	-95.00	2.47E+05	10	152	2.14E+03	10.68	5	455.18	21.91	48.14	45.0 kV D, 5.5 kV B, 24+28g C*

Figure A-3: Zone 1C Shot Log

EUT	Test Point	Components	Component A_H				Component B			Component C/C*			Notes
			Peak Amplitude (kA)	A/I (AAs)	Rise Time (µs)	Duration (µs)	Average Amplitude (A)	Charge Transfer (C)	Duration (ms)	Average Amplitude (A)	Charge Transfer (C)	Duration (ms)	
Al Cal Plate	WV03	A_H, B, C*	-153.33	9.26E+05	16	214	2.15E+03	10.74	5	481.45	20.72	43.03	43.0 kV A_H, 5.5 kV B, 24+28g C*
-09B	TP1	A_H, B, C*	-152.27	8.51E+05	16	176	2.13E+03	10.64	5	444.30	22.55	50.75	43.0 kV A_H, 5.5 kV B, 24+28g C*
-09B	TP2	A_H, B, C*	-153.13	8.67E+05	16	180	2.12E+03	10.61	5	441.74	22.51	50.97	43.0 kV A_H, 5.5 kV B, 24+28g C*
-09B	TP3	A_H, B, C*	-152.67	8.62E+05	16	180	2.13E+03	10.63	5	444.63	22.32	50.20	43.0 kV A_H, 5.5 kV B, 24+28g C*
-09B	TP4	A_H, B, C*	-152.67	8.68E+05	16	184	2.13E+03	10.65	5	449.83	21.88	48.63	43.0 kV A_H, 5.5 kV B, 24+28g C*
-09B	TP5	A_H, B, C*	-152.07	8.65E+05	16	184	2.13E+03	10.64	5	437.52	22.60	51.66	43.0 kV A_H, 5.5 kV B, 24+28g C*
-06A	TP1	A_H, B, C*	-153.73	8.71E+05	16	182	2.13E+03	10.63	5	456.63	21.76	47.64	43.0 kV A_H, 5.5 kV B, 24+28g C*
-06A	TP2	A_H, B, C*	-153.53	8.74E+05	16	184	2.11E+03	10.53	5	464.39	21.79	46.92	43.0 kV A_H, 5.5 kV B, 24+28g C*
-06A	TP3	A_H, B, C*	-152.20	8.62E+05	16	190	2.13E+03	10.63	5	458.41	21.53	46.98	43.0 kV A_H, 5.5 kV B, 24+28g C*

EUT	Test Point	Components	Component A_H				Component B			Component C/C*			Notes
			Peak Amplitude (kA)	A/I (AAs)	Rise Time (µs)	Duration (µs)	Average Amplitude (A)	Charge Transfer (C)	Duration (ms)	Average Amplitude (A)	Charge Transfer (C)	Duration (ms)	
-06A	TP4	A_H, B, C*	-151.80	8.59E+05	16	184	2.11E+03	10.52	5	459.14	21.82	47.53	43.0 kV A_H, 5.5 kV B, 24+28g C*
-06A	TP5	A_H, B, C*	-151.60	8.71E+05	16	190	2.11E+03	10.55	5	448.48	22.34	49.80	43.0 kV A_H, 5.5 kV B, 24+28g C*
-02A	TP1	A_H, B, C*	-153.80	8.68E+05	16	182	2.13E+03	10.67	5	471.72	21.36	45.30	43.0 kV A_H, 5.5 kV B, 24+28g C*
-02A	TP2	A_H, B, C*	-153.13	8.79E+05	14	190	2.13E+03	10.67	5	465.07	21.39	45.99	43.0 kV A_H, 5.5 kV B, 24+28g C*
-02A	TP3	A_H, B, C*	-152.07	8.62E+05	16	182	2.14E+03	10.69	5	462.24	21.34	46.17	43.0 kV A_H, 5.5 kV B, 24+28g C*
-02A	TP4	A_H, B, C*	-152.40	8.76E+05	16	190	2.12E+03	10.59	5	470.51	21.02	44.67	43.0 kV A_H, 5.5 kV B, 24+28g C*
-02A	TP5	A_H, B, C*	-151.93	8.81E+05	16	192	2.13E+03	10.64	5	451.24	22.13	49.04	43.0 kV A_H, 5.5 kV B, 24+28g C*
-02A	TP6	A_H, B, C*	-151.93	8.72E+05	16	192	2.13E+03	10.63	5	428.08	22.69	53.00	43.0 kV A_H, 5.5 kV B, 24+28g C*
-06B	TP1	A_H, B, C*	-154.40	8.74E+05	14	184	2.14E+03	10.68	5	467.94	20.97	44.82	43.0 kV A_H, 5.5 kV B, 24+28g C*
-06B	TP2	A_H, B, C*	-153.80	8.76E+05	16	184	2.13E+03	10.63	5	453.66	22.16	48.84	43.0 kV A_H, 5.5 kV B, 24+28g C*

Figure A-4: Zone 1A Shot Log

EUT	Test Point	Components	Component A				Component B			Component C/C*			Notes
			Peak Amplitude (kA)	A/I (AAs)	Rise Time (µs)	Duration (µs)	Average Amplitude (A)	Charge Transfer (C)	Duration (ms)	Average Amplitude (A)	Charge Transfer (C)	Duration (ms)	
Al Cal Plate	WV04	A, B, C*	-195.73	2.33E+06	20	340	2.13E+03	10.63	5	684.59	4.05	5.92	43.0 kV A, 5.5 kV B, 24+28g C*
Al Cal Plate	WV05	A, B, C*	-195.60	2.33E+06	20	342	2.14E+03	10.69	5	471.33	20.98	44.51	43.0 kV A, 5.5 kV B, 24+28g C*
-01A	TP1	A, B, C*	-194.60	2.14E+06	20	302	2.11E+03	10.53	5	449.77	22.02	48.96	43.0 kV A, 5.5 kV B, 24+28g C*
-01A	TP2	A, B, C*	-191.73	2.18E+06	20	328	0.00E+00	0.00	71.172	461.03	21.37	46.36	43.0 kV A, 5.5 kV B, 24+28g C*
-01A	TP3	A, B, C*	-189.53	2.03E+06	20	294	2.11E+03	10.54	5	457.73	21.65	47.30	43.0 kV A, 5.5 kV B, 24+28g C*
-01A	TP4	A, B, C*	-190.87	2.17E+06	18	314	2.12E+03	10.61	5	469.34	20.98	44.70	43.0 kV A, 5.5 kV B, 24+28g C*
-01A	TP5	A, B, C*	-190.40	2.10E+06	20	308	2.09E+03	10.45	5	448.01	21.96	49.01	43.0 kV A, 5.5 kV B, 24+28g C*
-01A	TP6	A, B, C*	-191.27	2.08E+06	18	310	0.00E+00	0.00	71.172	451.85	22.05	48.80	43.0 kV A, 5.5 kV B, 24+28g C*
Al Bar	WV06	A, B	-198.53	2.34E+06	18	328	2.11E+03	10.56	5	-1.00	0.00	0.00	43.0 kV A, 5.5 kV B
Al Cal Plate	WV07	A, B, C*	-196.67	2.30E+06	18	340	2.09E+03	10.45	5	476.16	20.92	43.94	43.0 kV A, 5.5 kV B, 24+28g C*

EUT	Test Point	Components	Component A				Component B			Component C/C*			Notes
			Peak Amplitude (kA)	A/I (AAs)	Rise Time (µs)	Duration (µs)	Average Amplitude (A)	Charge Transfer (C)	Duration (ms)	Average Amplitude (A)	Charge Transfer (C)	Duration (ms)	
-01B	TP1	A, B, C*	-193.40	2.04E+06	20	278	2.11E+03	10.53	5	453.01	21.84	48.22	43.0 kV A, 5.5 kV B, 24+28g C*
-01B	TP2	A, B, C*	-191.87	2.01E+06	20	276	2.07E+03	10.37	5	423.35	23.41	55.29	43.0 kV A, 5.5 kV B, 24+28g C*
-04A	TP1	A, B, C*	-193.13	2.03E+06	18	272	2.08E+03	10.39	5	463.37	21.39	46.17	43.0 kV A, 5.5 kV B, 24+28g C*
-04A	TP2	A, B, C*	-193.80	2.07E+06	18	284	2.06E+03	10.30	5	427.08	22.97	53.80	43.0 kV A, 5.5 kV B, 24+28g C*

Appendix B – Test Photos

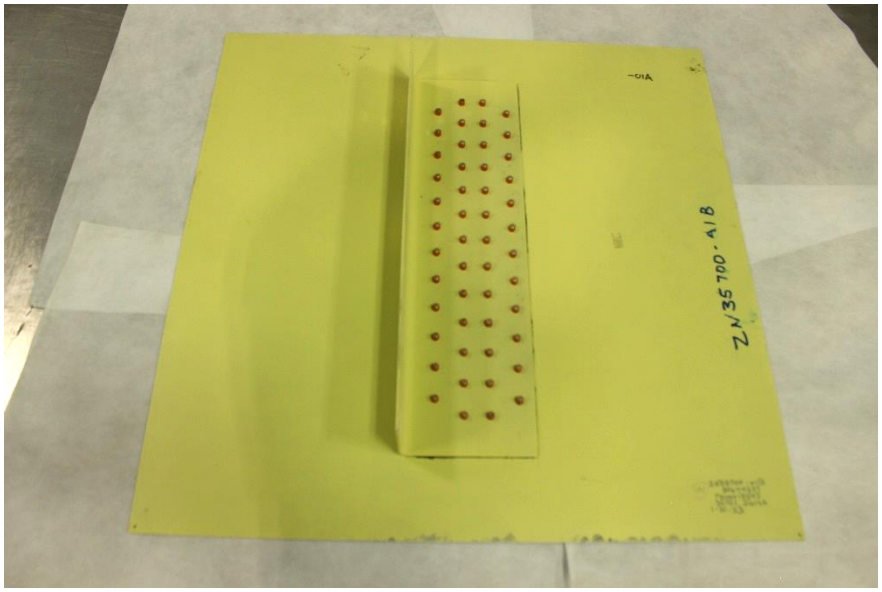

Figure B-1: Arc Entry Test -01A-Check-In-Back

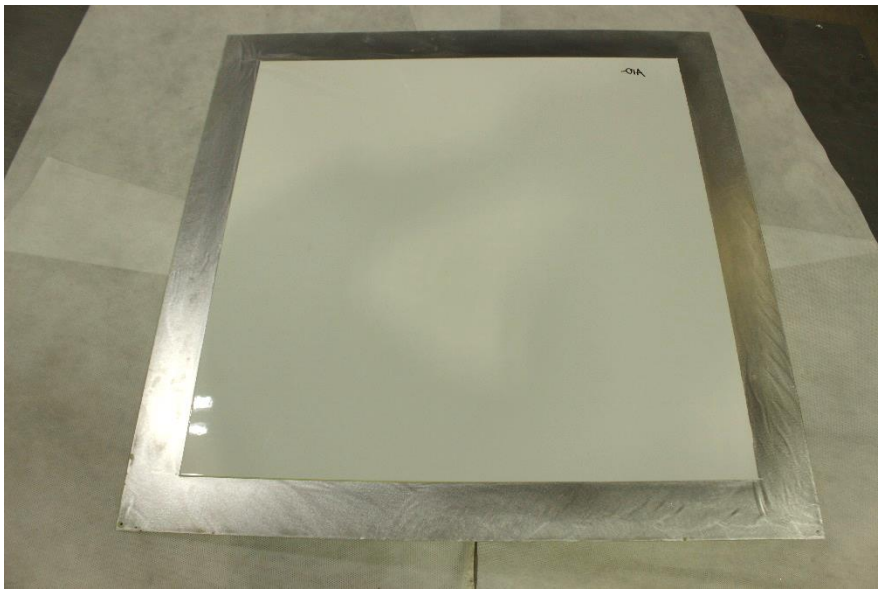

Figure B-2: Arc Entry Test -01A-Check-In-Front

Figure B-3: Arc Entry Test -01A-Post-Test-Back

Figure B-4: Arc Entry Test -01A-Post-Test-Front

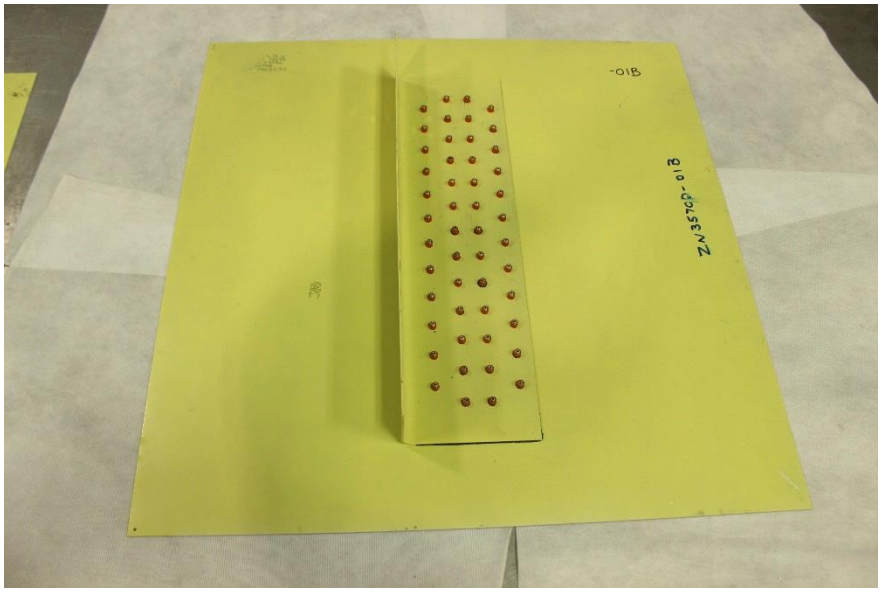

Figure B-5: Arc Entry Test -01B-Check-In-Back

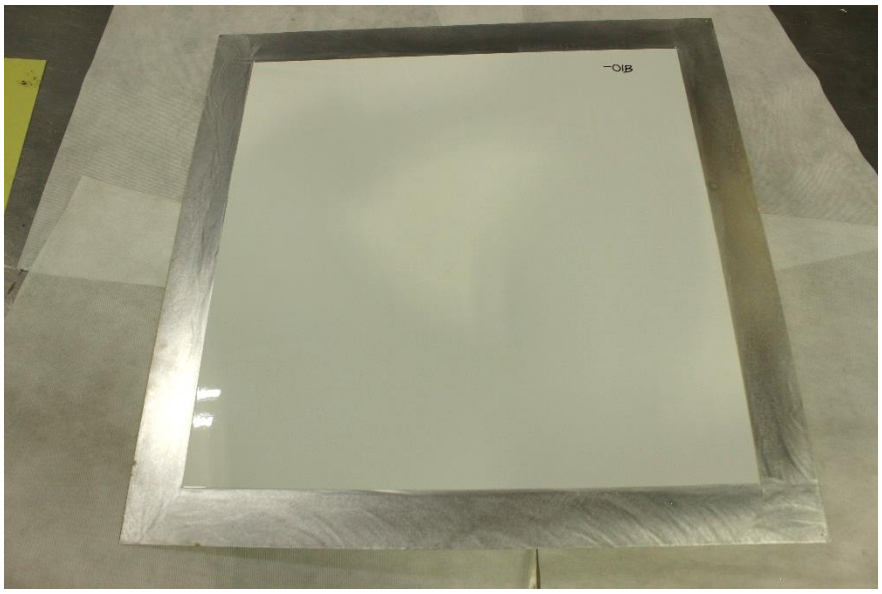

Figure B-6: Arc Entry Test -01B-Check-In-Front

Figure B-7: Arc Entry Test -01B-Post-Test-Back

Figure B-8: Arc Entry Test -01B-Post-Test-Front

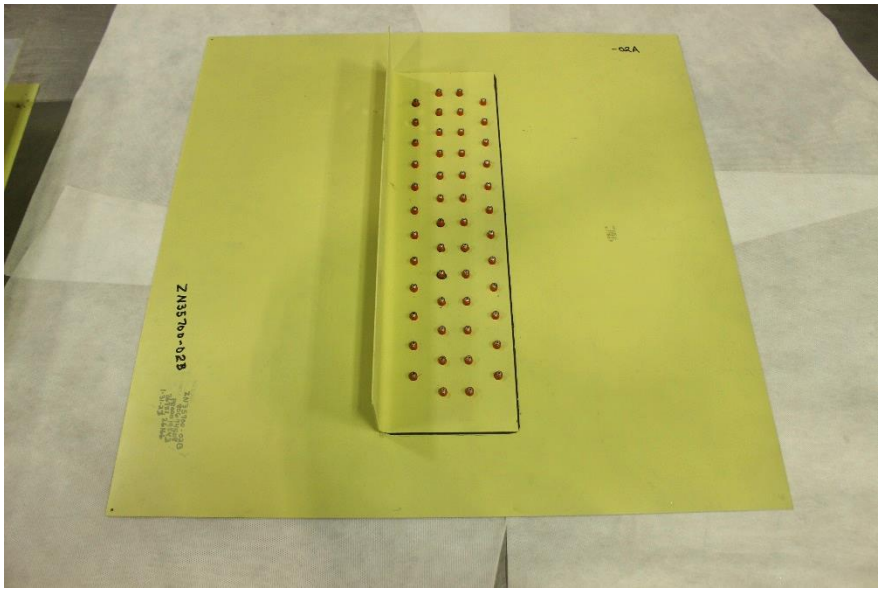

Figure B-9: Arc Entry Test -02A-Check-In-Back

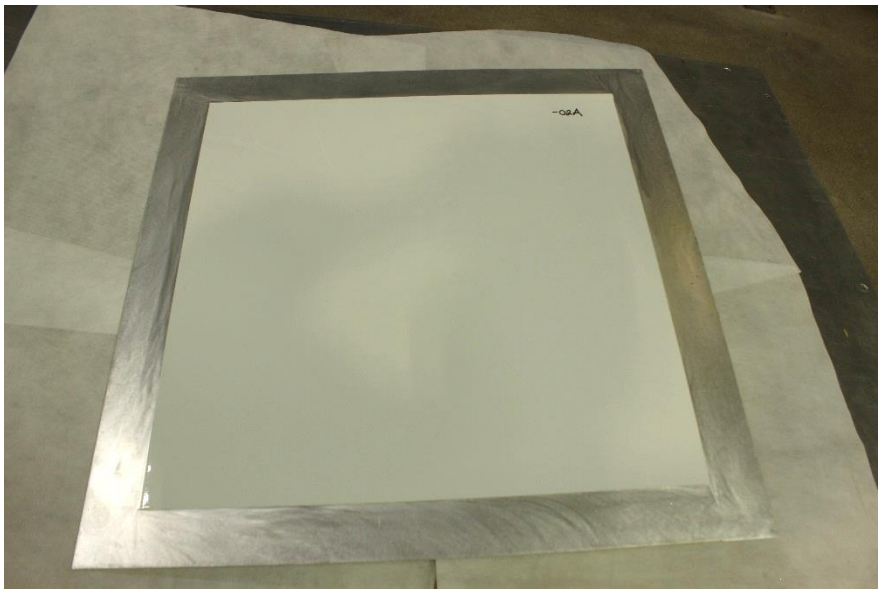

Figure B-10: Arc Entry Test -02A-Check-In-Front

Figure B-11: Arc Entry Test -02A-Post-Test-Back

Figure B-12: Arc Entry Test -02A-Post-Test-Front

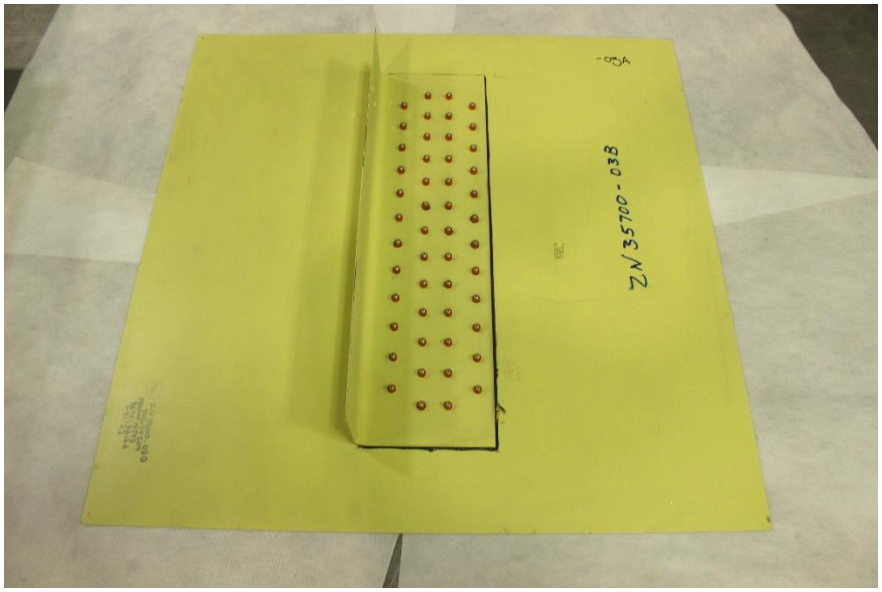

Figure B-13: Arc Entry Test -03A-Check-In-Back

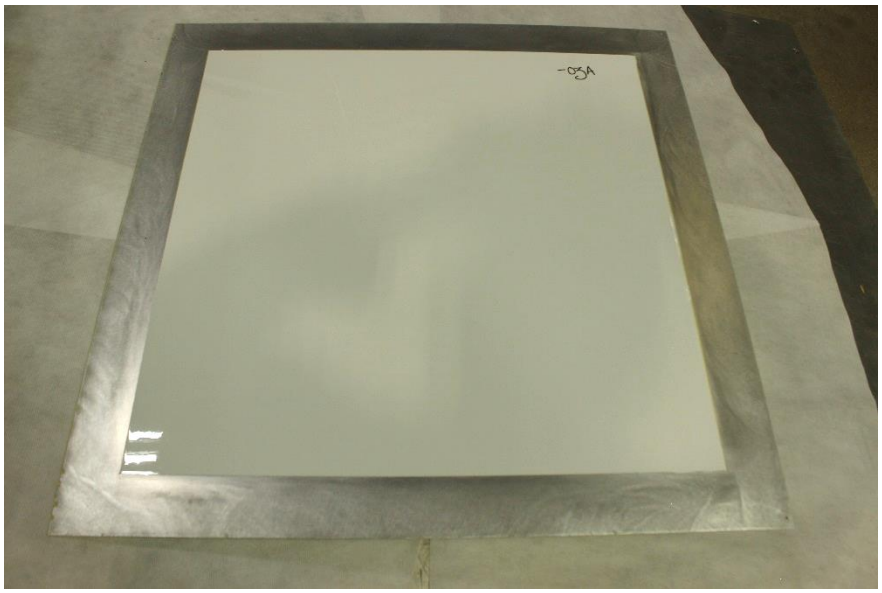

Figure B-14: Arc Entry Test -03A-Check-In-Front

Figure B-15: Arc Entry Test -03A-Post-Test-Back

Figure B-16: Arc Entry Test -03A-Post-Test-Front

Figure B-17: Arc Entry Test -04A-Check-In-Back-Reworked

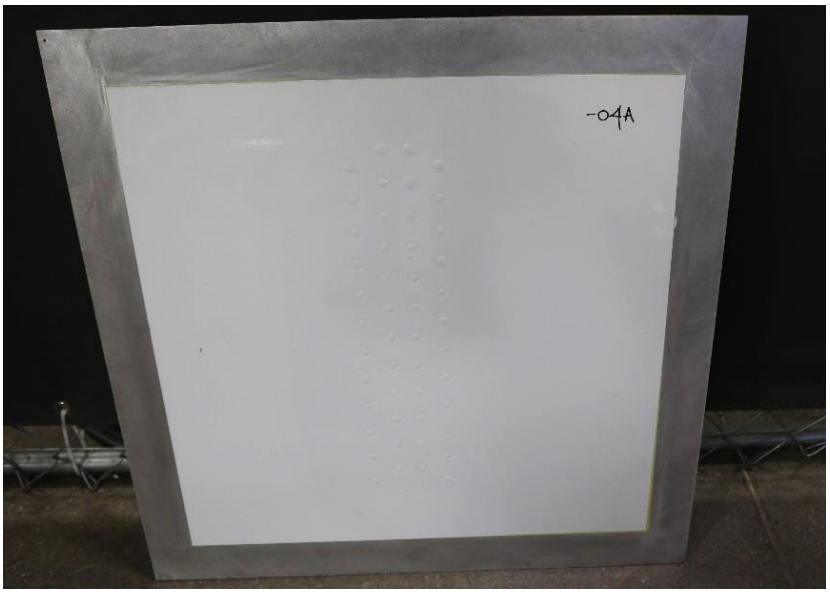

Figure B-18: Arc Entry Test -04A-Check-In-Front-Reworked

Figure B-19: Arc Entry Test -04A-Post-Test-Back

Figure B-20: Arc Entry Test -04A-Post-Test-Front

Figure B-21: Arc Entry Test -06A-Check-In-Back-Reworked

Figure B-22: Arc Entry Test -06A-Check-In-Front-Reworked

Figure B-23: Arc Entry Test -06A-Post-Test-Back

Figure B-24: Arc Entry Test -06A-Post-Test-Front

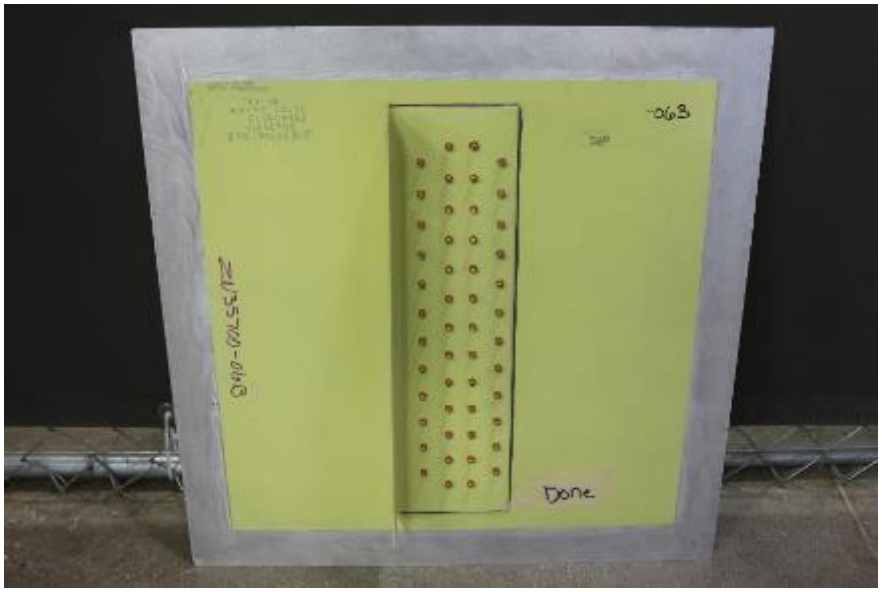

Figure B-25: Arc Entry Test -06B-Check-In-Back-Reworked

Figure B-26: Arc Entry Test -06B-Check-In-Front-Reworked

Figure B-27: Arc Entry Test -06B-Post-Test-Back

Figure B-28: Arc Entry Test -06B-Post-Test-Front

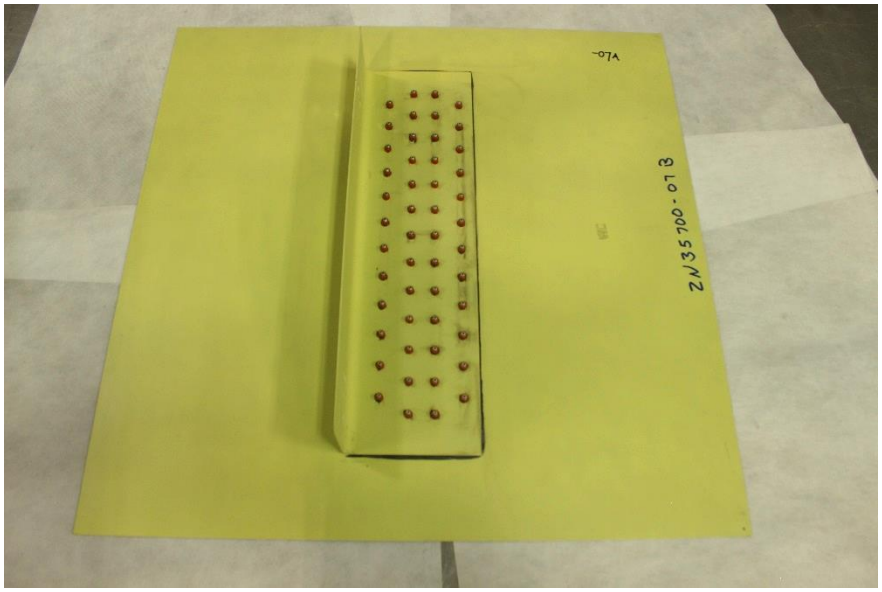

Figure B-29: Arc Entry Test -07A-Check-In-Back

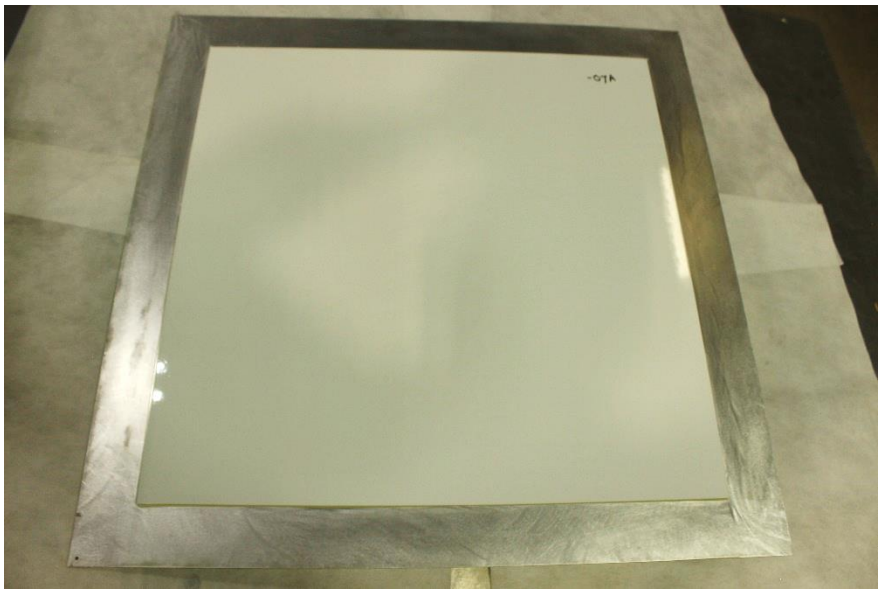

Figure B-30: Arc Entry Test -07A-Check-In-Front

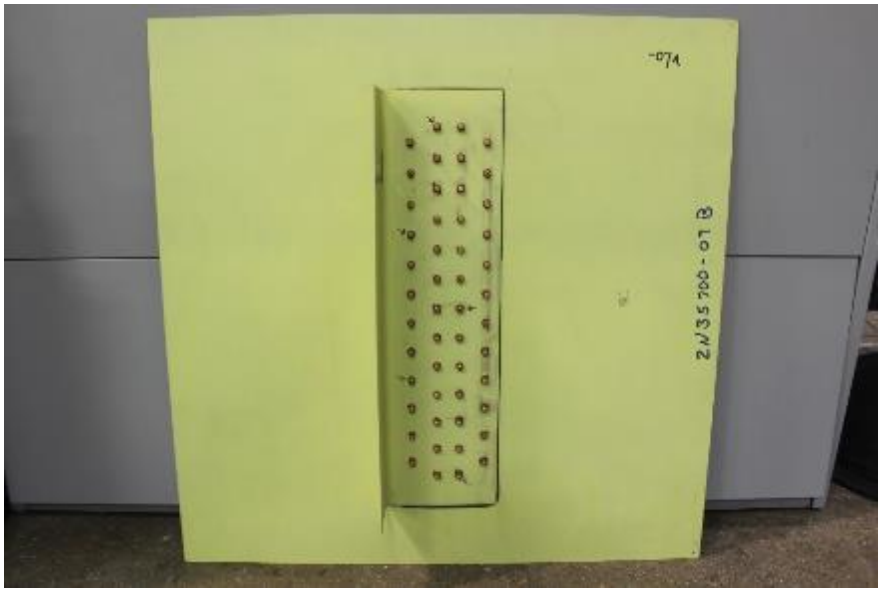

Figure B-31: Arc Entry Test -07A-Post-Test-Back

Figure B-32: Arc Entry Test -07A-Post-Test-Front

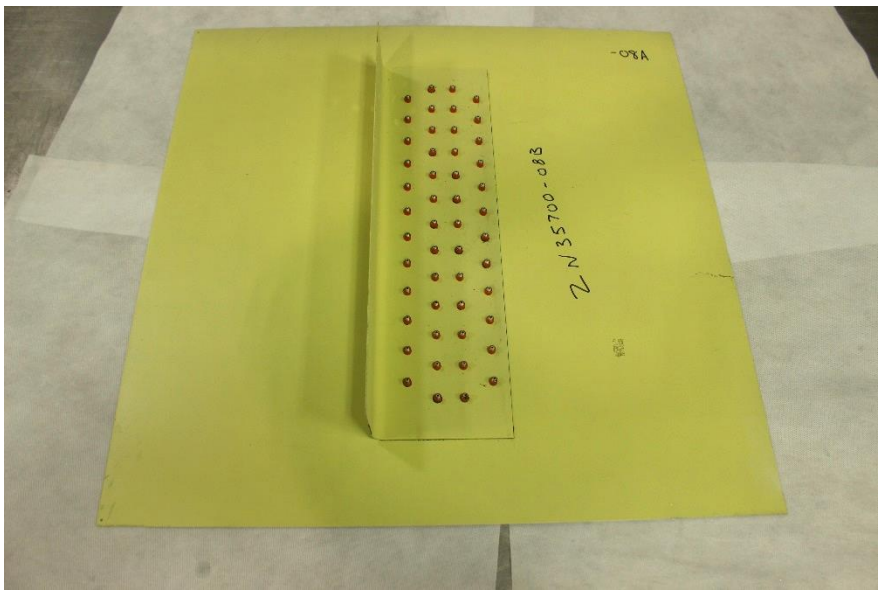

Figure B-33: Arc Entry Test -08A-Check-In-Back

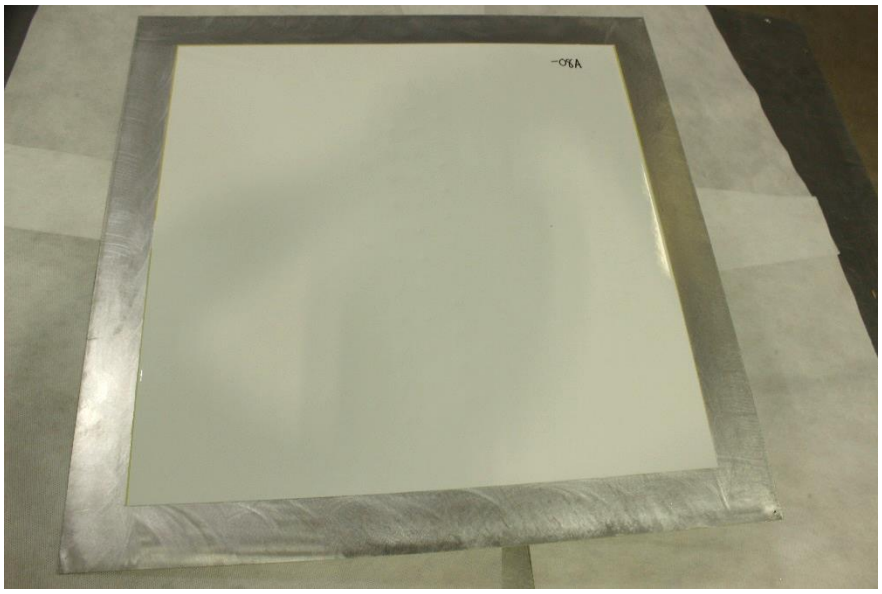

Figure B-34: Arc Entry Test -08A-Check-In-Front

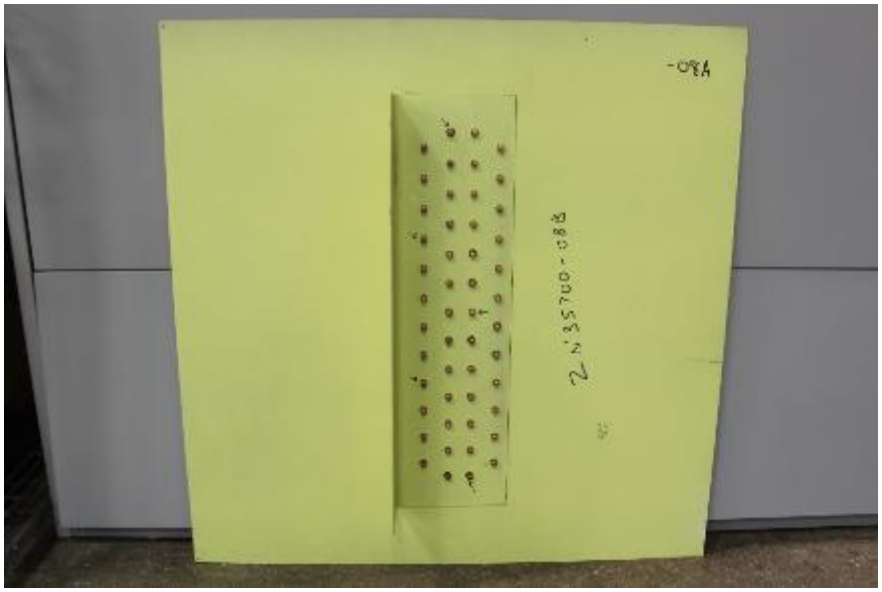

Figure B-35: Arc Entry Test -08A-Post-Test-Back

Figure B-36: Arc Entry Test -08A-Post-Test-Front

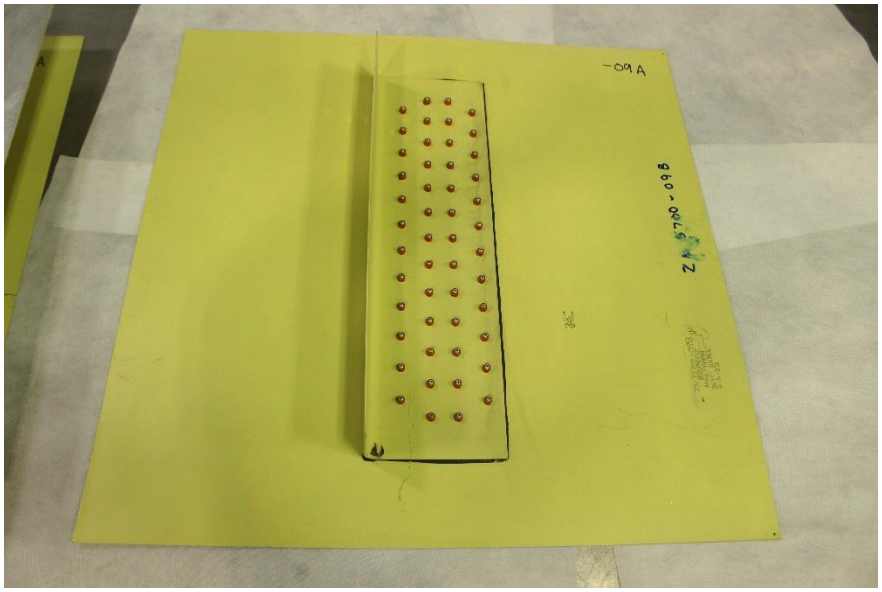

Figure B-37: Arc Entry Test -09A-Check-In-Back

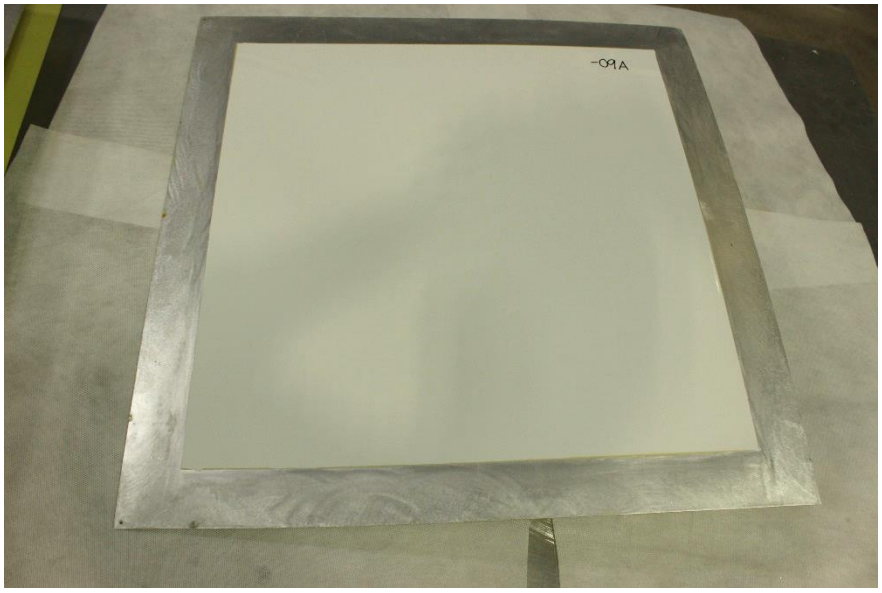

Figure B-38: Arc Entry Test -09A-Check-In-Front

Figure B-39: Arc Entry Test -09A-Post-Test-Back

Figure B-40: Arc Entry Test -09A-Post-Test-Front

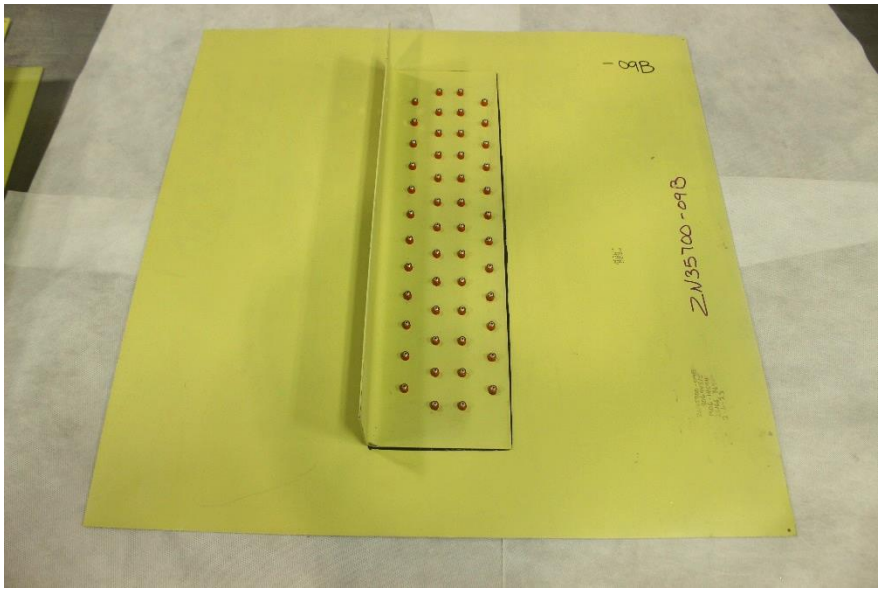

Figure B-41: Arc Entry Test -09B-Check-In-Back

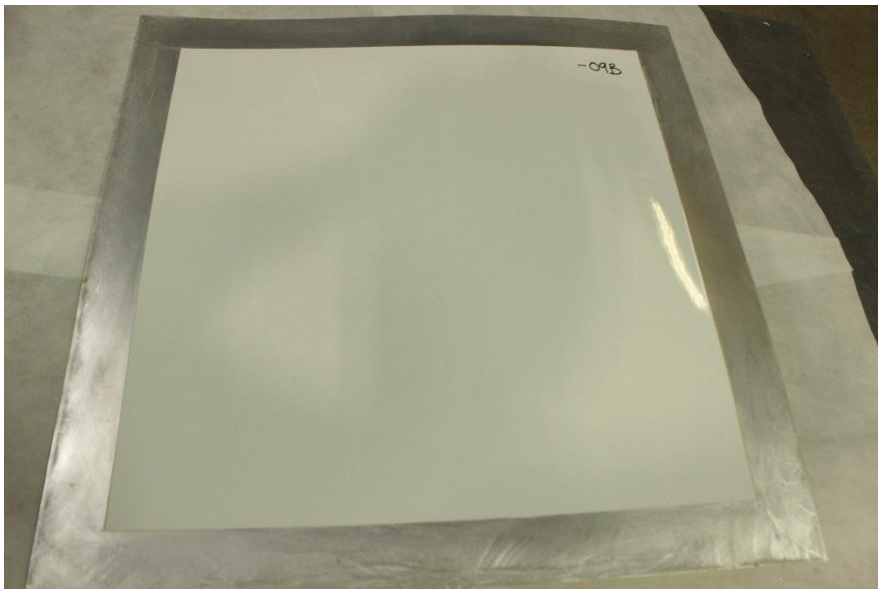

Figure B-42: Arc Entry Test -09B-Check-In-Front

Figure B-43: Arc Entry Test -09B-Post-Test-Back

Figure B-44: Arc Entry Test -09B-Post-Test-Front

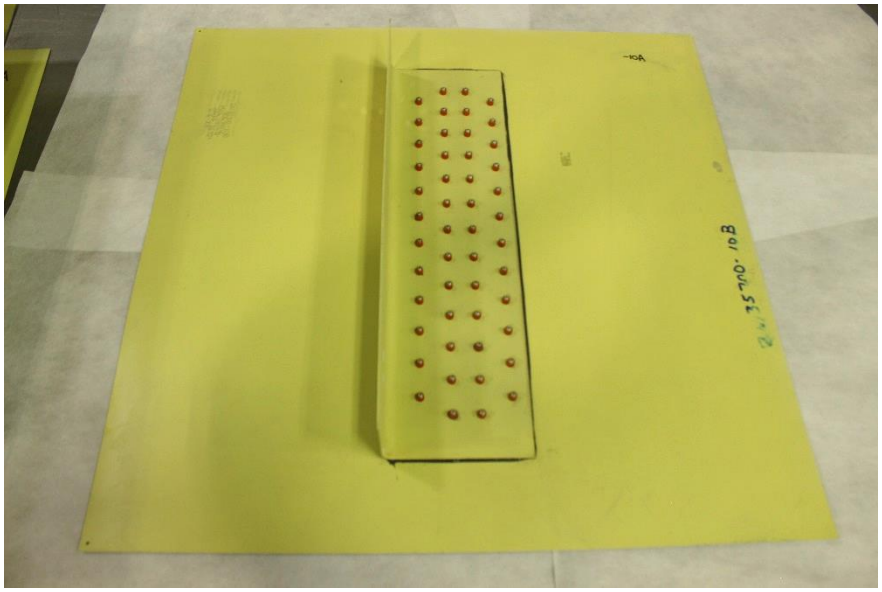

Figure B-45: Arc Entry Test -10A-Check-In-Back

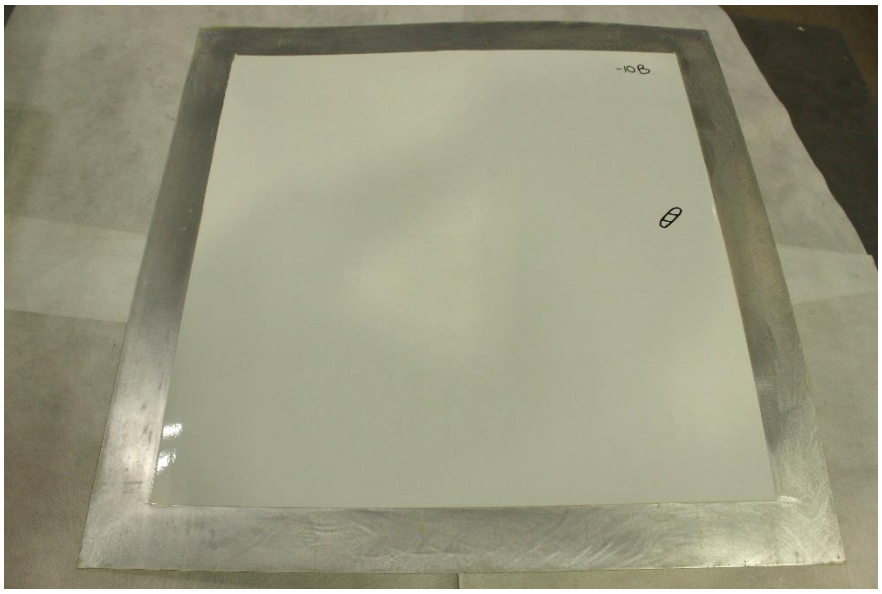

Figure B-46: Arc Entry Test -10B-Check-In-Front

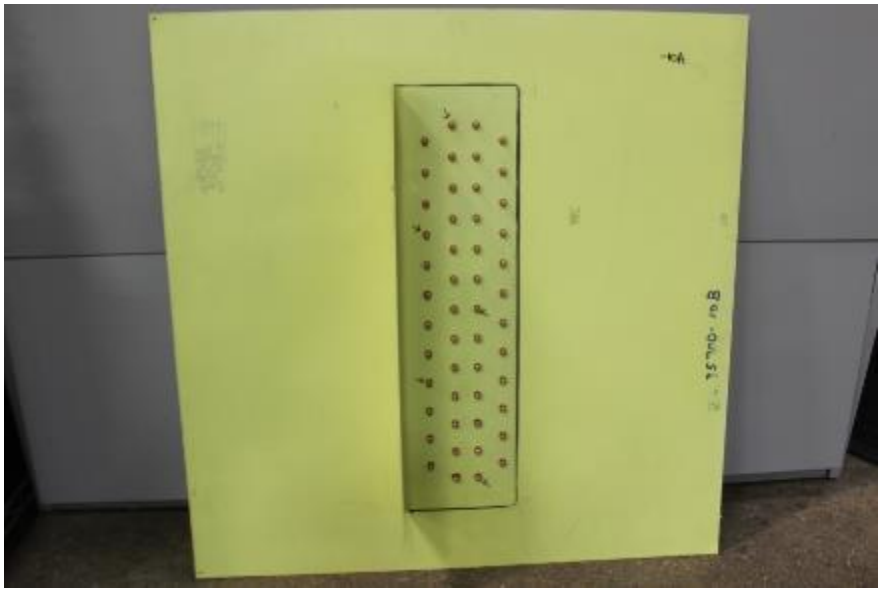

Figure B-47: Arc Entry Test -10A-Post-Test-Back

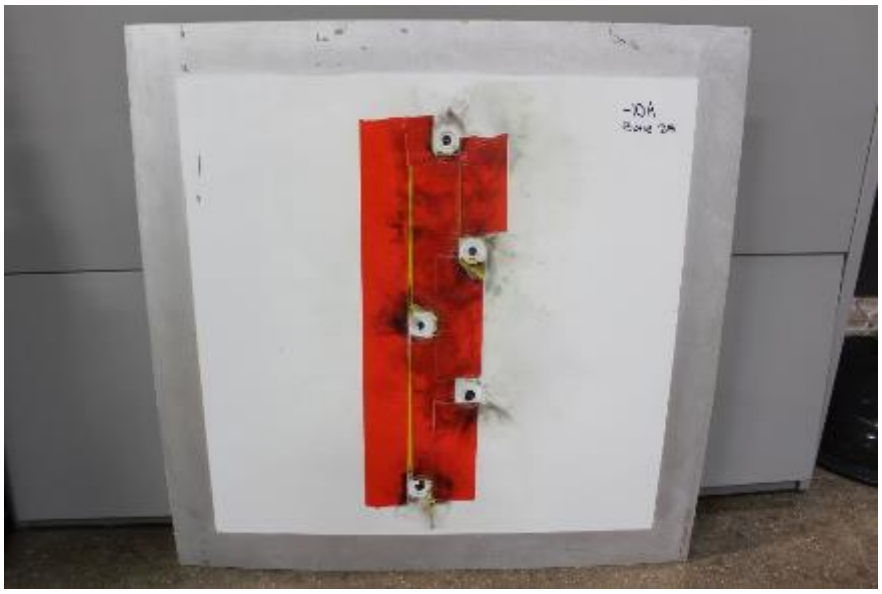

Figure B-48: Arc Entry Test -10A-Post-Test-Front

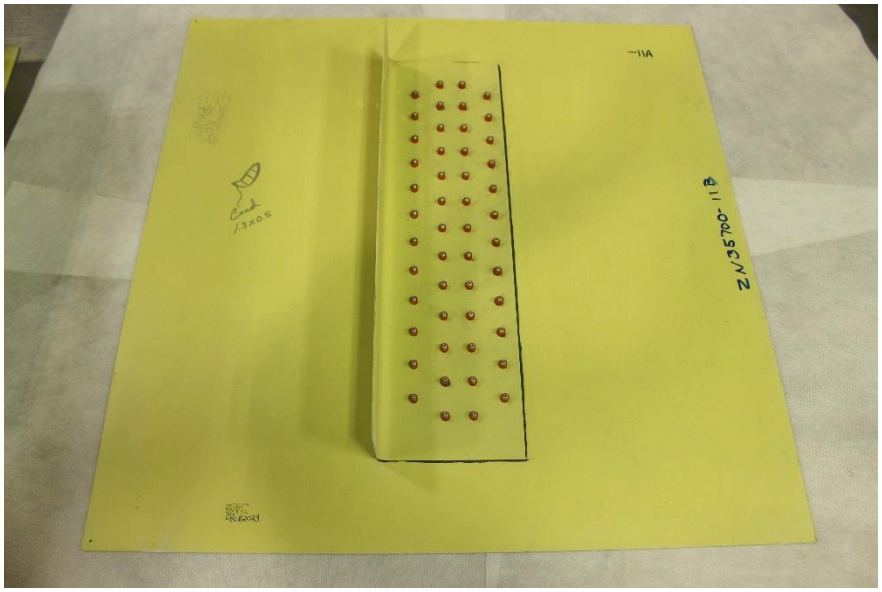

Figure B-49: Arc Entry Test -11A-Check-In-Back

Figure B-50: Arc Entry Test -11A-Check-In-Front

Figure B-51: Arc Entry Test -11A-Post-Test-Back

Figure B-52: Arc Entry Test -11A-Post-Test-Front

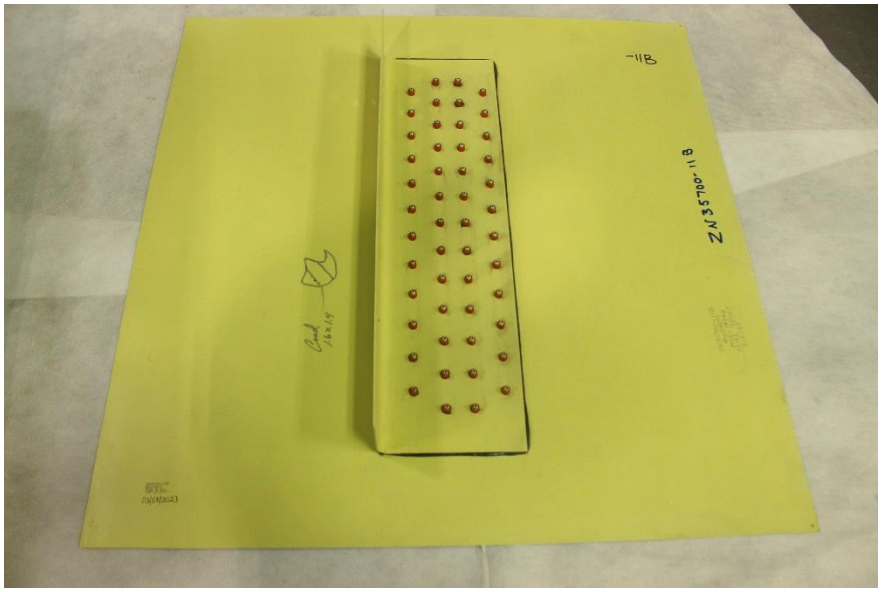

Figure B-53: Arc Entry Test -11B-Check-In-Back

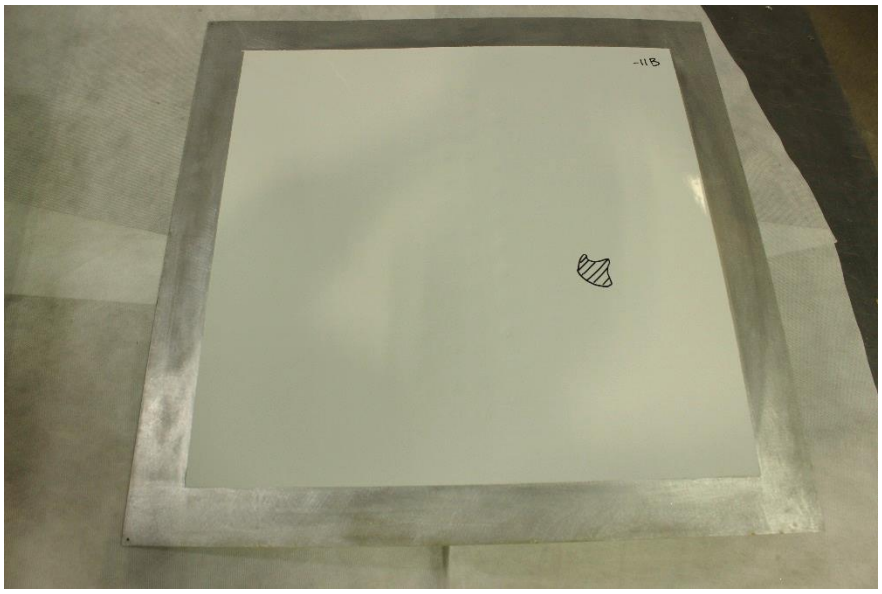

Figure B-54: Arc Entry Test -11B-Check-In-Front

Figure B-55: Arc Entry Test -11B-Post-Test-Back

Figure B-56: Arc Entry Test -11B-Post-Test-Front

Appendix C - Test Logs

Figure C-1: Lightning Direct Effects Test Log

Customer	KART						
Workorder	23-2152-WK035						
Tested To	23-2152-TP035						
EUT	Metal bonded skins with nominal fastener installations						
Part Number	Zn35700						
Serial Number	-01A, -01B, -02A, -20B, -03A, -03B, -04A, -04B, -05A, -05B, -06A, -06B, -07A, -07B, -08A, -08B, -09A, -09B, -10A, -10B, -11A, -11B						
Test Section	Lightning Direct Effects				**Category**	1A, 1C, 2A, 3	
Tested By	Rebeka Khajehpour, Alyssa Gonzalez, Beth Dalton, David Bruner, Mel St John, Ted Angleton						
Test Witness							
Start Date	4/6/23						
End Date	4/28/23						
Lab Conditions	**Date**	**Temp**	**Humidity**	**Date**	**Temp**	**Humidity**	
	4/6/23	71.0°F	18.6%RH	4/24/23	70.7°F	24.4%RH	
	4/7/23	67.1°F	21.6%RH	4/25/23	68.1°F	40.7%RH	
	4/10/23	73.5°F	34.6%RH	4/26/23	67.1°F	43.7%RH	
	4/11/23	73.2°F	40.6%RH	4/27/23	68.9°F	44.9%RH	

Test Log Data		
Date	**Time**	**Notes**
4/6/2023 TA, MSJ, DB, BD, AG, RK	8:00am	Arrived to begin testing
	8:05am	Repaired the ESVM (see form 23-2152-D035-1)
	2:00pm	Cleaned out the spark source and performed the gas verification. Shop air environment: 13.9 %RH Capacitance was set to 7.7 pF
	4:20pm	End of Day
4/7/2023 RK, AG, BD, MSJ	8:10am	Arrived to begin testing
	9:50am	Performed the gas verification with 9 successful ignitions of the flammable mixture between 180 and 200 µJ. 7% hydrogen. Capacitance was set to 11.7 pF Shop air environment: 13.3 %RH
	10:30am	Calibration plate has been set up with wire, fuse, and picture taken. Generator has been configured for Zone 3. Generator is in D bank configuration (6 caps, 1/3 of the A Bank wall resistor), with B spark gap set to 0.25", and a 24, 28 AWG gauge copper fuse for C* with inductor installed on output.

<table>
<tr><th colspan="3">Test Log Data</th></tr>
<tr><th>Date</th><th>Time</th><th>Notes</th></tr>
<tr><td></td><td></td><td>Bonding aluminum calibration plate to ground: 0.063 mΩ</td></tr>
<tr><td></td><td>11:05am</td><td>WV01 - Aluminum cal plate - Zone 3
<table>
<tr><th>Shot #</th><th>Charge Voltage, kV A bank:</th><th>Charge Voltage, kV B bank:</th><th>Peak I, kA (±10%)</th><th>Action Integral, kAAs (±20%)</th><th>B Charge Transfer, C (±10%)</th><th>C* Charge Transfer, C (±20%)</th></tr>
<tr><td>Target 40 kA</td><td>23.4</td><td>5.50</td><td>40</td><td>80</td><td>10</td><td>18</td></tr>
<tr><td>Actual</td><td>-</td><td>-</td><td>37.3</td><td>70.24</td><td>10.73</td><td>20.4</td></tr>
</table>
All waveform parameters met.</td></tr>
<tr><td></td><td>1:47pm</td><td>--11A TP1: Zone 3 - Invalid
Pre-test panel edge to generator return bond: 0.51 mΩ
<table>
<tr><th>Shot #</th><th>Charge Voltage, kV A bank:</th><th>Charge Voltage, kV B bank:</th><th>Peak I, kA (±10%)</th><th>Action Integral, kAAs (±20%)</th><th>B Charge Transfer, C (±10%)</th><th>C* Charge Transfer, C (±20%)</th></tr>
<tr><td>Target 40 kA</td><td>23.4</td><td>5.50</td><td>40</td><td>80</td><td>10</td><td>18</td></tr>
<tr><td>Actual</td><td>-</td><td>-</td><td>34.27</td><td>45.65</td><td>10.6</td><td>23.17</td></tr>
</table>
Initial attempt to complete this test point resulted in a failed discharge of the generator. The scope did not trigger and the initiating wire on the jet diverting electrode was still intact so it can be concluded that the arc was not directed into the panel. B spark gap spacing was increased to prevent the A bank misfiring into the B and C banks.

Test was repeated with a successful discharge into the panel with the recorded parameters in this entry. The arc attached at the unpainted edge of the panel rather than the head of the fastener at the intended test point location. This is considered an invalid test.

Flammable gas did not ignite on DEL test and was successfully ignited post-test with a less than 89 µJ spark (scope did not trigger, the spark source broke down below 4 kV).

The peak current and action integral on Component A/5 were below tolerance. The charge transfer and duration of Component C* were above tolerance. All other waveform parameters were met.</td></tr>
<tr><td></td><td>2:13pm</td><td>--11A TP2: Zone 3 - Invalid
<table>
<tr><th>Shot #</th><th>Charge Voltage, kV A bank:</th><th>Charge Voltage, kV B bank:</th><th>Peak I, kA (±10%)</th><th>Action Integral, kAAs (±20%)</th><th>B Charge Transfer, C (±10%)</th><th>C* Charge Transfer, C (±20%)</th></tr>
<tr><td>Target 40 kA</td><td>27.3</td><td>5.50</td><td>40</td><td>80</td><td>10</td><td>18</td></tr>
<tr><td>Actual</td><td>-</td><td>-</td><td>40.93</td><td>67.26</td><td>10.17</td><td>7.74</td></tr>
</table></td></tr>
</table>

<table>
<tr><th colspan="3">Test Log Data</th></tr>
<tr><th>Date</th><th>Time</th><th>Notes</th></tr>
<tr><td></td><td></td><td>Lightning arced to the bottom of the panel resulting in an invalid test point. It was decided to puncture the paint on all test points moving forward to facilitate attachment to the desired test point location.

Flammable gas did not ignite on DEL test and was successfully ignited post-test with a less than 60 µJ spark (scope did not trigger, the spark source broke down below 4 kV).

The charge transfer, duration, and average amplitude of Component C* were below tolerance. All other waveform parameters met.</td></tr>
<tr><td></td><td>2:30pm</td><td>--11A TP3: Zone 3 - Invalid

<table>
<tr><th>Shot #</th><th>Charge Voltage, kV A bank:</th><th>Charge Voltage, kV B bank:</th><th>Peak I, kA (±10%)</th><th>Action Integral, kAAs (±20%)</th><th>B Charge Transfer, C (±10%)</th><th>C* Charge Transfer, C (±20%)</th></tr>
<tr><td>Target 40 kA</td><td>27.3</td><td>5.50</td><td>40</td><td>80</td><td>10</td><td>18</td></tr>
<tr><td>Actual</td><td>-</td><td>-</td><td>44.27</td><td>94.344</td><td>10.68</td><td>22.36</td></tr>
</table>

Flammable gas did not ignite on DEL test and was successfully ignited post-test with a 216 µJ spark which resulted in an invalid test point.

The charge transfer of Component C* was above tolerance. The Component A/5 peak current was above tolerance. All other waveform parameters met.</td></tr>
<tr><td></td><td>2:45pm</td><td>Charge level on spark source power supply was set to 6.44 kV to try to limit over charging past 200 uJ.</td></tr>
<tr><td></td><td>2:55pm</td><td>-11A TP4: Zone 3 - Invalid

<table>
<tr><th>Shot #</th><th>Charge Voltage, kV A bank:</th><th>Charge Voltage, kV B bank:</th><th>Peak I, kA (±10%)</th><th>Action Integral, kAAs (±20%)</th><th>B Charge Transfer, C (±10%)</th><th>C* Charge Transfer, C (±20%)</th></tr>
<tr><td>Target 40 kA</td><td>24.8</td><td>5.50</td><td>40</td><td>80</td><td>10</td><td>18</td></tr>
<tr><td>Actual</td><td>-</td><td>-</td><td>39.8</td><td>75.55</td><td>10.68</td><td>21.3</td></tr>
</table>

Flammable gas did not ignite on DEL test and was successfully ignited post-test with a 216 µJ spark which resulted in an invalid test point.

All waveform parameters met.</td></tr>
<tr><td></td><td>3:00pm</td><td>Spark source was removed from the setup to inspect the variable capacitor. A loose screw as tightened with a new lock washer and the capacitance measured. System is now adjustable again.</td></tr>
<tr><td></td><td>3:15pm</td><td>Testing complete for the day.</td></tr>
<tr><td></td><td></td><td></td></tr>
<tr><td>4/10/2023
RK, BD, TA, MSJ</td><td>8:30am</td><td>Arrived to begin testing.</td></tr>
</table>

<table>
<tr><th colspan="3">Test Log Data</th></tr>
<tr><th>Date</th><th>Time</th><th>Notes</th></tr>
<tr><td></td><td>10:20am</td><td>Generator armed. Performed the gas verification with 9 successful ignitions of the flammable mixture between 160 and 194 µJ.
7% hydrogen.
Capacitance was set to 10.5 pF
Shop air environment: 13.9 %RH</td></tr>
<tr><td></td><td>10:37am</td><td>-11A TP5: Zone 3

<table>
<tr><th>Shot #</th><th>Charge Voltage, kV A bank:</th><th>Charge Voltage, kV B bank:</th><th>Peak I, kA (±10%)</th><th>Action Integral, kAAs (±20%)</th><th>B Charge Transfer, C (±10%)</th><th>C* Charge Transfer, C (±20%)</th></tr>
<tr><td>Target 40 kA</td><td>24.8</td><td>5.50</td><td>40</td><td>80</td><td>10</td><td>18</td></tr>
<tr><td>Actual</td><td>-</td><td>-</td><td>39.53</td><td>74.96</td><td>10.69</td><td>19.61</td></tr>
</table>

Bonding measurement: 0.63 mΩ

Flammable gas did not ignite on DEL test and was successfully ignited post-test with a 192 µJ spark.

All waveform parameters met.</td></tr>
<tr><td></td><td>11:25am</td><td>-11B TP1: Zone 3

<table>
<tr><th>Shot #</th><th>Charge Voltage, kV A bank:</th><th>Charge Voltage, kV B bank:</th><th>Peak I, kA (±10%)</th><th>Action Integral, kAAs (±20%)</th><th>B Charge Transfer, C (±10%)</th><th>C* Charge Transfer, C (±20%)</th></tr>
<tr><td>Target 40 kA</td><td>24.8</td><td>5.50</td><td>40</td><td>80</td><td>10</td><td>18</td></tr>
<tr><td>Actual</td><td>-</td><td>-</td><td>40</td><td>75.28</td><td>10.67</td><td>20.74</td></tr>
</table>

Bonding Measurement: 0.57 mΩ

Flammable gas did not ignite on DEL test and was successfully ignited post-test with a 184 µJ spark.

All waveform parameters met.</td></tr>
<tr><td></td><td>11:35am</td><td>-11B TP2: Zone 3

<table>
<tr><th>Shot #</th><th>Charge Voltage, kV A bank:</th><th>Charge Voltage, kV B bank:</th><th>Peak I, kA (±10%)</th><th>Action Integral, kAAs (±20%)</th><th>B Charge Transfer, C (±10%)</th><th>C* Charge Transfer, C (±20%)</th></tr>
<tr><td>Target 40 kA</td><td>24.8</td><td>5.50</td><td>40</td><td>80</td><td>10</td><td>18</td></tr>
<tr><td>Actual</td><td>-</td><td>-</td><td>39.8</td><td>73.9</td><td>10.72</td><td>20.85</td></tr>
</table>

Flammable gas did not ignite on DEL test and was successfully ignited post-test with a 182 µJ spark.</td></tr>
</table>

<table>
<tr><th colspan="3">Test Log Data</th></tr>
<tr><th>Date</th><th>Time</th><th>Notes</th></tr>
<tr><td></td><td></td><td>All waveform parameters met.</td></tr>
<tr><td></td><td>11:53am</td><td>-11B TP3: Zone 3

<table>
<tr><th>Shot #</th><th>Charge Voltage, kV A bank:</th><th>Charge Voltage, kV B bank:</th><th>Peak I, kA (±10%)</th><th>Action Integral, kAAs (±20%)</th><th>B Charge Transfer, C (±10%)</th><th>C* Charge Transfer, C (±20%)</th></tr>
<tr><td>Target 40 kA</td><td>24.8</td><td>5.50</td><td>40</td><td>80</td><td>10</td><td>18</td></tr>
<tr><td>Actual</td><td>-</td><td>-</td><td>39.8</td><td>77.12</td><td>10.75</td><td>21.48</td></tr>
</table>

Flammable gas did not ignite on DEL test and was successfully ignited post-test with a 194 µJ spark.

All waveform parameters met.</td></tr>
<tr><td></td><td>12:06pm</td><td>-11B TP4: Zone 3

<table>
<tr><th>Shot #</th><th>Charge Voltage, kV A bank:</th><th>Charge Voltage, kV B bank:</th><th>Peak I, kA (±10%)</th><th>Action Integral, kAAs (±20%)</th><th>B Charge Transfer, C (±10%)</th><th>C* Charge Transfer, C (±20%)</th></tr>
<tr><td>Target 40 kA</td><td>24.8</td><td>5.50</td><td>40</td><td>80</td><td>10</td><td>18</td></tr>
<tr><td>Actual</td><td>-</td><td>-</td><td>39.8</td><td>76.78</td><td>10.74</td><td>19.89</td></tr>
</table>

Flammable gas did not ignite on DEL test and was successfully ignited post-test with a 189 µJ spark.

It was noted that the shop airline had not been connected to the spark source box in the morning thus the humidity in the box is unknown. However, since the spark source has been breaking down consistently, it was decided to proceed without attaching the airline to the box to minimize change in the test from one panel to another. The airline will be connected to the box either when reconfiguring the generator for the next attachment zone or when the spark breakdown ceases to be as consistent, whichever comes first.

All waveform parameters met.</td></tr>
<tr><td></td><td>1:29pm</td><td>-08B TP1: Zone 3

<table>
<tr><th>Shot #</th><th>Charge Voltage, kV A bank:</th><th>Charge Voltage, kV B bank:</th><th>Peak I, kA (±10%)</th><th>Action Integral, kAAs (±20%)</th><th>B Charge Transfer, C (±10%)</th><th>C* Charge Transfer, C (±20%)</th></tr>
<tr><td>Target 40 kA</td><td>24.8</td><td>5.50</td><td>40</td><td>80</td><td>10</td><td>18</td></tr>
<tr><td>Actual</td><td>-</td><td>-</td><td>39.8</td><td>75.54</td><td>10.75</td><td>21.05</td></tr>
</table>

Bonding measurement: 0.12 mΩ</td></tr>
</table>

<table>
<tr><th colspan="3">Test Log Data</th></tr>
<tr><th>Date</th><th>Time</th><th>Notes</th></tr>
<tr><td></td><td></td><td>Flammable gas did not ignite on DEL test and was successfully ignited post-test with a 184 µJ spark.

All waveform parameters met.</td></tr>
<tr><td></td><td>1:43pm</td><td>-08B TP2: Zone 3

<table>
<tr><th>Shot #</th><th>Charge Voltage, kV A bank:</th><th>Charge Voltage, kV B bank:</th><th>Peak I, kA (±10%)</th><th>Action Integral, kAAs (±20%)</th><th>B Charge Transfer, C (±10%)</th><th>C* Charge Transfer, C (±20%)</th></tr>
<tr><td>Target 40 kA</td><td>24.8</td><td>5.50</td><td>40</td><td>80</td><td>10</td><td>18</td></tr>
<tr><td>Actual</td><td>-</td><td>-</td><td>39.67</td><td>73.21</td><td>10.7</td><td>20.27</td></tr>
</table>

Flammable gas did not ignite on DEL test and was successfully ignited post-test with a 189 µJ spark.

All waveform parameters met.</td></tr>
<tr><td></td><td>2:00pm</td><td>-08B TP3: Zone 3

<table>
<tr><th>Shot #</th><th>Charge Voltage, kV A bank:</th><th>Charge Voltage, kV B bank:</th><th>Peak I, kA (±10%)</th><th>Action Integral, kAAs (±20%)</th><th>B Charge Transfer, C (±10%)</th><th>C* Charge Transfer, C (±20%)</th></tr>
<tr><td>Target 40 kA</td><td>24.8</td><td>5.50</td><td>40</td><td>80</td><td>10</td><td>18</td></tr>
<tr><td>Actual</td><td>-</td><td>-</td><td>39.73</td><td>76.35</td><td>10.73</td><td>22.05</td></tr>
</table>

Flammable gas did not ignite on DEL test and was successfully ignited post-test with a 187 µJ spark.

The charge transfer of Component C* was above tolerance. All other waveform parameters met.</td></tr>
<tr><td></td><td>2:12pm</td><td>-08B TP4: Zone 3

<table>
<tr><th>Shot #</th><th>Charge Voltage, kV A bank:</th><th>Charge Voltage, kV B bank:</th><th>Peak I, kA (±10%)</th><th>Action Integral, kAAs (±20%)</th><th>B Charge Transfer, C (±10%)</th><th>C* Charge Transfer, C (±20%)</th></tr>
<tr><td>Target 40 kA</td><td>24.8</td><td>5.50</td><td>40</td><td>80</td><td>10</td><td>18</td></tr>
<tr><td>Actual</td><td>-</td><td>-</td><td>39.73</td><td>75.79</td><td>10.73</td><td>22.21</td></tr>
</table>

Flammable gas did not ignite on DEL test and was successfully ignited post-test with a 177 µJ spark.

The charge transfer of Component C* was above tolerance. All other waveform parameters met.</td></tr>
<tr><td></td><td>2:28pm</td><td>-08B TP5: Zone 3</td></tr>
</table>

Test Log Data

<table>
<tr><th>Date</th><th>Time</th><th>Notes</th></tr>
<tr><td></td><td></td><td>
<table>
<tr><th>Shot #</th><th>Charge Voltage, kV A bank:</th><th>Charge Voltage, kV B bank:</th><th>Peak I, kA (±10%)</th><th>Action Integral, kAAs (±20%)</th><th>B Charge Transfer, C (±10%)</th><th>C* Charge Transfer, C (±20%)</th></tr>
<tr><td>Target 40 kA</td><td>24.8</td><td>5.50</td><td>40</td><td>80</td><td>10</td><td>18</td></tr>
<tr><td>Actual</td><td>-</td><td>-</td><td>39.73</td><td>76.3</td><td>10.74</td><td>22.51</td></tr>
</table>
Flammable gas did not ignite on DEL test and was successfully ignited post-test with a 187 µJ spark.

The charge transfer of Component C* was above tolerance. All other waveform parameters met.
</td></tr>
<tr><td></td><td>2:56pm</td><td>Generator was reconfigured for Zone 2A (inductor was removed from output, 0.5” spacing for B Bank spark gap, 6 caps on D Bank, 1/3 of the wall resistors)</td></tr>
<tr><td></td><td>3:04pm</td><td>WV02: Zone 2A

<table>
<tr><th>Shot #</th><th>Charge Voltage, kV A bank:</th><th>Charge Voltage, kV B bank:</th><th>Peak I, kA (±10%)</th><th>Action Integral, kAAs (±20%)</th><th>B Charge Transfer, C (±10%)</th><th>C* Charge Transfer, C (±20%)</th></tr>
<tr><td>Target 100 kA</td><td>45.0</td><td>5.50</td><td>100</td><td>250</td><td>10</td><td>18</td></tr>
<tr><td>Actual</td><td>-</td><td>-</td><td>96.93</td><td>263.15</td><td>10.7</td><td>22.65</td></tr>
</table>
Bonding Measurement: 0.76 mΩ

The charge transfer of Component C* was above tolerance. All other waveform parameters met.</td></tr>
<tr><td></td><td>3:46pm</td><td>-10A TP1: Zone 2A

<table>
<tr><th>Shot #</th><th>Charge Voltage, kV A bank:</th><th>Charge Voltage, kV B bank:</th><th>Peak I, kA (±10%)</th><th>Action Integral, kAAs (±20%)</th><th>B Charge Transfer, C (±10%)</th><th>C* Charge Transfer, C (±20%)</th></tr>
<tr><td>Target 100 kA</td><td>45.0</td><td>5.50</td><td>100</td><td>250</td><td>10</td><td>18</td></tr>
<tr><td>Actual</td><td>-</td><td>-</td><td>96.53</td><td>242.33</td><td>10.64</td><td>21.8</td></tr>
</table>
Bonding Measurement: 0.49 mΩ

Flammable gas did not ignite on DEL test and was successfully ignited post-test with a 160 µJ spark.

The charge transfer of Component C* was above tolerance. All other waveform parameters met.</td></tr>
<tr><td></td><td>4:00pm</td><td>Generator was disarmed. Testing complete for the day.</td></tr>
</table>

<table>
<tr><th colspan="3">Test Log Data</th></tr>
<tr><th>Date</th><th>Time</th><th>Notes</th></tr>
<tr><td></td><td></td><td></td></tr>
<tr><td>4/11/23
RK, AG, MSJ, DB</td><td>8:00am</td><td>Arrived to begin testing.</td></tr>
<tr><td></td><td>9:20am</td><td>Generator armed.

Performed the gas verification with 9 successful ignitions of the flammable mixture between 177 and 182 µJ.
7% hydrogen.
Capacitance was set to 9.8 pF
Shop air environment: 13.9 %RH</td></tr>
<tr><td></td><td>9:55am</td><td>-10A TP2: Zone 2A

<table>
<tr><th>Shot #</th><th>Charge Voltage, kV A bank:</th><th>Charge Voltage, kV B bank:</th><th>Peak I, kA (±10%)</th><th>Action Integral, kAAs (±20%)</th><th>B Charge Transfer, C (±10%)</th><th>C* Charge Transfer, C (±20%)</th></tr>
<tr><td>Target 100 kA</td><td>45.0</td><td>5.50</td><td>100</td><td>250</td><td>10</td><td>18</td></tr>
<tr><td>Actual</td><td>-</td><td>-</td><td>96</td><td>241.46</td><td>10.37</td><td>21.49</td></tr>
</table>

Flammable gas did not ignite on DEL test and was successfully ignited post-test with a 170 µJ spark.

All waveform parameters met.</td></tr>
<tr><td></td><td>10:21am</td><td>-10ATP3: Zone 2A

<table>
<tr><th>Shot #</th><th>Charge Voltage, kV A bank:</th><th>Charge Voltage, kV B bank:</th><th>Peak I, kA (±10%)</th><th>Action Integral, kAAs (±20%)</th><th>B Charge Transfer, C (±10%)</th><th>C* Charge Transfer, C (±20%)</th></tr>
<tr><td>Target 100 kA</td><td>45.0</td><td>5.50</td><td>100</td><td>250</td><td>10</td><td>18</td></tr>
<tr><td>Actual</td><td>-</td><td>-</td><td>96</td><td>244.59</td><td>10.59</td><td>22.18</td></tr>
</table>

Flammable gas did not ignite on DEL test and was successfully ignited post-test with a 173 µJ spark.

The charge transfer of Component C* was above tolerance. All other waveform parameters met.</td></tr>
<tr><td></td><td>10:35am</td><td>-10A TP4: Zone 2A

<table>
<tr><th>Shot #</th><th>Charge Voltage, kV A bank:</th><th>Charge Voltage, kV B bank:</th><th>Peak I, kA (±10%)</th><th>Action Integral, kAAs (±20%)</th><th>B Charge Transfer, C (±10%)</th><th>C* Charge Transfer, C (±20%)</th></tr>
</table>
</td></tr>
</table>

Test Log Data

Date	Time	Notes

Target 100 kA	45.0	5.50	100	250	10	18
Actual	-	-	95.53	244.3	10.67	20.91

Flammable gas did not ignite on DEL test and was successfully ignited post-test with a 177 µJ spark.

All waveform parameters met.

10:46am

-10A TP5: Zone 2A

Shot #	Charge Voltage, kV A bank:	Charge Voltage, kV B bank:	Peak I, kA (±10%)	Action Integral, kAAs (±20%)	B Charge Transfer, C (±10%)	C* Charge Transfer, C (±20%)
Target 100 kA	45.0	5.50	100	250	10	18
Actual	-	-	95	247.47	10.67	20.99

Flammable gas did not ignite on DEL test and was successfully ignited post-test with a 180 µJ spark.

All other waveform parameters met.

11:22am

-07A TP1: Zone 2A

Shot #	Charge Voltage, kV A bank:	Charge Voltage, kV B bank:	Peak I, kA (±10%)	Action Integral, kAAs (±20%)	B Charge Transfer, C (±10%)	C* Charge Transfer, C (±20%)
Target 100 kA	45.0	5.50	100	250	10	18
Actual	-	-	96.73	242.15	10.66	20.84

Bonding measurement: 0.34 mΩ

Flammable gas did not ignite on DEL test and was successfully ignited post-test with a 175 µJ spark.

All other waveform parameters met.

11:38am

-07A TP2: Zone 2A - Invalid

Shot #	Charge Voltage, kV A bank:	Charge Voltage, kV B bank:	Peak I, kA (±10%)	Action Integral, kAAs (±20%)	B Charge Transfer, C (±10%)	C* Charge Transfer, C (±20%)

Test Log Data

Date	Time	Notes

Target 100 kA	45.0	5.50	100	250	10	18
Actual	-	-	96.53	242.57	10.65	21.55

The valves were mistakenly opened and air was flowed into the chamber prior to igniting the mixture after the lightning test. This evacuated the flammable mixture before it could be verified that the environment was ignitable below 200 µ J resulting in an invalid test point. An additional fastener location on the panel was identified to replace this data.

All waveform parameters met.

11:56am

-07A TP3: Zone 2A

Shot #	Charge Voltage, kV A bank:	Charge Voltage, kV B bank:	Peak I, kA (±10%)	Action Integral, kAAs (±20%)	B Charge Transfer, C (±10%)	C* Charge Transfer, C (±20%)
Target 100 kA	45.0	5.50	100	250	10	18
Actual	-	-	95.93	245.42	10.61	21.75

Flammable gas did not ignite on DEL test and was successfully ignited post-test with a 175 µJ spark.

The charge transfer of Component C* was above tolerance. All other waveform parameters met.

12.55pm

-07A TP4: Zone 2A

Shot #	Charge Voltage, kV A bank:	Charge Voltage, kV B bank:	Peak I, kA (±10%)	Action Integral, kAAs (±20%)	B Charge Transfer, C (±10%)	C* Charge Transfer, C (±20%)
Target 100 kA	45.0	5.50	100	250	10	18
Actual	-	-	96.07	248.68	10.65	21.08

Flammable gas did not ignite on DEL test and was successfully ignited post-test with a 159 µJ spark.

All waveform parameters met.

1:10pm

-07A TP5: Zone 2A

Shot #	Charge Voltage, kV A bank:	Charge Voltage, kV B bank:	Peak I, kA (±10%)	Action Integral, kAAs (±20%)	B Charge Transfer, C (±10%)	C* Charge Transfer, C (±20%)

Test Log Data

Date	Time	Notes

Target 100 kA	45.0	5.50	100	250	10	18
Actual	-	-	95.33	245.69	10.64	21.67

Flammable gas did not ignite on DEL test and was successfully ignited post-test with a 173 µJ spark.

The charge transfer of Component C* was above tolerance. All other waveform parameters met.

-07A TP6: Zone 2A

Shot #	Charge Voltage, kV A bank:	Charge Voltage, kV B bank:	Peak I, kA (±10%)	Action Integral, kAAs (±20%)	B Charge Transfer, C (±10%)	C* Charge Transfer, C (±20%)
Target 100 kA	45.0	5.50	100	250	10	18
Actual	-	-	95.33	246.59	10.58	22.8

Flammable gas did not ignite on DEL test and was successfully ignited post-test with a 152 µJ spark.

The charge transfer of Component C* was above tolerance. All other waveform parameters met.

-03A TP1: Zone 2A

Shot #	Charge Voltage, kV A bank:	Charge Voltage, kV B bank:	Peak I, kA (±10%)	Action Integral, kAAs (±20%)	B Charge Transfer, C (±10%)	C* Charge Transfer, C (±20%)
Target 100 kA	45.0	5.50	100	250	10	18
Actual	-	-	97.27	245.07	10.65	22.06

Bonding Measurement: 0.35 mΩ

Flammable gas did not ignite on DEL test and was successfully ignited post-test with a 159 µJ spark.

The charge transfer of Component C* was above tolerance. All other waveform parameters met.

-03A TP2: Zone 2A

Shot #	Charge Voltage, kV A bank:	Charge Voltage, kV B bank:	Peak I, kA (±10%)	Action Integral, kAAs (±20%)	B Charge Transfer, C (±10%)	C* Charge Transfer, C (±20%)

Test Log Data

Date	Time	Notes

Target 100 kA	45.0	5.50	100	250	10	18
Actual	-	-	96.33	244.24	10.68	21.78

Flammable gas did not ignite on DEL test and was successfully ignited post-test with a 106 µJ spark.

The charge transfer of Component C* was above tolerance. All other waveform parameters met.

-03A TP3: Zone 2A

Shot #	Charge Voltage, kV A bank:	Charge Voltage, kV B bank:	Peak I, kA (±10%)	Action Integral, kAAs (±20%)	B Charge Transfer, C (±10%)	C* Charge Transfer, C (±20%)
Target 100 kA	45.0	5.50	100	250	10	18
Actual	-	-	95.8	247.36	10.66	24.91

Flammable gas did not ignite on DEL test and was successfully ignited post-test with a 159 µJ spark.

The charge transfer and duration of Component C* was above tolerance. Average amplitude of Component C* was below tolerance. All other waveform parameters met.

-03A TP4: Zone 2A

Shot #	Charge Voltage, kV A bank:	Charge Voltage, kV B bank:	Peak I, kA (±10%)	Action Integral, kAAs (±20%)	B Charge Transfer, C (±10%)	C* Charge Transfer, C (±20%)
Target 100 kA	45.0	5.50	100	250	10	18
Actual	-	-	95.47	246.79	10.64	22.31

Flammable gas did not ignite on DEL test and was successfully ignited post-test with a 168 µJ spark.

The charge transfer of Component C* was above tolerance. All other waveform parameters met.

2:50pm

-03A TP5: Zone 2A

Shot #	Charge Voltage, kV A bank:	Charge Voltage, kV B bank:	Peak I, kA (±10%)	Action Integral, kAAs (±20%)	B Charge Transfer, C (±10%)	C* Charge Transfer, C (±20%)

Test Log Data

Date	Time	Notes

Target 100 kA	45.0	5.50	100	250	10	18
Actual	-	-	95.13	247.4	10.6	22.14

Flammable gas did not ignite on DEL test and was successfully ignited post-test with a 144 µJ spark.

The charge transfer of Component C* was above tolerance. All other waveform parameters met.

3:30pm

-09A TP1: Zone 1C Shot 1 (Components B, C*, D)

Shot #	Charge Voltage, kV A bank:	Charge Voltage, kV B bank:	Peak I, kA (±10%)	Action Integral, kAAs (±20%)	B Charge Transfer, C (±10%)	C* Charge Transfer, C (±20%)
Target 100 kA	45.0	5.50	100	250	10	18
Actual	-	-	96.6	242.8	10.51	22.73

Bonding Measurement: 0.46 mΩ

Flammable gas did not ignite on DEL test and was successfully ignited post-test with a 152 µJ spark.

The charge transfer of Component C* was above tolerance. All other waveform parameters met.

3:41pm

-09A TP2: Zone 1C Shot 1 (Components B, C*, D) - Invalid

Shot #	Charge Voltage, kV A bank:	Charge Voltage, kV B bank:	Peak I, kA (±10%)	Action Integral, kAAs (±20%)	B Charge Transfer, C (±10%)	C* Charge Transfer, C (±20%)
Target 100 kA	45.0	5.50	100	250	10	18
Actual	-	-	95.6	240.76	10.7	21.88

Flammable gas did not ignite on DEL test and was successfully ignited post-test with a 157 µJ spark.

The charge transfer of Component C* was above tolerance. All other waveform parameters met.

3:56pm

-09A TP3: Zone 1C Shot 1 (Components B, C*, D) - Invalid

Shot #	Charge Voltage, kV A bank:	Charge Voltage, kV B bank:	Peak I, kA (±10%)	Action Integral, kAAs (±20%)	B Charge Transfer, C (±10%)	C* Charge Transfer, C (±20%)

Test Log Data

Date	Time	Notes
		Target 100 kA | 45.0 | 5.50 | 100 | 250 | 10 | 18 **Actual** | - | - | 96.07 | 243.76 | 10.68 | 22.19 Flammable gas did not ignite on DEL test and was successfully ignited post-test with a 117 µJ spark. The charge transfer of Component C* was above tolerance. All other waveform parameters met.
	4:09pm	-09A TP4: Zone 1C Shot 1 (Components B, C*, D) - Invalid **Shot # | Charge Voltage, kV A bank: | Charge Voltage, kV B bank: | Peak I, kA (±10%) | Action Integral, kAAs (±20%) | B Charge Transfer, C (±10%) | C* Charge Transfer, C (±20%)** **Target 100 kA** | 45.0 | 5.50 | 100 | 250 | 10 | 18 **Actual** | - | - | 95.6 | 246.4 | 10.6 | 22.83 Flammable gas did not ignite on DEL test and was successfully ignited post-test with a 148 µJ spark. The charge transfer of Component C* was above tolerance. All other waveform parameters met.
	4:17pm	-09A TP5: Zone 1C Shot 1 (Components B, C*, D) - Invalid **Shot # | Charge Voltage, kV A bank: | Charge Voltage, kV B bank: | Peak I, kA (±10%) | Action Integral, kAAs (±20%) | B Charge Transfer, C (±10%) | C* Charge Transfer, C (±20%)** **Target 100 kA** | 45.0 | 5.50 | 100 | 250 | 10 | 18 **Actual** | - | - | 95 | 246.56 | 10.68 | 21.91 Flammable gas did not ignite on DEL test and was successfully ignited post-test with a 142 µJ spark. The charge transfer of Component C* was above tolerance. All other waveform parameters met.
	4:23pm	Generator disarmed, testing complete for the day.
4/27/23	1:00pm	It was decided to move forward with Zone 1C as laid out in Table 4 of customer test plan. No current component D will be applied as in a real aircraft the A_H and D components would not arrive at the same time and place therefore only the more severe component (that being A_H) will be tested.

<table>
<tr><th colspan="3">Test Log Data</th></tr>
<tr><th>Date</th><th>Time</th><th>Notes</th></tr>
<tr><td>4/24/23
DB, RK</td><td>10:30am</td><td>Arrived to begin testing.</td></tr>
<tr><td></td><td></td><td>Too much moisture in the shop air to test. Water traps were emptied and allowed to dry out, testing complete for the day.</td></tr>
<tr><td></td><td></td><td></td></tr>
<tr><td>4/25/23
DB, RK</td><td>8:15am</td><td>Arrived to begin testing.</td></tr>
<tr><td></td><td>10:20am</td><td>Performed the gas verification with 9 successful ignitions of the flammable mixture between 142 and 177 µJ.
7% hydrogen.
Capacitance was set to 9.8 pF
Shop air environment: 15.4 %RH</td></tr>
<tr><td></td><td>10:50am</td><td>Generator was configured for Component A_H (17 capacitors, 1/3 wall resistors)</td></tr>
<tr><td></td><td>11:25am</td><td>WV03: Zone 1C (A_H, B, C*)
<table>
<tr><th>Shot #</th><th>Charge Voltage, kV A bank:</th><th>Charge Voltage, kV B bank:</th><th>Peak I, kA (±10%)</th><th>Action Integral, kAAs (±20%)</th><th>B Charge Transfer, C (±10%)</th><th>C* Charge Transfer, C (±20%)</th></tr>
<tr><td>Target 150 kA</td><td>43.0</td><td>5.50</td><td>150</td><td>800</td><td>10</td><td>18</td></tr>
<tr><td>Actual</td><td>-</td><td>-</td><td>150</td><td>926</td><td>10.74</td><td>20.7</td></tr>
</table>
Bonding Measurement: 0.62 mΩ

All waveform parameters met.</td></tr>
<tr><td></td><td>12:55pm</td><td>-09B TP1: Zone 1C
<table>
<tr><th>Shot #</th><th>Charge Voltage, kV A bank:</th><th>Charge Voltage, kV B bank:</th><th>Peak I, kA (±10%)</th><th>Action Integral, kAAs (±20%)</th><th>B Charge Transfer, C (±10%)</th><th>C* Charge Transfer, C (±20%)</th></tr>
<tr><td>Target 150 kA</td><td>43.0</td><td>5.50</td><td>150</td><td>800</td><td>10</td><td>18</td></tr>
<tr><td>Actual</td><td>-</td><td>-</td><td>152</td><td>850</td><td>10.64</td><td>22.55</td></tr>
</table>
Bonding Measurement: 0.49 mΩ

Flammable gas mixture ignited during the DEL strike resulting in a failure.

The charge transfer of Component C* was above tolerance. All other waveform parameters met.</td></tr>
<tr><td></td><td>1:09pm</td><td>-09B TP2: Zone 1C
<table>
<tr><th>Shot #</th><th>Charge Voltage, kV A bank:</th><th>Charge Voltage, kV B bank:</th><th>Peak I, kA (±10%)</th><th>Action Integral, kAAs (±20%)</th><th>B Charge Transfer, C (±10%)</th><th>C* Charge Transfer, C</th></tr>
</table></td></tr>
</table>

Test Log Data

Date	Time	Notes

						(±20%)
Target 150 kA	43.0	5.50	150	800	10	18
Actual	-	-	153	866	10.61	22.51

Flammable gas mixture ignited during the DEL strike resulting in a failure.

The charge transfer of Component C* was above tolerance. All other waveform parameters met.

1:30pm

-09B TP3: Zone 1C

Shot #	Charge Voltage, kV A bank:	Charge Voltage, kV B bank:	Peak I, kA (±10%)	Action Integral, kAAs (±20%)	B Charge Transfer, C (±10%)	C* Charge Transfer, C (±20%)
Target 150 kA	43.0	5.50	150	800	10	18
Actual	-	-	152	861	10.63	22.32

Flammable gas did not ignite on DEL test and was successfully ignited post-test with a 159 µJ spark.

The charge transfer of Component C* was above tolerance. All other waveform parameters met.

1:45pm

-09B TP4: Zone 1C

Shot #	Charge Voltage, kV A bank:	Charge Voltage, kV B bank:	Peak I, kA (±10%)	Action Integral, kAAs (±20%)	B Charge Transfer, C (±10%)	C* Charge Transfer, C (±20%)
Target 150 kA	43.0	5.50	150	800	10	18
Actual	-	-	152	868	10.65	21.88

Flammable gas did not ignite on DEL test and was successfully ignited post-test with a 159 µJ spark.

The charge transfer of Component C* was above tolerance. All other waveform parameters met.

1:58pm

-09B TP5: Zone 1C

Shot #	Charge Voltage, kV A bank:	Charge Voltage, kV B bank:	Peak I, kA (±10%)	Action Integral, kAAs (±20%)	B Charge Transfer, C (±10%)	C* Charge Transfer, C (±20%)

Test Log Data

Date	Time	Notes

Target 150 kA	43.0	5.50	150	800	10	18
Actual	-	-	152	865	10.64	22.6

Flammable gas did not ignite on DEL test and was successfully ignited post-test with a 164 µJ spark.

The charge transfer of Component C* was above tolerance. All other waveform parameters met.

2:38pm

-06A TP1: Zone 1C - Invalid

Shot #	Charge Voltage, kV A bank:	Charge Voltage, kV B bank:	Peak I, kA (±10%)	Action Integral, kAAs (±20%)	B Charge Transfer, C (±10%)	C* Charge Transfer, C (±20%)
Target 150 kA	43.0	5.50	150	800	10	18
Actual	-	-	153	871	10.63	21.76

Bonding Measurement: 0.43 mΩ

Flammable gas did not ignite on DEL test and was successfully ignited post-test with a 146 µJ spark.

The charge transfer of Component C* was above tolerance. All other waveform parameters met.

Strike resulted in a split attachment making the test point invalid.

2:52pm

-06A TP2: Zone 1C

Shot #	Charge Voltage, kV A bank:	Charge Voltage, kV B bank:	Peak I, kA (±10%)	Action Integral, kAAs (±20%)	B Charge Transfer, C (±10%)	C* Charge Transfer, C (±20%)
Target 150 kA	43.0	5.50	150	800	10	18
Actual	-	-	153	873	10.53	21.79

Flammable gas did not ignite on DEL test and was successfully ignited post-test with a 155 µJ spark. Scope did not trigger but the spark breakdown was between 5.6 - 6.0 kV according to the read out on the ESVM.

The charge transfer of Component C* was above tolerance. All other waveform parameters met.

3:06pm

-06A TP3: Zone 1C - Invalid

Test Log Data

Date	Time	Notes
		Shot # | **Charge Voltage, kV A bank:** | **Charge Voltage, kV B bank:** | **Peak I, kA (±10%)** | **Action Integral, kAAs (±20%)** | **B Charge Transfer, C (±10%)** | **C* Charge Transfer, C (±20%)** **Target 150 kA** | 43.0 | 5.50 | 150 | 800 | 10 | 18 **Actual** | - | - | 152 | 861 | 10.63 | 21.53 Flammable gas did not ignite on DEL test and was successfully ignited post-test with a 177 µJ spark. Scope did not trigger but the spark breakdown was less than 6.0 kV according to the read out on the ESVM All waveform parameters met. Strike did not attach to the fastener head resulting in an invalid test point.
	3:20pm	-06A TP4: Zone 1C **Shot #** | **Charge Voltage, kV A bank:** | **Charge Voltage, kV B bank:** | **Peak I, kA (±10%)** | **Action Integral, kAAs (±20%)** | **B Charge Transfer, C (±10%)** | **C* Charge Transfer, C (±20%)** **Target 150 kA** | 43.0 | 5.50 | 150 | 800 | 10 | 18 **Actual** | - | - | 151 | 858 | 10.52 | 21.82 Flammable gas did not ignite on DEL test and was successfully ignited post-test with a 164 µJ spark. The charge transfer of Component C* was above tolerance. All other waveform parameters met.
		-06A TP5: Zone 1C **Shot #** | **Charge Voltage, kV A bank:** | **Charge Voltage, kV B bank:** | **Peak I, kA (±10%)** | **Action Integral, kAAs (±20%)** | **B Charge Transfer, C (±10%)** | **C* Charge Transfer, C (±20%)** **Target 150 kA** | 43.0 | 5.50 | 150 | 800 | 10 | 18 **Actual** | - | - | 151 | 871 | 10.55 | 22.34 Flammable gas did not ignite on DEL test and was successfully ignited post-test with a 167 µJ spark. The charge transfer of Component C* was above tolerance. All other waveform parameters met.
	4:00pm	Generator disarmed and testing complete for the day.

<table>
<tr><th colspan="3">Test Log Data</th></tr>
<tr><th>Date</th><th>Time</th><th>Notes</th></tr>
<tr><td></td><td></td><td></td></tr>
<tr><td>4/26/23
RK, DB, BD</td><td>8:00am</td><td>Arrived to begin testing.</td></tr>
<tr><td></td><td>9:14am</td><td>Performed the gas verification with 9 successful ignitions of the flammable mixture between 168 and 200 µJ.
7% hydrogen.
Capacitance was set to 9.8 pF
Shop air environment: 12.6 %RH

Generator armed</td></tr>
<tr><td></td><td>9;40am</td><td>-02A TP1: Zone 1C - Invalid

<table>
<tr><th>Shot #</th><th>Charge Voltage, kV A bank:</th><th>Charge Voltage, kV B bank:</th><th>Peak I, kA (±10%)</th><th>Action Integral, kAAs (±20%)</th><th>B Charge Transfer, C (±10%)</th><th>C* Charge Transfer, C (±20%)</th></tr>
<tr><td>Target 150 kA</td><td>43.0</td><td>5.50</td><td>150</td><td>800</td><td>10</td><td>18</td></tr>
<tr><td>Actual</td><td>-</td><td>-</td><td>153</td><td>868</td><td>10.67</td><td>21.36</td></tr>
</table>

Bonding Measurement: 0.33 mΩ

Flammable gas did not ignite on DEL test and was successfully ignited post-test with a 137 µJ spark.

All waveform parameters met.

Strike did not attach to fastener head resulting in an invalid test point.</td></tr>
<tr><td></td><td>9:53am</td><td>-02A TP2: Zone 1C

<table>
<tr><th>Shot #</th><th>Charge Voltage, kV A bank:</th><th>Charge Voltage, kV B bank:</th><th>Peak I, kA (±10%)</th><th>Action Integral, kAAs (±20%)</th><th>B Charge Transfer, C (±10%)</th><th>C* Charge Transfer, C (±20%)</th></tr>
<tr><td>Target 150 kA</td><td>43.0</td><td>5.50</td><td>150</td><td>800</td><td>10</td><td>18</td></tr>
<tr><td>Actual</td><td>-</td><td>-</td><td>153</td><td>878</td><td>10.67</td><td>21.39</td></tr>
</table>

Flammable gas did not ignite on DEL test and was successfully ignited post-test with a 164 µJ spark.

All waveform parameters met.</td></tr>
<tr><td></td><td>10:12am</td><td>-02A TP3: Zone 1C

<table>
<tr><th>Shot #</th><th>Charge Voltage, kV</th><th>Charge Voltage, kV</th><th>Peak I, kA (±10%)</th><th>Action Integral,</th><th>B Charge Transfer, C (±10%)</th><th>C* Charge</th></tr>
</table>
</td></tr>
</table>

Test Log Data

Date	Time	Notes

	A bank:	B bank:		kAAs (±20%)		Transfer, C (±20%)
Target 150 kA	43.0	5.50	150	800	10	18
Actual	-	-	152	861	10.69	21.34

Flammable gas did not ignite on DEL test and was successfully ignited post-test with a 168 µJ spark.

All waveform parameters met.

10:32am

-02A TP4: Zone 1C

Shot #	Charge Voltage, kV A bank:	Charge Voltage, kV B bank:	Peak I, kA (±10%)	Action Integral, kAAs (±20%)	B Charge Transfer, C (±10%)	C* Charge Transfer, C (±20%)
Target 150 kA	43.0	5.50	150	800	10	18
Actual	-	-	152	875	10.59	21.02

Flammable gas did not ignite on DEL test and was successfully ignited post-test with a 164 µJ spark.

All waveform parameters met.

10:53am

-02A TP5: Zone 1C

Shot #	Charge Voltage, kV A bank:	Charge Voltage, kV B bank:	Peak I, kA (±10%)	Action Integral, kAAs (±20%)	B Charge Transfer, C (±10%)	C* Charge Transfer, C (±20%)
Target 150 kA	43.0	5.50	150	800	10	18
Actual	-	-	151	880	10.64	22.13

Flammable gas did not ignite on DEL test and was successfully ignited post-test with a 173 µJ spark.

The charge transfer of Component C* was above tolerance. All other waveform parameters met.

12:16pm

-02A TP6: Zone 1C

Shot #	Charge Voltage, kV A bank:	Charge Voltage, kV B bank:	Peak I, kA (±10%)	Action Integral, kAAs (±20%)	B Charge Transfer, C (±10%)	C* Charge Transfer, C (±20%)

Test Log Data

Date	Time	Notes

Target 150 kA	43.0	5.50	150	800	10	18
Actual	-	-	151	871	10.63	22.69

Bonding Measurement: 0.38 mΩ

Flammable gas did not ignite on DEL test and was successfully ignited post-test with a 146 µJ spark.

The charge transfer of Component C* was above tolerance. All other waveform parameters met.

2:22pm

-06B TP1: Zone 1C

Shot #	Charge Voltage, kV A bank:	Charge Voltage, kV B bank:	Peak I, kA (±10%)	Action Integral, kAAs (±20%)	B Charge Transfer, C (±10%)	C* Charge Transfer, C (±20%)
Target 150 kA	43.0	5.50	150	800	10	18
Actual	-	-	154	874	10.68	20.97

Bonding Measurement: 0.43 mΩ

Flammable gas did not ignite on DEL test and was successfully ignited post-test with a 159 µJ spark.

All waveform parameters met.

2:40pm

-06B TP2: Zone 1C

Shot #	Charge Voltage, kV A bank:	Charge Voltage, kV B bank:	Peak I, kA (±10%)	Action Integral, kAAs (±20%)	B Charge Transfer, C (±10%)	C* Charge Transfer, C (±20%)
Target 150 kA	43.0	5.50	150	800	10	18
Actual	-	-	153	876	10.63	22.16

Flammable gas did not ignite on DEL test and was successfully ignited post-test with a 173 µJ spark.

The charge transfer of Component C* was above tolerance. All other waveform parameters met.

Generator was reconfigured for Zone 1A (22 caps, full wall resistor, ½ inch spacing on B bank spark gap)

4:00pm — Testing complete for the day.

4/27/23 8:15am — Arrived to begin testing. Generator armed.

<table>
<tr><th colspan="3">Test Log Data</th></tr>
<tr><th>Date</th><th>Time</th><th>Notes</th></tr>
<tr><td>RK, DB, BD</td><td></td><td></td></tr>
<tr><td></td><td>8:40am</td><td>WV04: Zone 1A (A, B, C*)

<table>
<tr><th>Shot #</th><th>Charge Voltage, kV A bank:</th><th>Charge Voltage, kV B bank:</th><th>Peak I, kA (±10%)</th><th>Action Integral, kAAs (±20%)</th><th>B Charge Transfer, C (±10%)</th><th>C* Charge Transfer, C (±20%)</th></tr>
<tr><td>Target 200 kA</td><td>43.0</td><td>5.50</td><td>200</td><td>2000</td><td>10</td><td>18</td></tr>
<tr><td>Actual</td><td>-</td><td>-</td><td>195</td><td>2333</td><td>10.63</td><td>4.05</td></tr>
</table>

Bonding Measurement: 0.40 mΩ

Charge transfer and duration of Component C* were blow tolerance. All other waveform parameters met. Loose connections were tightened.</td></tr>
<tr><td></td><td>8:53am</td><td>WV05: Zone 1A (A, B, C*)

<table>
<tr><th>Shot #</th><th>Charge Voltage, kV A bank:</th><th>Charge Voltage, kV B bank:</th><th>Peak I, kA (±10%)</th><th>Action Integral, kAAs (±20%)</th><th>B Charge Transfer, C (±10%)</th><th>C* Charge Transfer, C (±20%)</th></tr>
<tr><td>Target 200 kA</td><td>43.0</td><td>5.50</td><td>200</td><td>2000</td><td>10</td><td>18</td></tr>
<tr><td>Actual</td><td>-</td><td>-</td><td>195</td><td>2334.07</td><td>10.69</td><td>20.98</td></tr>
</table>

All waveform parameters met.</td></tr>
<tr><td></td><td>9:20am</td><td>Performed the gas verification with 9 successful ignitions of the flammable mixture between 168 and 200 µJ.
7% hydrogen.
Capacitance was set to 9.8 pF
Shop air environment: 17.6 %RH</td></tr>
<tr><td></td><td>9:48am</td><td>-01A TP1: Zone 1A

<table>
<tr><th>Shot #</th><th>Charge Voltage, kV A bank:</th><th>Charge Voltage, kV B bank:</th><th>Peak I, kA (±10%)</th><th>Action Integral, kAAs (±20%)</th><th>B Charge Transfer, C (±10%)</th><th>C* Charge Transfer, C (±20%)</th></tr>
<tr><td>Target 200 kA</td><td>43.0</td><td>5.50</td><td>200</td><td>2000</td><td>10</td><td>18</td></tr>
<tr><td>Actual</td><td>-</td><td>-</td><td>194</td><td>2137</td><td>10.53</td><td>22.02</td></tr>
</table>

Bonding Measurement: 0.37 mΩ

Flammable gas did not ignite on DEL test and was successfully ignited post-test with a 177 µJ spark.</td></tr>
</table>

<table>
<tr><th colspan="3">Test Log Data</th></tr>
<tr><th>Date</th><th>Time</th><th>Notes</th></tr>
<tr><td></td><td></td><td>Charge transfer of Component C* was above tolerance. All other waveform parameters met.</td></tr>
<tr><td></td><td>10:15am</td><td>-01A TP2: Zone 1A - Invalid
<table>
<tr><th>Shot #</th><th>Charge Voltage, kV A bank:</th><th>Charge Voltage, kV B bank:</th><th>Peak I, kA (±10%)</th><th>Action Integral, kAAs (±20%)</th><th>B Charge Transfer, C (±10%)</th><th>C* Charge Transfer, C (±20%)</th></tr>
<tr><td>Target 200 kA</td><td>43.0</td><td>5.50</td><td>200</td><td>2000</td><td>10</td><td>18</td></tr>
<tr><td>Actual</td><td>-</td><td>-</td><td>191</td><td>2177</td><td>0</td><td>21.37</td></tr>
</table>
Flammable gas mixture was evacuated after test as the B Component did not fire resulting in an invalid test.

No Component B. All other waveform parameters met.

It was observed that the internal connections of the B Bank spark gap had become damaged through high current densities through small cross sectional areas over time. Sphere gap was repaired before testing continued.</td></tr>
<tr><td></td><td>11:08am</td><td>-01A TP3: Zone 1A
<table>
<tr><th>Shot #</th><th>Charge Voltage, kV A bank:</th><th>Charge Voltage, kV B bank:</th><th>Peak I, kA (±10%)</th><th>Action Integral, kAAs (±20%)</th><th>B Charge Transfer, C (±10%)</th><th>C* Charge Transfer, C (±20%)</th></tr>
<tr><td>Target 200 kA</td><td>43.0</td><td>5.50</td><td>200</td><td>2000</td><td>10</td><td>18</td></tr>
<tr><td>Actual</td><td>-</td><td>-</td><td>189</td><td>2030</td><td>10.54</td><td>21.65</td></tr>
</table>
Flammable gas did not ignite on DEL test and was successfully ignited post-test with a 166 µJ spark. Scope did not trigger, breakdown voltage was read off of the ESVM display.

Charge transfer of Component C* was above tolerance. All other waveform parameters met.</td></tr>
<tr><td></td><td>11:29am</td><td>-01A TP4: Zone 1A
<table>
<tr><th>Shot #</th><th>Charge Voltage, kV A bank:</th><th>Charge Voltage, kV B bank:</th><th>Peak I, kA (±10%)</th><th>Action Integral, kAAs (±20%)</th><th>B Charge Transfer, C (±10%)</th><th>C* Charge Transfer, C (±20%)</th></tr>
<tr><td>Target 200 kA</td><td>43.0</td><td>5.50</td><td>200</td><td>2000</td><td>10</td><td>18</td></tr>
<tr><td>Actual</td><td>-</td><td>-</td><td>190</td><td>2172</td><td>10.61</td><td>20.98</td></tr>
</table></td></tr>
</table>

<table>
<tr><th colspan="3">Test Log Data</th></tr>
<tr><th>Date</th><th>Time</th><th>Notes</th></tr>
<tr><td></td><td></td><td>Flammable gas did not ignite on DEL test and was successfully ignited post-test with a 187 µJ spark.

All waveform parameters met.</td></tr>
<tr><td></td><td>11:38am</td><td>-01A TP5: Zone 1A - Invalid

<table>
<tr><th>Shot #</th><th>Charge Voltage, kV A bank:</th><th>Charge Voltage, kV B bank:</th><th>Peak I, kA (±10%)</th><th>Action Integral, kAAs (±20%)</th><th>B Charge Transfer, C (±10%)</th><th>C* Charge Transfer, C (±20%)</th></tr>
<tr><td>Target 200 kA</td><td>43.0</td><td>5.50</td><td>200</td><td>2000</td><td>10</td><td>18</td></tr>
<tr><td>Actual</td><td>-</td><td>-</td><td>190</td><td>2098</td><td>10.45</td><td>21.96</td></tr>
</table>

Flammable gas did not ignite on DEL test and was successfully ignited post-test with a 177 µJ spark.

Charge transfer of Component C* was above tolerance. All other waveform parameters met. Test is marked as invalid due to a split attachment to multiple fastener heads.</td></tr>
<tr><td></td><td>12:03pm</td><td>-01A TP6: Zone 1A - Invalid

<table>
<tr><th>Shot #</th><th>Charge Voltage, kV A bank:</th><th>Charge Voltage, kV B bank:</th><th>Peak I, kA (±10%)</th><th>Action Integral, kAAs (±20%)</th><th>B Charge Transfer, C (±10%)</th><th>C* Charge Transfer, C (±20%)</th></tr>
<tr><td>Target 200 kA</td><td>43.0</td><td>5.50</td><td>200</td><td>2000</td><td>10</td><td>18</td></tr>
<tr><td>Actual</td><td>-</td><td>-</td><td>191</td><td>2077</td><td>0</td><td>22.05</td></tr>
</table>

Flammable gas mixture was evacuated after test as the B Component did not fire resulting in an invalid test.

No Component B. All other waveform parameters met.</td></tr>
<tr><td></td><td>1:30pm</td><td>Output was cleaned and connections were tightened.</td></tr>
<tr><td></td><td>1:46pm</td><td>WV06 - Aluminum bar

<table>
<tr><th>Shot #</th><th>Charge Voltage, kV A bank:</th><th>Charge Voltage, kV B bank:</th><th>Peak I, kA (±10%)</th><th>Action Integral, kAAs (±20%)</th><th>B Charge Transfer, C (±10%)</th><th>C* Charge Transfer, C (±20%)</th></tr>
<tr><td>Target 200 kA</td><td>43.0</td><td>5.50</td><td>200</td><td>2000</td><td>10</td><td>N/A</td></tr>
<tr><td>Actual</td><td>-</td><td>-</td><td>198</td><td>2338</td><td>10.56</td><td>-</td></tr>
</table>

All waveform parameters were met.</td></tr>
</table>

Test Log Data

<table>
<tr><th>Date</th><th>Time</th><th>Notes</th></tr>
<tr><td></td><td>1:58pm</td><td>WV07 - Aluminum calibration plate

<table>
<tr><th>Shot #</th><th>Charge Voltage, kV A bank:</th><th>Charge Voltage, kV B bank:</th><th>Peak I, kA (±10%)</th><th>Action Integral, kAAs (±20%)</th><th>B Charge Transfer, C (±10%)</th><th>C* Charge Transfer, C (±20%)</th></tr>
<tr><td>Target 200 kA</td><td>43.0</td><td>5.50</td><td>200</td><td>2000</td><td>10</td><td>18</td></tr>
<tr><td>Actual</td><td>-</td><td>-</td><td>196</td><td>23</td><td>10.45</td><td>20.92</td></tr>
</table>

Bonding measurement: 0.37 mΩ

All waveform parameters were met.</td></tr>
<tr><td></td><td>2:52pm</td><td>-01B TP1: Zone 1A

<table>
<tr><th>Shot #</th><th>Charge Voltage, kV A bank:</th><th>Charge Voltage, kV B bank:</th><th>Peak I, kA (±10%)</th><th>Action Integral, kAAs (±20%)</th><th>B Charge Transfer, C (±10%)</th><th>C* Charge Transfer, C (±20%)</th></tr>
<tr><td>Target 200 kA</td><td>43.0</td><td>5.50</td><td>200</td><td>2000</td><td>10</td><td>18</td></tr>
<tr><td>Actual</td><td>-</td><td>-</td><td>193</td><td>2041</td><td>10.53</td><td>21.84</td></tr>
</table>

Bonding measurement: 0.38 mΩ

Flammable gas did not ignite on DEL test and was successfully ignited post-test with a 164 µJ spark.

Charge transfer of Component C* was above tolerance. All other waveform parameters met.</td></tr>
<tr><td></td><td>3:06pm</td><td>-01B TP2: Zone 1A

<table>
<tr><th>Shot #</th><th>Charge Voltage, kV A bank:</th><th>Charge Voltage, kV B bank:</th><th>Peak I, kA (±10%)</th><th>Action Integral, kAAs (±20%)</th><th>B Charge Transfer, C (±10%)</th><th>C* Charge Transfer, C (±20%)</th></tr>
<tr><td>Target 200 kA</td><td>43.0</td><td>5.50</td><td>200</td><td>2000</td><td>10</td><td>18</td></tr>
<tr><td>Actual</td><td>-</td><td>-</td><td>191</td><td>2013</td><td>10.37</td><td>23.41</td></tr>
</table>

Flammable gas mixture ignited during the DEL strike resulting in a failure.

The charge transfer and duration of Component C* were above tolerance. All other waveform parameters met.</td></tr>
<tr><td></td><td>3:49pm</td><td>-04A TP1: Zone 1A</td></tr>
</table>

<table>
<tr><th colspan="3">Test Log Data</th></tr>
<tr><th>Date</th><th>Time</th><th>Notes</th></tr>
<tr><td></td><td></td><td>
<table>
<tr><th>Shot #</th><th>Charge Voltage, kV A bank:</th><th>Charge Voltage, kV B bank:</th><th>Peak I, kA (±10%)</th><th>Action Integral, kAAs (±20%)</th><th>B Charge Transfer, C (±10%)</th><th>C* Charge Transfer, C (±20%)</th></tr>
<tr><td>Target 200 kA</td><td>43.0</td><td>5.50</td><td>200</td><td>2000</td><td>10</td><td>18</td></tr>
<tr><td>Actual</td><td>-</td><td>-</td><td>193</td><td>2033</td><td>10.39</td><td>21.39</td></tr>
</table>
Bonding Measurement: 0.32 mΩ

Flammable gas mixture ignited during the DEL strike resulting in a failure Force of the gas ignition caused the fastener to be ejected from the panel.

All waveform parameters met.
</td></tr>
<tr><td></td><td></td><td>Testing complete for the day.</td></tr>
<tr><td></td><td></td><td></td></tr>
<tr><td>4/29/23
RK, TA, BD</td><td>8:25am</td><td>Arrived to begin testing.</td></tr>
<tr><td></td><td>10:15am</td><td>Performed the gas verification with 9 successful ignitions of the flammable mixture between 150 and 182 µJ.
7% hydrogen.
Capacitance was set to 9.8 pF
Shop air environment: 15.1 %RH

Generator armed</td></tr>
<tr><td></td><td>10:23am</td><td>-04A TP2: Zone 1A

<table>
<tr><th>Shot #</th><th>Charge Voltage, kV A bank:</th><th>Charge Voltage, kV B bank:</th><th>Peak I, kA (±10%)</th><th>Action Integral, kAAs (±20%)</th><th>B Charge Transfer, C (±10%)</th><th>C* Charge Transfer, C (±20%)</th></tr>
<tr><td>Target 200 kA</td><td>43.0</td><td>5.50</td><td>200</td><td>2000</td><td>10</td><td>18</td></tr>
<tr><td>Actual</td><td>-</td><td>-</td><td>193.8</td><td>2074</td><td>10.3</td><td>22.97</td></tr>
</table>
Flammable gas mixture ignited during the DEL strike resulting in a failure Force of the gas ignition caused the fastener to be ejected from the panel.

The charge transfer of Component C* was above tolerance. All other waveform parameters met.</td></tr>
<tr><td></td><td>1:00pm</td><td>The rest of testing was aborted due to the scale of damage seen on the -04 configuration which was expected to also occur on the -05 configuration.

Testing complete.</td></tr>
</table>

Appendix D - Test Deviations

WICHITA STATE UNIVERSITY
NATIONAL INSTITUTE FOR AVIATION RESEARCH
Environmental Test Labs

NIAR ETL Deviation Form

VER 01252022

Deviation #	23-2152-D035-1	Company	NIAR Internal - KART
Date	4/6/2023	Company POC	Rebeka Khajehpour
Work Order #	23-2152-WK035	POC Email	Rebeka.khajehpour@idp.wichita.edu
PO #	N/A	Originator Name	David Bruner

Deviation from requirements ☒

Waiver for nonconforming work ☐

REQUEST FOR DEVIATION/WAIVER	
Test Plan & Rev / Standard	**23-2152-TP035**
Section	**4.1 - Table 3**

Customer agreed to the use of a TREK Electrostatic Voltmeter that required a minor repair to a ground plug terminal. This in turn resulted in the TREK ESVM to break its calibration seal. The TREK ESVM was verified using other calibrated equipment and another ESD Guns ESVM. TREK ESVM was found to be within the manufacturer's tolerances.

Nick Conquest	**Rebeka Khajehpour**	**Reid Owens**
NIAR Manager Name	Customer Name	NIAR Quality Name
NIAR Manager Signature	Customer Signature	NIAR Quality Signature

WICHITA STATE UNIVERSITY - National Institute for Aviation Research - 1845 Fairmount Street - Wichita, KS 67260-0093
tele: (316)978-6427 - web: www.niar.wichita.edu

Figure D-1: 23-2152-D035-1

NIAR ETL Deviation Form VER 01252022

Deviation #	23-2152-D035-2	Company	NIAR Internal - KART
Date	4/11/2023	Company POC	Rebeka Khajehpour
Work Order #	23-2152-WK035	POC Email	Rebeka.khajehpour@idp.wichita.edu
PO #	N/A	Originator Name	Melvin St. John

Deviation from requirements ☐

Waiver for nonconforming work ☒

REQUEST FOR DEVIATION/WAIVER	
Test Plan & Rev / Standard	23-2152-TP035
Section	5.1 Step 3 (c) (ii)

Valves that hold the flammable gas mixture in the chamber were opened after lightning test (which did not ignite the gas mixture) but before verifying that the environment was ignatable at or below 200 µJ resulting in an invalid test point. A new fastener was selected for an alternate test point as specified in the customer test plan.

Nick Conquest	**Rebeka Khajehpour**	**Reid Owens**
NIAR Manager Name	Customer Name	NIAR Quality Name
NIAR Manager Signature	Customer Signature	NIAR Quality Signature

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tele. (316)978-6427 - web. www.niar.wichita.edu

Figure D-2: 23-2152-D035-2

NIAR ETL Deviation Form

VER 01252022

Deviation #	23-2152-D035-3	Company	NIAR Internal - KART
Date	4/7/2023	Company POC	Rebeka Khajehpour
Work Order #	23-2152-WK035	POC Email	Rebeka.khajehpour@idp.wichita.edu
PO #	N/A	Originator Name	Melvin St. John

Deviation from requirements ☐

Waiver for nonconforming work ☒

REQUEST FOR DEVIATION/WAIVER	
Test Plan & Rev / Standard	**23-2152-TP035**
Section	**5.1 Step 3 (c) (ii)**

When verifying the flammability of the environment after the lightning strike on -11A TP3 and TP4, the spark energy exceeded 200 µJ. The capacitance of the spark source was changed to bring the new spark breakdown range within 200 µJ and the invalid test points were re-tested per the customer test plan on substitute fasteners.

Nick Conquest	**Rebeka Khajehpour**	**Reid Owens**
NIAR Manager Name	Customer Name	NIAR Quality Name
NIAR Manager Signature	Customer Signature	NIAR Quality Signature

Figure D-3: 23-2152-D035-3

NIAR ETL Deviation Form VER 01252022

Deviation #	23-2152-D035-4	Company	NIAR Internal - KART
Date	4/11/2023	Company POC	Rebeka Khajehpour
Work Order #	23-2152-WK035	POC Email	Rebeka.khajehpour@idp.wichita.edu
PO #	N/A	Originator Name	David Bruner

Deviation from requirements ☐

Waiver for nonconforming work ☒

REQUEST FOR DEVIATION/WAIVER	
Test Plan & Rev / Standard	23-2152-TP035
Section	4.2 Table 4

Section 4.2 of the customer test plan says:

The waveform components applied for each zone are shown in Table 4. The waveforms are shown in Table 4 below and are defined in SAE ARP 5412B.

Table 4: List of Components Applied in Each Lightning Zone

Zone	Components
1A	A, B, C*
1C	A_{11}, B, C*
2A	D, B, C*
3	A/5, B, C*

Table 4 mistakenly leaves out current component D from the Zone 1C configuration. On test article -09A TP1-TP5, Component D was applied even though not in Table 4 as it is called out in 5412B with customer permission.

Nick Conquest	**Rebeka Khajehpour**	**Reid Owens**
NIAR Manager Name	Customer Name	NIAR Quality Name
NIAR Manager Signature	Customer Signature	NIAR Quality Signature

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Figure D-4: 23-2152-D035-4

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NATIONAL INSTITUTE FOR AVIATION RESEARCH
Environmental Test Labs

NIAR ETL Deviation Form

VER 01252022

Deviation #	23-2152-D035-6	Company	NIAR Internal - KART
Date	4/7/2023	Company POC	Rebeka Khajehpour
Work Order #	23-2152-WK035	POC Email	Rebeka.khajehpour@idp.wichita.edu
PO #	N/A	Originator Name	David Bruner

Deviation from requirements ☐

Waiver for nonconforming work ☒

REQUEST FOR DEVIATION/WAIVER	
Test Plan & Rev / Standard	**23-2152-TP035**
Section	**4.2**

The waveforms applied to the following test points were out of tolerance:

- -11A TP1: Comp. A peak amplitude and action integral were below tolerance. Comp. C charge transfer and duration were above tolerance.
- -11A TP2: Comp C average amplitude was below tolerance.
- -11A TP3: Comp. C charge transfer was above tolerance.
- -08A TP3: Comp. C charge transfer was above tolerance.
- -08A TP4: Comp. C charge transfer was above tolerance.
- -08A TP5: Comp. C charge transfer was above tolerance.
- WW02: Comp. C charge transfer was above tolerance.
- -10A TP3: Comp. C charge transfer was above tolerance.
- -07A TP3: Comp. C charge transfer was above tolerance.
- -07A TP5: Comp. C charge transfer was above tolerance.
- -07A TP6: Comp. C charge transfer was above tolerance.
- -03A TP1: Comp. C charge transfer was above tolerance.
- -03A TP2: Comp. C charge transfer was above tolerance.
- -03A TP3: Comp. C average amplitude was below tolerance, and the charge transfer and duration were above tolerance.
- -03A TP4: Comp. C charge transfer was above tolerance.
- -03A TP5: Comp. C charge transfer was above tolerance.
- -09A TP1: Comp. C charge transfer was above tolerance.
- -09A TP2: Comp. C charge transfer was above tolerance.
- -09A TP3: Comp. C charge transfer was above tolerance.
- -09A TP4: Comp. C charge transfer was above tolerance.
- -09A TP5: Comp. C charge transfer was above tolerance.

The invalid test points on test article -11A were replaced with the duplicate panel per the customer test plan. All other invalid test points listed here were accepted by the customer as the waveforms applied resulted in a more conservative charge transfer and did not result in a failure. All future waveforms that are either:

a. above tolerance but do not result in an ignition of the flammable gas mixture or
b. below tolerance but do result in an ignition of the flammable gas mixture,

are considered acceptable by the customer.

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Figure D-5: 23-2152-D035-6_Page_1

NIAR ETL Deviation Form

VER 01252022

Nick Conquest	Rebeka Khajehpour	Reid Owens
NIAR Manager Name	Customer Name	NIAR Quality Name
NIAR Manager Signature	Customer Signature	NIAR Quality Signature

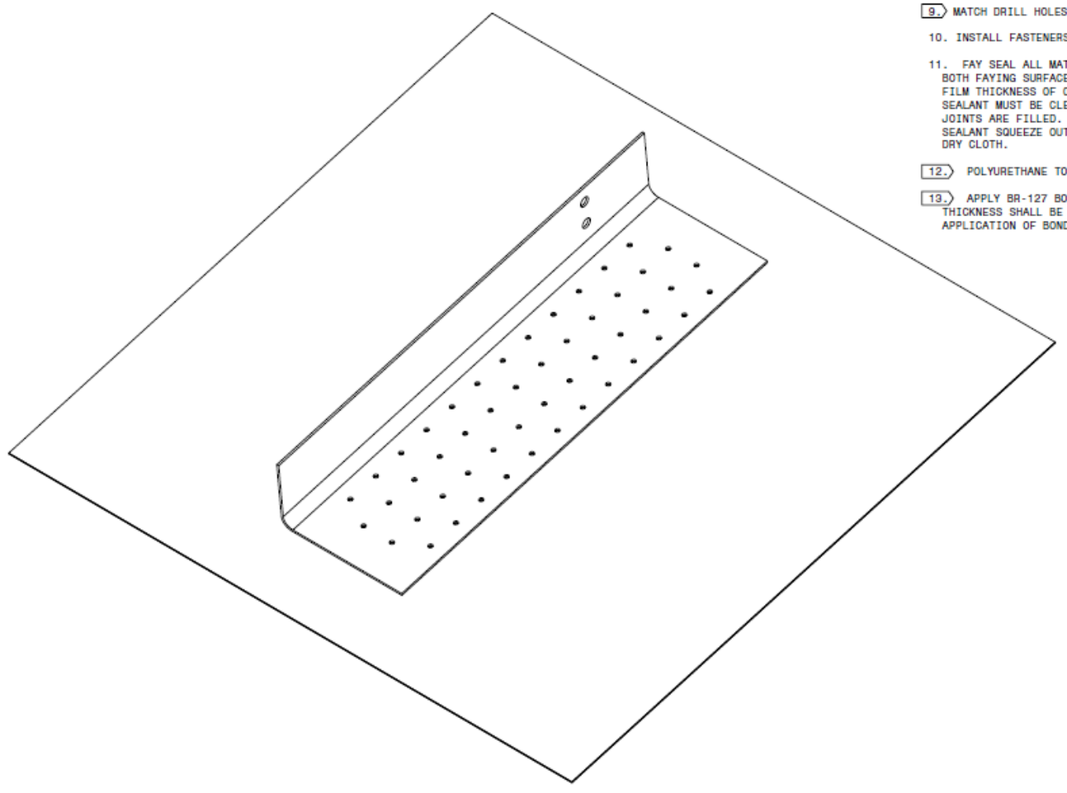
WICHITA STATE UNIVERSITY - National Institute for Aviation Research - 1845 Fairmount Street - Wichita, KS 67260-0093
tele. (316)978-6427 - web: www.niar.wichita.edu

Figure D-6: 23-2152-D035-6_Page_2

Appendix E - Engineering Drawings

NOTES:

1. INTERPRET THIS DATASET PER ASME Y14. 100 - 2017
2. DIMENSIONS AND TOLERANCES PER ASME Y14.5 - 2018
3. MASK OFF INDICATED AREA BEFORE APPLYING ANY COATINGS.
4. FINISH ALODINE OR ANODIZE PLUS ONE COAT OF FUEL TANK PRIMER. 1-1.5 MIL DRY FILM THICKNESS
5. CHROMIC ACID ANODIZE (CAA) MILPRF-8625 TYPE 1, CLASS 1 IS USED TO PREVENT CORROSION. IT SHALL BE SEALED BY IMMERSION IN A SEALING MEDIUM SUCH AS A 5 PERCENT AQUEOUS SOLUTION OF SODIUM DICHROMATE (pH 5.0 to 6.0) FOR 15 MINUTES AT 90°C TO 100°C, IN BOILING DEIONIZED WATER, COBALT OR NICKEL ACETATE, OR OTHER SUITABLE CHEMICAL SOLUTIONS.
6. ADHESIVE: FM73C FILM
7. FM® 73 IS USED WITH STANDARD CLEANING TECHNIQUES INVOLVING A FOUR STEP PROCEDURE OF SOLVENT DEGREASING, ALKALINE CLEANING, CHEMICAL DEOXIDIZING (ETCHING), AND PHOSPHORIC ACID ANODIZING
8. CURE THE FM73C FILM ADHESIVE MATERIAL AT 245-260°F FOR A CURE DWELL TIME OF 60-90 MINUTES AT 50 PSI WITH RAMP RATE AT 0.5 -12 °F/MIN.
9. MATCH DRILL HOLES IN -103 PANEL.
10. INSTALL FASTENERS PER HSTR_HLR_IS01_Rev_A.
11. 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.
12. POLYURETHANE TOP COAT APPLIED EXCEPT WHERE NOTED. MEASURE TOTAL DRY COATING THICKNESS 11-13 MILS.
13. APPLY BR-127 BOND PRIMER AFTER PHOSPHORIC ACID ANODIZE AND PRIOR TO BONDING WITH FM73C. CURE THICKNESS SHALL BE 0.00015-0.0040 INCHES. ENSURE SURFACES ARE CLEAN OF CONTAMINATS PRIOR TO APPLICATION OF BOND PRIMER.



Fasteners in Metal Bonded
Skins Test Article Assy
Isometric view
For reference only
Scale: 4:5

NATIONAL INSTITUTE FOR AVIATION RESEARCH, ETL

TITLE: FASTENERS IN METAL BONDED SKINS TEST ARTICLE ASSY

SIZE: E | DWG NO: Z3CS700 | REV: -

SCALE: NOTED | SHEET 1 OF 3

Figure E-1: Engineering Drawing page 1

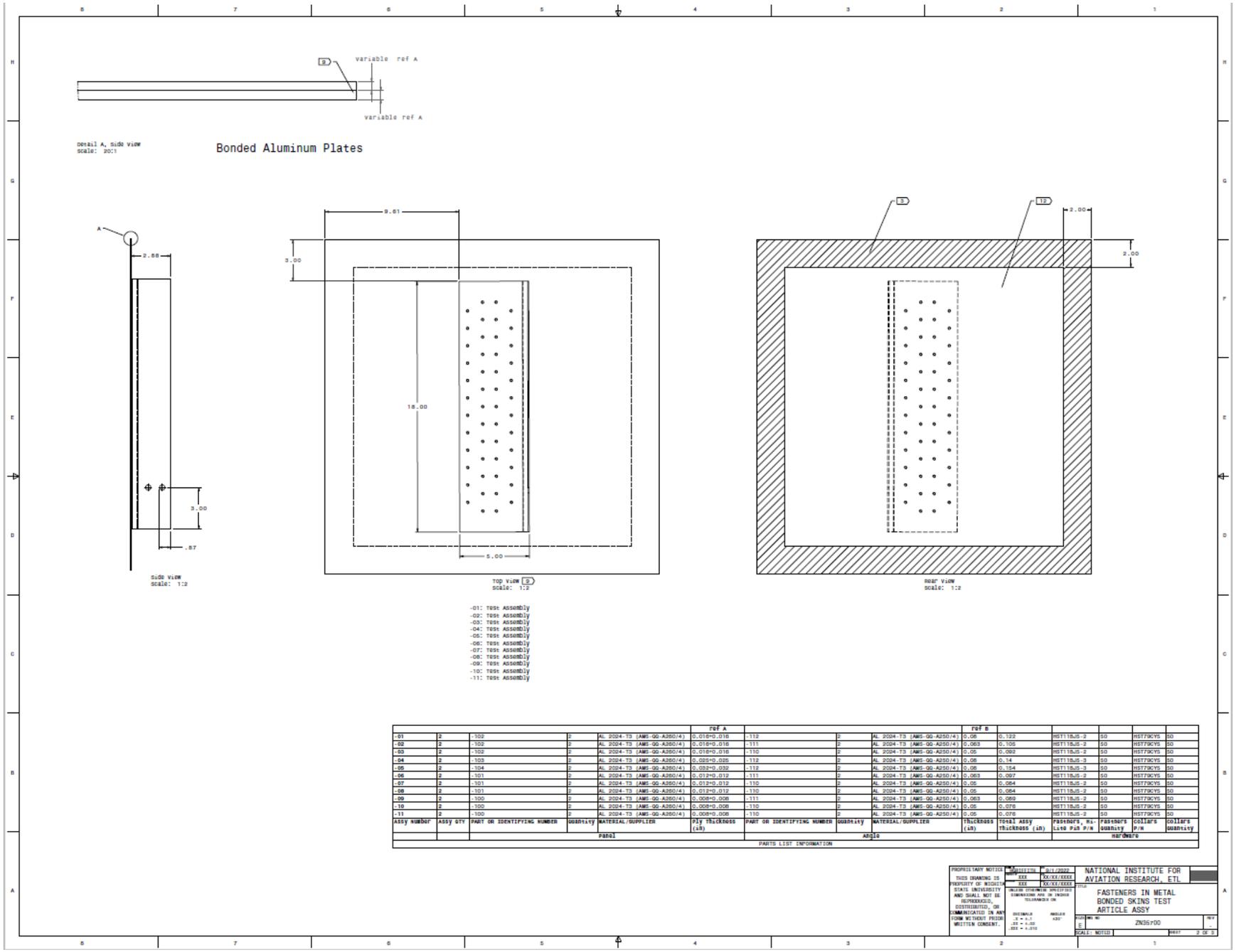


Figure E-2: Engineering Drawing page 2

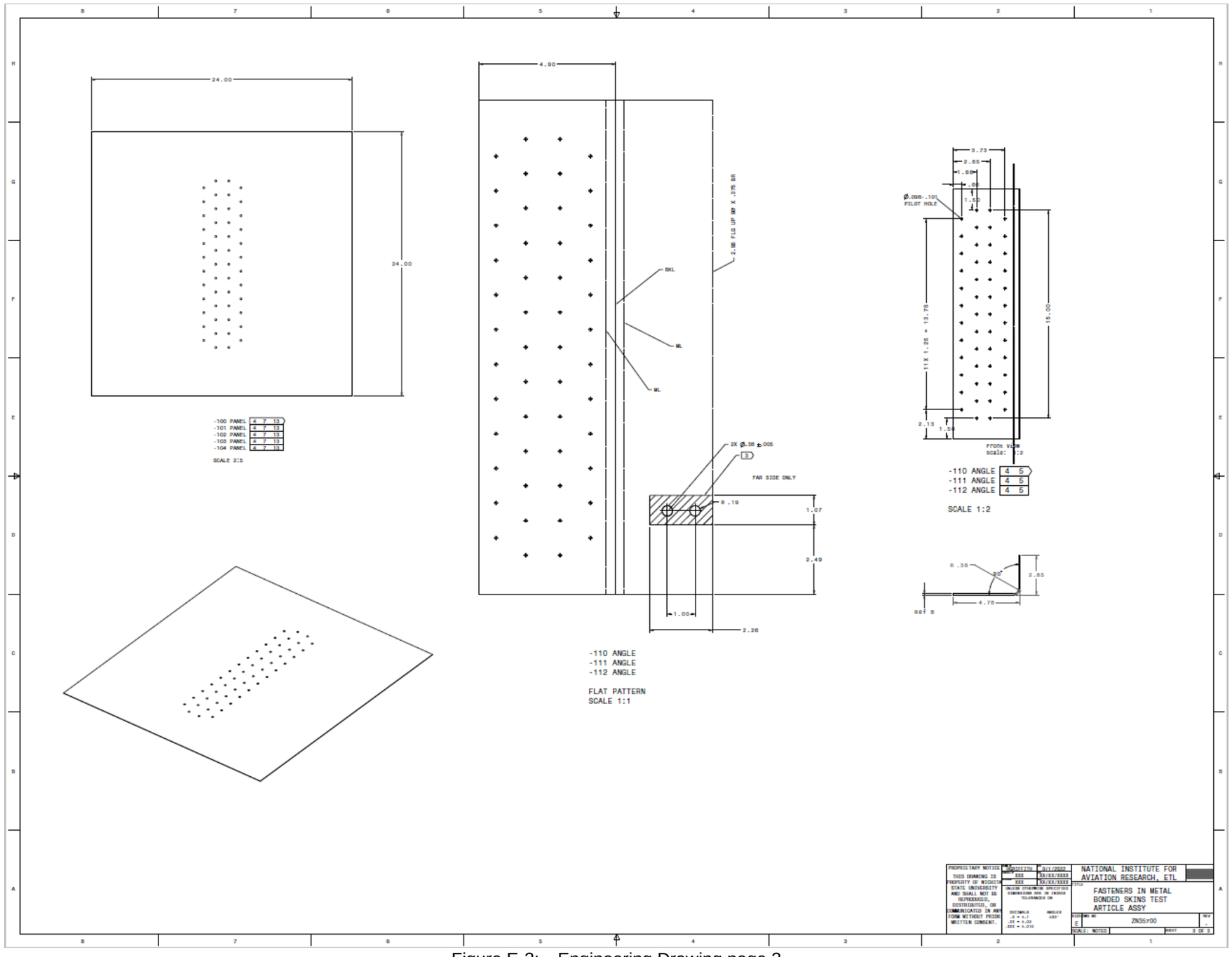


Figure E-3: Engineering Drawing page 3