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Kansas Aviation Research and Technology (KART)

Minimum Thickness of Aluminum Skins in Lightning Direct Attachment Zones

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The results and data of this report apply only to the test articles as listed in the Customer Equipment List and in the environments described.

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Revision -		
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Approved by: Kyle McMullen		Date: 04/28/2022

Section	Description
All	Initial Release of Document

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 Reaffirmed 2012	Aircraft Lightning Zone
SAE Aerospace ARP 5416A Revised 2013	Aircraft Lightning Test Methods
SAE Aerospace ARP 5577 Reaffirmed 2008	Aircraft Lightning Direct Effects Certification

2.0 Scope

This document contains the test results for the environmental effects testing of the KART test articles in Table 2. This test was performed in accordance with the test methods defined in SAE ARP 5416A, with the waveform parameters defined in SAE ARP 5412B based on the aircraft lightning zones in ARP 5414B.

Testing took place at the NIAR Environmental Test Lab located at 3800 S. Oliver Wichita, Kansas 67210 and from November 2, 2021 to February 2, 2022.

The test shot log containing waveform data for each test point is provided in Appendix A. A full listing of the test data can be found in Appendix B. Appendix C contains the test article engineering drawings.

2.1 Purpose

This test was designed to determine the minimum thickness of aluminum skins that will resist melt-through for each lightning direct attachment Zone that occurs in the fuel tank region. Both solid and bonded aluminum skins were evaluated for melt-through in Zones 1A, 1C, 2A, and 3 using the flammable gas ignition source detection method from SAE ARP 5416A. Tests were repeated for each Zone, and again for Component C* charge transfer values of 6 C and 18 C to show the effect of continuing current on the thresholds.

These Component C* charge transfer values were selected because 18 C is the standard test parameter defined in ARP 5412, and 6 C is an alternative often used by industry. Only the charge transfer from the current Component C* was considered, because per the AGATE Lightning Handbook, Component D stroke currents (and similar) “do not typically melt-though aluminum skins as their time duration and charge transfers are too low” (AGATE Lightning Direct Effects Handbook - Rev E, p. 49). Additionally, Component B was not varied for this test, because although it also imparts a significant enough charge transfer to cause melting, it is not typical to vary Component B due to the setup of the lightning generator. It is fairly typical to adjust the Component C* charge transfer. The details of the waveform parameters for each test point can be found in the shot log in Appendix A.

3.0 General Requirements

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

3.1 General Test Setup

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

3.1.1 Test Article Design

The test article design represented generic aluminum wing skin fuel tank structure, which did not contain fasteners or underlying internal structure. The test articles consisted of a solid sheet of 2024 T3 aluminum for solid panels, or two-ply aluminum sheets bonded with an adhesive between the aluminum layers for bonded panels. Multiple test points were performed on each panel but were spaced far enough apart so that the damage from the test points did not visibly overlap.

The following is a listing of the panels that were tested:

Table 2 – Test Article Panel List

Description	Part #	Serial #'s
Solid panel, 0.071" thick	71	-1, -2, -3, -4
Solid panel, 0.063" thick	63	-1, -2, -3, -4
Solid panel, 0.050" thick	50	-1, -2, -3, -4
Solid panel, 0.040" thick	40	-1, -2, -3, -4
Solid panel, 0.032" thick	32	-1, -2, -3, -4
Bond panel, 0.032" + 0.032" thick	B32	-1, -2, -3
Bond panel, 0.025" + 0.025" thick	25	-1, -2, -3
Bond panel, 0.016" + 0.016" thick	16	-1, -2, -3
Bond panel, 0.012" + 0.012" thick	12	-1, -2, -3
Bond panel, 0.008" + 0.008" thick	8	-1, -2, -3

Appendix C contains the test article engineering drawings.

3.1.1 High Current Generator

The test panels were installed near the output of the high current generator, allowing the arc to be discharged into the panel via the jet-diverting electrode. The panels were

electrically bonded to the generator return by clamping to copper straps between the panel and generator return.

A high current probe connected to an oscilloscope recorder for each waveform Component A (and all variations, including A/5, A_H, and D), B, and C*, recorded the waveform output of the generator. The required parameters for each waveform Component are listed in Table 3. Laboratory equipment utilized for testing is listed in Table 4.

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

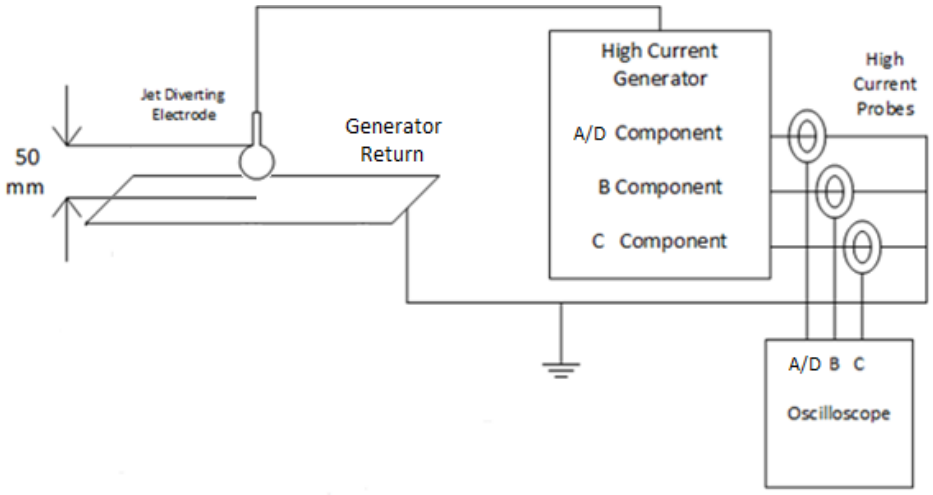


Figure 1: Waveform Verification Setup

The arc was directed to the selected test point using an initiating wire extending from the jet-diverting electrode to 50 mm from the surface of the test article, as depicted in Figure 2.

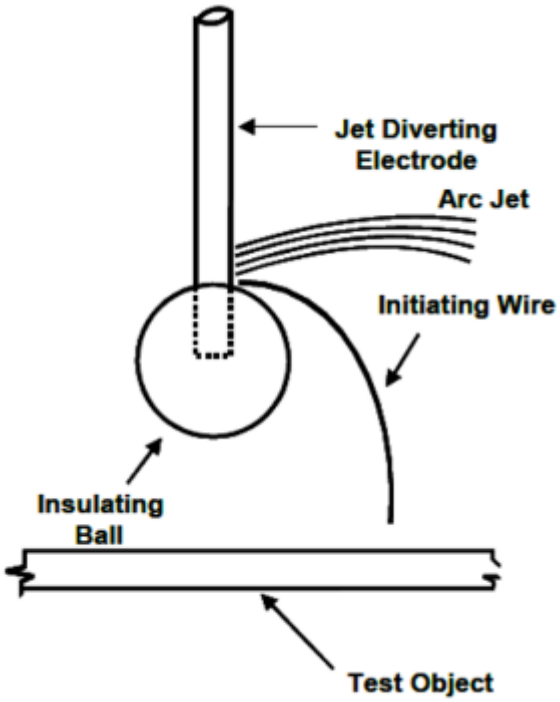


Figure 2: Jet-Diverting Electrode

The current Components listed in Table 3 were applied to the test panels for each lightning Zone:

- 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
Mico-Ohmmeter	Keithley	580	0685151	2/28/2022
High Current Generator	NIAR	HC1	001	N/A
Current Monitor Probe	Pearson Electronics Inc.	301X	147836	8/24/2022
Barometric Pressure and Humidity	Extech	SD700	Q774074	2/28/2022
Oscilloscope	Yokogawa	DL850E	91P313729	9/30/2022
HV Power Supply	Spellman	SL8PN2000X4874	102151349-A00001	N/A
Current Probe 1:1500	Danisense	DS600IDSA	14170020014	10/18/2022
Current Monitor Probe	Pearson Electronics Inc.	1423	147997	8/24/2022
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	9/30/2022
Analog Voltage Input Module	Yokogawa	701250	91P321166	9/30/2022
="4 Channel 100MHz 1GSa/s"	Rigol	DS1104	DS1ZA181305414	9/30/2022
Fuel Flow control	NIAR	FFC001	001	N/A
Massflow Controler Economical Gas	Omega	FMA5543	483712-1	10/13/2022
Mass Flow Controller 0-20 SKM H2	Omega	FMA5524A-H2	484161-1	10/13/2022
="200uj Spark Circuit"	NIAR	SS001	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
Digibridge	Gen Rad Inc.	1689	8243454004	5/31/2022
Single Stage Best Value Regulator Oxygen	Harris	25GX-145-540	N/A	N/A
Isolation Transformer 125-115-105V	Chicago Standard	P-6161	NA	N/A

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

Figure 3: General Test Setup

Figure 4: General Test Setup

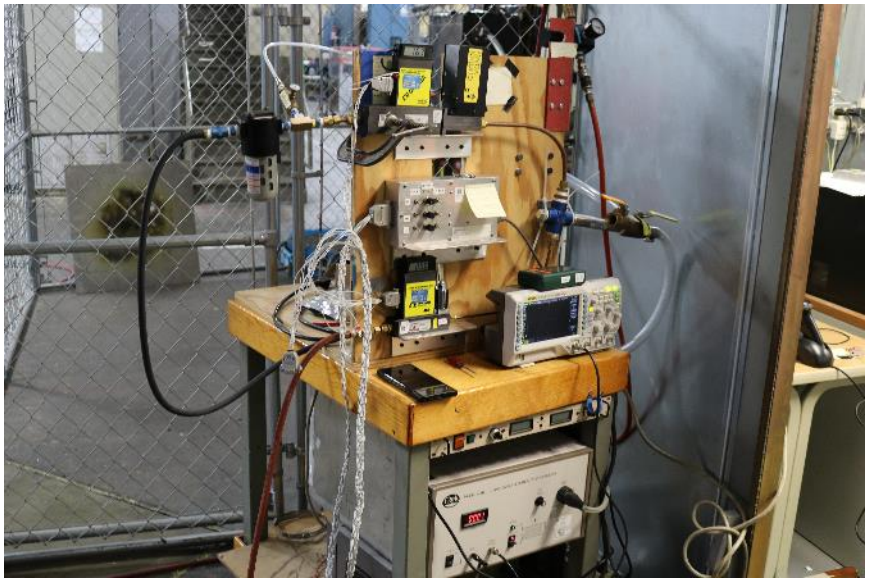


Figure 5: General Test Setup

3.1.1 Flammable Gas Ignition Detection

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

The test setup consisted of a fuel flow setup and a voltage spark-source setup. 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.

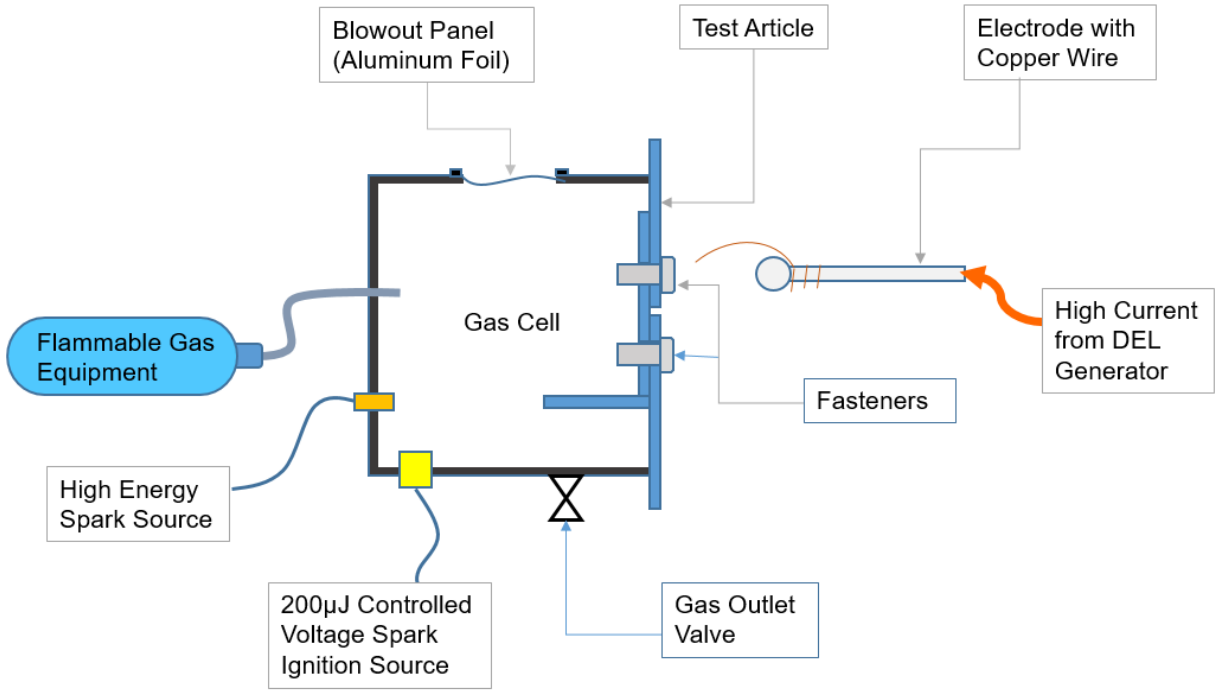


Figure 6: Test Setup Diagram

3.1.2 Test Witnessing

Testing was conducted by NIAR's Rebeka Khajehpour, Alyssa Gonzalez, Ted Angleton, and Brendan Murphy.

3.2 Arc Entry Test Procedure with Ignition Source Detection

Testing was performed per the following procedure:

1. Seal the flammable gas chamber and perform the flammable gas verification procedure to show that the gas mixture will ignite at least nine out of ten times with an arc energy of 200μJ or less, per the procedure in SAE ARP 5416A Section 7.7.2.
2. Initiate a lightning discharge to an unpainted aluminum dummy test article to verify that the output of the lightning generator falls within the required waveform parameters
3. Install the test article onto the test fixture and direct the initiating wire to the desired test point.
4. Seal the flammable gas test chamber and fill the chamber with the flammable gas mixture, displacing five test volumes.
5. Initiate a lightning discharge to the test article. Determine whether ignition of the flammable gas mixture occurred because of the lightning discharge, or if a hole was made.
6. If ignition due to the lightning test did not occur and there is no hole through the test article, ignite the flammable gas mixture with the controlled voltage spark ignition source to prove that the atmosphere was ignitable during the lightning test.
7. Record the results of the ignition, and any damage to the test article.
8. Repeat steps 3-7 for each test point on each test article.

4.0 Results and Testing

Minimum skin thickness thresholds were sought for Zones 1A, 1C, 2A, and 3, with both 6 and 18 Coulomb charge transfer for the current Component C*. A non-ignition threshold was identified for the thinnest panel in a particular lightning Zone when both of the following conditions were present:

1. Testing resulted in non-ignitions for 3 of 3 test points, and
2. No through-holes were present upon post-test inspection.

The thresholds determined through testing are listed in Table 5.

Table 5: Minimum Skin Thickness Thresholds for Solid and Metal Bond Panels

Solid Panels		
Zone	18 C	6 C
1A	None determined	None
1C	0.071	0.05
2A	None determined	0.05
3	0.071	0.05

Metal Bond Panels		
Zone	18 C	6 C
1A	0.025+0.025	0.025+0.025
1C	0.012+0.012	0.012+0.012
2A	0.012+0.012	0.012+0.012
3	0.008+0.008	0.008+0.008

Due to the occurrence of ignition on the thickest panel tested (0.071”), a threshold was not successfully determined for solid panels in Zone 1A or Zone 2A with 18 C charge transfer, or for solid panels in Zone 1A with 6 C charge transfer.

All data regarding the waveform parameters for each test point are located in Appendix A. Tables containing data for each test point, including information regarding the presence of holes and ignition can be found in Appendix B.

4.1 Ignition

Ignition and non-ignition results for all test points on each panel in each lightning Zone are listed in Appendix B.

4.2 Physical Damage

After lightning testing, the panels were visually evaluated for melt-through damage and measurement of holes. Melt-through holes were categorized into two designations regarding the type of damage visible on the interior (fuel tank side) of the panel.

1. Panels with “damage” show evidence of melting on the interior side of the panel, but the damage area is intact and does not contain a through hole.
2. Panels with “through holes” are damaged areas in which daylight can be seen all the way through the panel.

Examples of damage compared with through hole are shown in Figure 7 and Figure 8.

Figure 7: Left: Exterior-side damage, and right: through hole

Figure 8: Left: Interior-side damage, and right: through hole

A third type of damage contained large holes with bent aluminum near the edges, apparently created by the shockwave effects from the arc channel from high amplitude lighting stroke currents (Component A) applied to very thin panels, rather than holes from heating due to continuing current from Components B or C*. This was seen on 0.008”, 0.012”, and 0.016” metal bond panels in Zone 1A and on 0.008” panels in Zone 1C and Zone 2A.These large holes always coincided with ignition, and an example of this type of damage is shown in Figure 9.

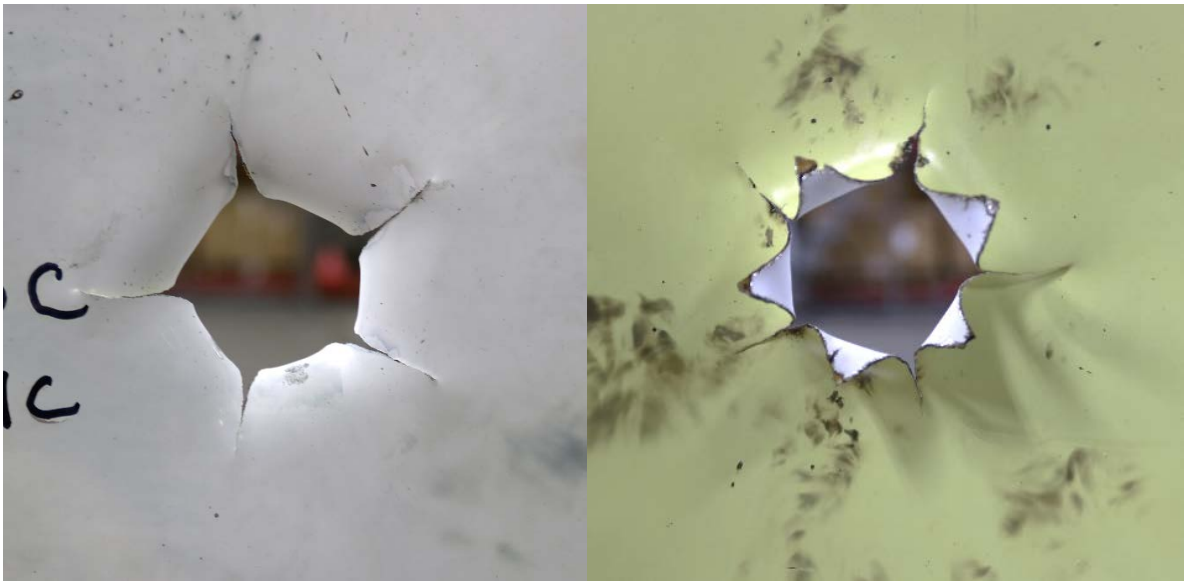


Figure 9: Front side (left) and backside (right) views of a large shockwave-driven through-hole

Multiple panels were found to have through holes but did not ignite the flammable gas during the lightning test. This seemed to occur for two different reasons. One possible cause was a thin layer of fuel tank primer that stayed in place on the inside surface of the panel despite the aluminum panel experiencing material loss due to melting. This primer layer may have prevented the gas from igniting, however, this primer layer was so thin that it later flaked off during handling of the panel with minimal force post-test. The second possible explanation was a lightning attachment producing a small pinhole in the panel, which was insufficient to heat the test point or introduce the flammable mixture to the lighting plasma channel to the point of ignition.

Metal bond assemblies sustained less damage on the inside (fuel tank side) of the test article than the equivalent thickness solid aluminum panels. The improved performance of metal bond panels is likely an effect of the dielectric layer of adhesive between the two aluminum plies.

Test points with 6 C charge transfer sustained less damage than equivalent test points (same panel thickness and lightning Zone) with 18 C charge transfer for all holes that

melting was the primary damage mechanism. The only test points which did not follow this trend had very large holes which did not result from melting alone, but also due to shockwave effects.

Panels which contained through holes, and their corresponding hole size data, are listed in Appendix B.

4.2.1 Melt-through Hole Size – Actual Panel Measurement vs Calculated

Intermediate and continuing currents can produce melting of metallic skins. According to *Lightning Protection of Aircraft,* the length of time the continuing current remains attached to the metal skin is the primary factor in the resulting melt-through damage. The likelihood of melt-through is also influenced by paint and primer, which act as a dielectric layer on metal surfaces, increasing the dwell time of lightning. Protection of metallic skins should aim to prevent melt-through in areas that endanger safety of flight. Hole formation due to melt-through presents a threat to the safety of flight if:

- the lightning channel comes into contact with flammable materials inside the fuel tank,
- a hole causes depressurization, or
- the hole degrades mechanical strength of a primary structure.

The equations below are taken from Section 6.2.1 of *Lightning Protection of Aircraft*, which were originally obtained from Hagenguth's work in 1949 (Fisher, Plumer, & Perala, p. 150). These equations determine hole size based on the charge transfer delivered during the lightning continuing currents and can be used to predict melt-through hole size on solid metal skins.

$$A = 0.93Qt^{-.09} \text{ for } 0 < t < 0.8 \text{ mm} \quad (1)$$

$$A = 0.81Qt^{-1.54} \text{ for } 0.8 < t < 4 \text{ mm} \quad (2)$$

Where,

A=area of hole melted (square millimeters)

Q=charge (coulombs) delivered to the point by the arc

t=thickness of metal sheets (centimeters)

There was no consistent relationship between the expected (calculated) hole size and observed (measured) hole size in any Zone for solid panels. Thinner solid panels had expected hole sizes that were larger than observed hole sizes, however, thicker solid panels had expected hole sizes that were smaller than the observed hole size. This data is in Table 6 and Table 7.

These equations do not apply to metal bond panels, nor do they take into account the impact of the pressure shockwave resulting from high amplitude initial stroke current Components (A and A_H) on very thin panels (solid or bonded) as seen in Figure 9. The hole sizes in these shockwave scenarios were dramatically increased as compared to holes formed purely by the mechanism of melting. Despite this, the equations were still applied to shockwave holes in the data tables in Appendix B to allow comparison to the rest of the data.

Hole size comparison data averaged for each panel thickness in each lighting Zone is available in Table 6 through Table 9. The full data listing for each test point is available in Appendix B.

Table 6: Average of observed vs expected hole size for solid panels with 18 C charge transfer

Panel Thickness (in)	Zone 3			Zone 2A			Zone 1C			Zone 1A		
	Charge Transfer (C)	Hole Area (mm^2)		Charge Transfer (C)	Hole Area (mm^2)		Charge Transfer (C)	Hole Area (mm^2)		Charge Transfer (C)	Hole Area (mm^2)	
		Observed	Expected		Observed	Expected		Observed	Expected		Observed	Expected
0.032	19.66	31.41	21.92	17.61	39.16	19.63	N/A	N/A	N/A	16.73	67.49	18.65
0.040	19.31	21.46	15.27	20.64	30.78	16.31	18.98	89.42	15.00	18.37	35.89	14.52
0.050	18.53	0.00	10.39	17.86	30.68	10.01	18.83	25.16	10.56	19.38	23.67	10.86
0.063	19.63	0.65	7.71	18.48	1.78	7.26	20.31	5.43	7.98	20.32	11.62	7.98
0.071	18.75	0.00	6.12	18.27	1.69	5.97	18.76	0.00	6.13	18.40	0.00	6.01

Table 7: Average of observed vs expected hole size for solid panels with 6 C charge transfer

Panel Thickness (in)	Zone 3			Zone 2A			Zone 1C			Zone 1A		
	Charge Transfer (C)	Hole Area (mm^2)		Charge Transfer (C)	Hole Area (mm^2)		Charge Transfer (C)	Hole Area (mm^2)		Charge Transfer (C)	Hole Area (mm^2)	
		Observed	Expected		Observed	Expected		Observed	Expected		Observed	Expected
0.032	6.36	15.71	7.08	6.13	18.20	6.83	6.07	71.78	6.77	8.12	50.90	9.05
0.040	6.00	2.14	4.75	6.50	0.00	5.14	6.12	24.63	4.84	5.81	12.63	4.59
0.050	6.12	0.00	3.43	5.87	0.00	3.29	6.21	0.00	3.48	6.00	0.00	0.03
0.063	6.03	0.00	2.37	6.23	0.00	2.45	6.23	0.00	2.45	5.94	0.00	2.33
0.071	6.17	0.00	2.02	5.98	0.00	1.95	6.35	0.00	2.07	5.85	0.00	1.91

Table 8: Average of observed hole size for metal bond panels with 18 C charge transfer

Panel Thickness (in)	Zone 3		Zone 2A		Zone 1C		Zone 1A	
	Charge Transfer (C)	Hole Area (mm^2)	Charge Transfer (C)	Hole Area (mm^2)	Charge Transfer (C)	Hole Area (mm^2)	Charge Transfer (C)	Hole Area (mm^2)
0.008	18.64	0.00	16.83	628.32	17.33	1963.50	N/A	N/A
0.012	18.53	0.00	18.02	0.00	19.38	0.00	19.13	6018.11
0.016	18.30	0.00	17.57	0.00	19.13	0.00	20.87	1590.43
0.025	17.69	0.00	17.87	0.00	20.37	0.00	20.25	0.00
0.032	18.48	0.00	19.17	0.00	20.31	0.00	18.38	0.00

Table 9: Average of observed hole size for metal bond panels with 6 C charge transfer

Panel Thickness (in)	Zone 3		Zone 2A		Zone 1C		Zone 1A	
	Charge Transfer (C)	Hole Area (mm^2)	Charge Transfer (C)	Hole Area (mm^2)	Charge Transfer (C)	Hole Area (mm^2)	Charge Transfer (C)	Hole Area (mm^2)
0.008	6.07	0.00	6.23	254.47	5.83	3019.07	N/A	N/A
0.012	5.84	0.00	6.23	0.00	6.24	0.00	6.04	5674.50
0.016	5.72	0.00	6.22	0.00	5.90	0.00	6.66	2827.43
0.025	5.71	0.00	6.29	0.00	6.51	0.00	6.76	0.00
0.032	5.93	0.00	5.75	0.00	6.29	0.00	6.03	0.00

5.0 Conclusions

For solid panels, the minimum skin thickness that withstood 6 C charge transfer was thinner than the minimum skin thickness that withstood 18 C charge transfer in every Zone.

For metal bond panels, charge transfer had less of an effect on thresholds. The minimum skin thickness required to withstand 6 C charge transfer was the same as what was required to withstand 18 C charge transfer.

For all panels, test points with 6 C charge transfer contained smaller damaged areas than equivalent test points (same thickness, panel type, lightning Zone) tested with 18 C charge transfer, with the exception of holes that resulted from shockwave effects.

For all test points, metal bond panels sustained less damage than their equivalent (same overall panel thickness, lightning Zone, charge transfer) solid panel counterparts.

On thin metal bond panels (0.008”, 0.012”, and 0.016”) in Zone 1A the pressure shockwave of the lighting stroke current influences the resulting hole size more than melting due to charge transfer does. This was also true for 0.008” panels in Zone 1C and Zone 2A.

Based on the hole size equation in section 4.2.1 from the LTI Handbook, thinner solid panels had expected (calculated) hole sizes that were larger than observed (measured) hole sizes, however, thicker solid panels had expected hole sizes that were smaller than the observed hole size.

6.0 References

AGATE Lightning Direct Effects Handbook - Rev E. (2021). Wichita: NIAR.

Fisher, F. A., Plumer, J. A., & Perala, R. A. (2004). *Lightning Protection of Aircraft.* Pittsfield: Lightning Technologies Inc.

Appendix A – **Waveform Test Data Shot Log**

EUT	Test Point	Components	Component A/D				Component B			Component C/C*		
			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)
Aluminum Calibration Plate	WV01	A/5, B, C*	-46.00	9.92E+04	14	248	0.00E+00	0.00	90.662	516.71	18.15	35.17
Al Cal Plate	WV02	A/5, B, C*	-40.07	7.29E+04	14	250	0.00E+00	0.00	253.708	538.77	17.91	33.21
Al Cal Plate	WV03	A/5, B, C*	-39.47	6.97E+04	14	216	2.13E+03	10.64	5.002	507.72	18.90	37.23
32-1	TP1-18C	A/5, B, C*	-38.67	6.25E+04	14	194	2.13E+03	10.66	5	515.13	18.65	36.20
40-1	TP1-18C	A/5, B, C*	-38.73	6.25E+04	14	194	2.13E+03	10.66	5	514.80	18.75	36.43
50-1	TP1-18C	A/5, B, C*	-38.73	6.33E+04	14	192	2.13E+03	10.66	5	522.94	18.17	34.75
63-1	TP1-18C	A/5, B, C*	-38.87	6.38E+04	14	192	2.10E+03	10.52	5.002	525.10	18.26	34.78
Al Cal Plate	WV01	A, B, C*	-195.80	2.39E+06	18	328	2.14E+03	10.69	5	555.38	17.27	31.09
Al Cal Plate	WV02	A, B, C*	-196.40	2.46E+06	18	352	2.12E+03	10.61	5	457.65	20.87	45.61
63-4	TP1-18C	A, B, C*	-193.73	2.17E+06	20	308	2.11E+03	10.52	5	413.76	23.16	55.98
Al Cal Plate	WV04	A/5, B, C*	-39.27	7.62E+04	14	268	0.00E+00	0.00	1802	551.20	17.31	31.39
32-1	TP2-18C	A/5, B, C*	-39.20	6.35E+04	12	194	2.14E+03	10.70	5	445.12	21.19	47.60
32-1	TP3-18C	A/5, B, C*	-39.00	6.52E+04	12	200	2.14E+03	10.70	5	499.29	19.15	38.35
32-1	TP1-6C	A/5, B, C*	-39.33	6.41E+04	14	194	2.14E+03	10.71	5	497.19	6.32	12.70
32-1	TP2-6C	A/5, B, C*	-38.73	6.50E+04	14	202	2.15E+03	10.75	5.002	504.30	6.29	12.47
32-1	TP3-6C	A/5, B, C*	-38.80	6.55E+04	14	204	2.13E+03	10.66	5	495.90	6.46	13.03
40-1	TP2-18C	A/5, B, C*	-39.13	6.32E+04	12	192	2.14E+03	10.70	5	491.82	19.61	39.88
40-1	TP3-18C	A/5, B, C*	-38.87	6.47E+04	14	200	2.14E+03	10.69	5	489.54	19.58	39.99
40-1	TP1-6C	A/5, B, C*	-38.66667	6.49E+04	14	204	2.144E+03	10.72	5	514.71	6.18	12.004
40-1	TP3-6C	A/5, B, C*	-38.87	6.59E+04	12	210	2.14E+03	10.72	5	513.55	6.10	11.87
40-1	TP4-6C	A/5, B, C*	-39.13	6.59E+04	12	202	2.14E+03	10.72	5	560.39	5.73	10.22
50-1	TP2-18C	A/5, B, C*	-39.47	6.39E+04	14	198	2.14E+03	10.71	5.002	516.65	18.64	36.07

EUT	Test Point	Components	Component A/D				Component B			Component C/C*		
			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)
50-1	TP3-18C	A/5, B, C*	-38.87	6.36E+04	14	196	2.14E+03	10.72	5	513.73	18.78	36.56
50-1	TP1-6C	A/5, B, C*	-38.87	6.61E+04	14	208	2.14E+03	10.72	5	526.02	18.17	34.54
50-1	TP2-6C	A/5, B, C*	-38.60	6.49E+04	12	208	2.13E+03	10.67	5	486.42	6.42	13.20
50-1	TP3-6C	A/5, B, C*	-38.40	6.45E+04	14	206	2.15E+03	10.75	5.002	539.36	6.00	11.12
50-1	TP4-6C	A/5, B, C*	-38.60	6.46E+04	14	198	2.15E+03	10.75	5	538.92	5.95	11.03
63-1	TP3-18C	A/5, B, C*	-39.47	6.64E+04	12	198	2.13E+03	10.64	5	494.90	19.60	39.60
63-1	TP4-18C	A/5, B, C*	-39.47	6.62E+04	14	200	2.10E+03	10.52	5.002	452.88	21.04	46.47
63-1	TP1-6C	A/5, B, C*	-39.13	6.46E+04	12	198	2.14E+03	10.67	5	514.96	6.15	11.95
63-1	TP2-6C	A/5, B, C*	-39.27	6.50E+04	14	196	2.14E+03	10.70	5	538.02	5.90	10.96
63-1	TP3-6C	A/5, B, C*	-39.40	6.44E+04	14	194	2.15E+03	10.74	5	524.58	6.03	11.50
71-1	TP1-18C	A/5, B, C*	-39.00	6.46E+04	12	198	2.13E+03	10.67	5	501.02	19.27	38.46
71-1	TP2-18C	A/5, B, C*	-38.87	6.44E+04	14	200	2.14E+03	10.73	5.002	526.35	18.05	34.29
71-1	TP3-18C	A/5, B, C*	-39.00	6.57E+04	12	200	2.15E+03	10.76	5	499.16	18.93	37.93
71-1	TP1-6C	A/5, B, C*	-38.87	6.44E+04	14	198	2.13E+03	10.64	5.002	516.35	6.17	11.95
71-1	TP2-6C	A/5, B, C*	-39.13	6.49E+04	14	198	2.14E+03	10.70	5.002	511.81	6.16	12.04
71-1	TP3-6C	A/5, B, C*	-39.13	6.51E+04	14	194	2.13E+03	10.65	5	517.88	6.19	11.94
12-1	TP1-18C	A/5, B, C*	-38.73	6.36E+04	14	192	2.15E+03	10.74	5	499.19	19.22	38.49
12-1	TP2-18C	A/5, B, C*	-38.60	6.35E+04	14	194	2.14E+03	10.69	5.002	525.01	17.95	34.18
12-1	TP3-18C	A/5, B, C*	-38.40	6.28E+04	14	194	2.14E+03	10.72	5	522.11	18.34	35.13
12-1	TP1-6C	A/5, B, C*	-38.67	6.31E+04	14	192	2.13E+03	10.63	5.002	549.40	5.80	10.59
12-1	TP2-6C	A/5, B, C*	-38.73	6.39E+04	12	194	2.14E+03	10.69	5	554.63	5.74	10.35

EUT	Test Point	Components	Component A/D				Component B			Component C/C*		
			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)
12-1	TP3-6C	A/5, B, C*	-38.13	6.34E+04	12	198	2.14E+03	10.71	5	535.70	5.98	11.16
16-1	TP1-18C	A/5, B, C*	-39.2	6.35E+04	12	194	2.134E+03	10.70	5	445.12	21.19	47.60
16-1	TP2-18C	A/5, B, C*	-38.27	6.22E+04	14	194	2.13E+03	10.67	5	531.01	18.08	34.05
16-1	TP3-18C	A/5, B, C*	-38.40	6.33E+04	16	200	2.14E+03	10.67	5	500.29	19.04	38.06
16-1	TP1-6C	A/5, B, C*	-38.33	6.34E+04	14	200	2.14E+03	10.72	5	556.76	5.73	10.29
16-1	TP2-6C	A/5, B, C*	-38.60	6.33E+04	14	198	2.15E+03	10.73	5.002	561.36	5.68	10.12
16-1	TP3-6C	A/5, B, C*	-38.33	6.30E+04	14	196	2.15E+03	10.74	5.002	559.21	5.75	10.28
25-1	TP1-18C	A/5, B, C*	-38.20	6.18E+04	14	192	2.14E+03	10.69	5.002	525.68	18.13	34.49
25-1	TP2-18C	A/5, B, C*	-38.33	6.32E+04	14	196	2.14E+03	10.70	5	543.90	17.62	32.39
25-1	TP3-18C	A/5, B, C*	-38.47	6.35E+04	14	196	2.14E+03	10.72	5	552.05	17.32	31.37
25-1	TP1-6C	A/5, B, C*	-38.26667	6.33E+04	14	200	2.137E+03	10.689	5.002	553.86	5.77	10.41
25-1	TP2-6C	A/5, B, C*	-38.40	6.41E+04	14	202	2.14E+03	10.71	5	554.84	5.75	10.36
25-1	TP3-6C	A/5, B, C*	-38.20	6.34E+04	16	198	2.14E+03	10.71	5	568.06	5.61	9.87
B32-1	TP1-18C	A/5, B, C*	-38.20	6.34E+04	14	202	2.15E+03	10.76	5.002	512.14	18.84	36.79
B32-1	TP2-18C	A/5, B, C*	-38.20	6.24E+04	14	196	2.15E+03	10.74	5.002	517.82	18.41	35.55
B32-1	TP3-18C	A/5, B, C*	-38.20	6.32E+04	12	198	2.15E+03	10.74	5	524.90	18.18	34.64
B32-1	TP1-6C	A/5, B, C*	-38.33	6.43E+04	12	200	2.15E+03	10.72	5	515.75	6.06	11.76
B32-1	TP2-6C	A/5, B, C*	-38.20	6.32E+04	12	200	2.14E+03	10.69	5	549.80	5.78	10.52
B32-1	TP3-6C	A/5, B, C*	-38.07	6.33E+04	14	202	2.14E+03	10.70	5.002	530.03	5.94	11.21
Al Cal Plate	WV01	D, B, C*	-101.13	2.65E+05	8	162	2.13E+03	10.65	5	552.76	5.73	10.37

EUT	Test Point	Components	Component A/D				Component B			Component C/C*		
			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)
B32-1	TP1-18C	D, B, C*	-100.20	2.39E+05	8	134	2.13E+03	10.66	5	495.82	19.41	39.14
B32-1	TP2-18C	D, B, C*	-100.07	2.38E+05	8	136	2.11E+03	10.55	5	495.04	19.22	38.83
B32-1	TP3-18C	D, B, C*	-100.53	2.45E+05	8	138	2.12E+03	10.62	5	507.43	18.87	37.18
B32-1	TP1-6C	D, B, C*	-99.93	2.40E+05	8	136	2.12E+03	10.58	5	556.77	5.69	10.24
B32-1	TP2-6C	D, B, C*	-100.67	2.40E+05	8	134	2.13E+03	10.66	5	560.65	5.65	10.07
B32-1	TP3-6C	D, B, C*	-100.27	2.38E+05	8	132	2.13E+03	10.62	5	533.10	5.91	11.09
25-1	TP1-18C	D, B, C*	-99.80	2.42E+05	8	134	2.12E+03	10.59	5	510.43	18.53	36.30
25-1	TP2-18C	D, B, C*	-98.67	2.33E+05	8	128	2.08E+03	10.42	5	545.56	17.34	31.84
25-1	TP3-18C	D, B, C*	-99.20	2.37E+05	8	132	2.11E+03	10.54	5	537.73	17.75	33.02
25-1	TP1-6C	D, B, C*	-99.93	2.38E+05	8	130	2.11E+03	10.54	5	505.55	6.24	12.33
25-1	TP2-6C	D, B, C*	-100.27	2.39E+05	8	132	2.12E+03	10.61	5	525.85	6.04	11.47
25-1	TP3-6C	D, B, C*	-100.07	2.36E+05	8	130	2.11E+03	10.55	5	472.64	6.55	13.85
71-1	TP1-18C	D, B, C*	-99.67	2.36E+05	8	134	2.11E+03	10.57	5	514.87	18.65	36.23
71-1	TP2-18C	D, B, C*	-100.53	2.44E+05	8	142	2.13E+03	10.62	5	572.05	16.72	29.22
71-1	TP3-18C	D, B, C*	-99.93	2.39E+05	8	130	2.10E+03	10.52	5	495.95	19.43	39.17
71-1	TP1-6C	D, B, C*	-100.33	2.37E+05	8	132	2.11E+03	10.55	5	509.61	6.14	12.05
71-1	TP2-6C	D, B, C*	-99.80	2.37E+05	8	134	2.10E+03	10.49	5	533.64	5.92	11.11
71-1	TP3-6C	D, B, C*	-99.80	2.36E+05	8	130	2.10E+03	10.51	5	537.35	5.87	10.94
63-2	TP1-18C	D, B, C*	-99.13	2.43E+05	8	136	2.09E+03	10.44	5	486.51	19.70	40.50
63-2	TP2-18C	D, B, C*	-101.07	2.51E+05	8	146	2.10E+03	10.47	5	501.89	18.92	37.71

EUT	Test Point	Components	Component A/D				Component B			Component C/C*		
			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)
63-2	TP3-18C	D, B, C*	-100.00	2.37E+05	8	134	2.11E+03	10.57	5	563.93	16.82	29.83
63-2	TP1-6C	D, B, C*	-99.27	2.41E+05	10	140	2.09E+03	10.43	5	452.76	6.72	14.91
63-2	TP2-6C	D, B, C*	-100.07	2.49E+05	8	144	2.11E+03	10.57	5	520.48	6.11	11.75
63-2	TP3-6C	D, B, C*	-100.13	2.40E+05	8	140	2.10E+03	10.49	5	540.24	5.86	10.86
40-2	TP1-18C	D, B, C*	-99.47	2.42E+05	8	134	2.09E+03	10.43	5	459.46	20.64	44.93
40-2	TP1-6C	D, B, C*	-99.00	2.42E+05	8	142	2.10E+03	10.49	5	479.46	6.50	13.56
50-2	TP1-18C	D, B, C*	-96.67	2.42E+05	8	146	2.11E+03	10.57	5	526.06	17.86	33.96
50-2	TP1-6C	D, B, C*	-96.20	2.45E+05	10	146	2.07E+03	10.34	5	541.30	5.77	10.74
50-2	TP2-6C	D, B, C*	-97.40	2.48E+05	8	148	2.12E+03	10.58	5	505.70	6.25	12.36
50-2	TP3-6C	D, B, C*	-97.20	2.46E+05	8	152	2.13E+03	10.65	5	566.80	5.59	9.88
32-1	TP1-6C	D, B, C*	-97.33	2.47E+05	8	150	2.11E+03	10.53	5	511.37	6.13	11.99
32-1	TP2-18C	D, B, C*	-97.73	2.48E+05	8	148	2.11E+03	10.55	5	543.23	17.61	32.42
12-1	TP1-18C	D, B, C*	-97.80	2.48E+05	8	146	2.11E+03	10.53	5	518.16	18.46	35.63
12-1	TP2-18C	D, B, C*	-97.87	2.48E+05	8	146	2.11E+03	10.56	5	543.19	17.73	32.63
12-1	TP3-18C	D, B, C*	-97.27	2.45E+05	8	146	2.10E+03	10.52	5	539.71	17.87	33.11
12-1	TP1-6C	D, B, C*	-98.00	2.44E+05	8	138	2.11E+03	10.54	5	505.37	6.20	12.27
12-1	TP2-6C	D, B, C*	-97.53	2.46E+05	8	146	2.10E+03	10.48	5	539.49	5.86	10.88
12-1	TP3-6C	D, B, C*	-97.40	2.44E+05	8	142	2.10E+03	10.51	5	471.45	6.62	14.04
16-1	TP1-18C	D, B, C*	-97.07	2.41E+05	8	144	2.11E+03	10.57	5	546.59	17.57	32.14
16-1	TP1-6C	D, B, C*	-97.80	2.45E+05	8	144	2.11E+03	10.56	5	509.42	6.22	12.22

EUT	Test Point	Components	Component A/D				Component B			Component C/C*		
			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	AH, B, C*	-157.93	9.41E+05	14	206	2.09E+03	10.46	5	536.02	17.74	33.14
12-2	TP1-18C	AH, B, C*	-154.27	8.76E+05	16	182	2.09E+03	10.47	5	506.07	19.12	37.77
12-2	TP2-18C	AH, B, C*	-155.13	8.82E+05	14	180	2.10E+03	10.48	5	520.18	18.40	35.37
12-2	TP3-18C	AH, B, C*	-155.60	8.76E+05	16	176	2.10E+03	10.50	5	456.97	20.87	45.66
12-2	TP1-6C	AH, B, C*	-154.27	8.88E+05	14	184	2.10E+03	10.50	5	501.67	6.33	12.63
12-2	TP2-6C	AH, B, C*	-154.40	8.89E+05	16	186	2.07E+03	10.33	5	514.61	6.04	11.81
12-2	TP3-6C	AH, B, C*	-155.20	8.75E+05	14	178	2.12E+03	10.61	5	495.63	6.36	12.83
16-2	TP2-18C	AH, B, C*	-155.13	8.80E+05	16	180	2.10E+03	10.52	5	503.75	19.13	37.96
16-2	TP1-6C	AH, B, C*	-153.53	8.69E+05	16	180	2.11E+03	10.54	5	538.97	5.90	10.94
25-2	TP1-18C	AH, B, C*	-154.53	8.77E+05	16	182	2.09E+03	10.46	5	473.03	20.37	43.07
25-2	TP1-6C	AH, B, C*	-152.93	8.65E+05	16	182	2.11E+03	10.52	5	643.62	6.51	10.12
B32-2	TP1-18C	AH, B, C*	-153.5333	8.67E+05	16	184	2.077E+03	10.38	5	470.81	20.31	43.14
B32-2	TP1-6C	AH, B, C*	-154.53	8.71E+05	16	178	2.12E+03	10.59	5	496.85	6.29	12.65
40-3	TP1-18C	AH, B, C*	Scope Failure									
40-3	TP2-18C	AH, B, C*	-155.60	8.82E+05	16	182	2.11E+03	10.56	5	499.97	18.98	37.98
40-3	TP1-6C	AH, B, C*	-154.07	8.87E+05	16	186	2.13E+03	10.63	5	531.19	6.12	11.52
32-2	TP2-18C	AH, B, C*	Scope Failure									
32-3	TP3-18C	AH, B, C*	Scope Failure									
32-2	TP1-6C	AH, B, C*	-154.53	8.80E+05	15	184	2.09E+03	10.47	5	521.78	6.07	11.64
50-3	TP1-18C	AH, B, C*	-153.93	8.75E+05	15	183	2.12E+03	10.60	5	511.39	18.83	36.83

EUT	Test Point	Components	Component A/D				Component B			Component C/C*		
			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)
50-3	TP1-6C	AH, B, C*	-153.40	8.75E+05	15	186	2.11E+03	10.55	5	507.15	6.19	12.20
50-4	TP2-6C	AH, B, C*	-154.47	8.83E+05	15	190	2.13E+03	10.67	5	499.74	6.29	12.58
50-5	TP3-6C	AH, B, C*	-154.27	8.64E+05	15	178	2.14E+03	10.69	5	512.10	6.14	11.99
63-3	TP1-18C	AH, B, C*	-153.20	8.61E+05	15	177	2.08E+03	10.41	5	468.90	20.31	43.32
63-3	TP1-6C	AH, B, C*	-153.40	8.68E+05	15	181	2.12E+03	10.59	5	504.69	6.23	12.35
71-2	TP1-18C	AH, B, C*	-154.20	8.71E+05	15	180	2.10E+03	10.49	5	501.53	18.84	37.57
71-2	TP1-6C	AH, B, C*	-152.93	8.63E+05	16	183	2.12E+03	10.62	5	500.29	6.35	12.69
71-2	TP2-18C	AH, B, C*	-153.67	8.54E+05	15	176	2.13E+03	10.63	5	492.11	19.49	39.60
71-2	TP5-18C	AH, B, C*	-154.20	8.78E+05	15	189	2.12E+03	10.61	5	528.97	17.95	33.93
Al Cal Plate	WV03	A, B, C*	-197.33	2.31E+06	19	334	2.08E+03	10.39	5	466.68	20.31	43.52
12-3	TP1-18C	A, B, C*	-193.40	2.10E+06	19	274	2.07E+03	10.35	5	445.58	20.73	46.53
12-3	TP2-18C	A, B, C*	-195.73	2.17E+06	19	284	2.07E+03	10.34	5	545.38	17.53	32.16
12-3	TP2-6C	A, B, C*	-194.20	2.12E+06	19	274	2.08E+03	10.39	5	526.04	6.04	11.49
B32-2	TP1-18C	A, B, C*	-193.80	2.09E+06	18	286	2.08E+03	10.42	5	465.02	19.89	42.76
25-3	TP3-18C	A, B, C*	-195.07	2.13E+06	19	296	2.11E+03	10.53	5	484.97	19.86	40.96
25-3	TP1-6C	A, B, C*	-192.67	2.13E+06	20	321	2.07E+03	10.36	5	416.85	7.33	17.57
16-3	TP1-18C	A, B, C*	-187.13	2.11E+06	20	313	2.09E+03	10.42	5	457.54	20.87	45.60
16-3	TP1-6C	A, B, C*	-187.20	2.13E+06	20	299	2.09E+03	10.44	5	474.94	6.66	14.02
25-3	TP2-6C	A, B, C*	-188.67	2.16E+06	20	317	2.09E+03	10.46	5	481.66	6.58	13.67
25-3	TP3-6C	A, B, C*	-188.47	2.12E+06	19	305	2.09E+03	10.46	5	493.55	6.38	12.92

EUT	Test Point	Components	Component A/D				Component B			Component C/C*		
			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)
25-3	TP5-18C	A, B, C*	-189.07	2.15E+06	20	317	2.10E+03	10.52	5	540.65	17.71	32.75
25-3	TP6-18C	A, B, C*	-188.47	2.14E+06	20	311	2.07E+03	10.37	5	403.60	23.19	57.45
B32-2	TP3-6C	A, B, C*	-189.20	2.10E+06	20	306	2.10E+03	10.50	5	526.60	6.03	11.46
B32-2	TP2-18C	A, B, C*	-188.20	2.12E+06	20	312	2.11E+03	10.57	5	588.88	16.26	27.62
B32-2	TP3-18C	A, B, C*	-188.60	2.11E+06	20	300	2.09E+03	10.46	5	500.79	18.99	37.93
32-2	TP1-18C	A, B, C*	-189.13	2.12E+06	20	304	2.10E+03	10.51	5	572.17	16.73	29.25
32-2	TP4-6C	A, B, C*	-186.40	2.07E+06	20	305	2.09E+03	10.45	5	551.28	8.12	14.73
Al Cal Plate	WV04	A, B, C*	-196.27	2.34E+06	20	334	2.07E+03	10.35	5	503.43	6.15	12.26
40-4	TP1-18C	A, B, C*	-186.40	2.07E+06	19	322	2.12E+03	10.59	5	524.15	18.37	35.05
40-4	TP1-6C	A, B, C*	-192.13	2.14E+06	20	305	2.10E+03	10.51	5	545.69	5.81	10.65
50-4	TP1-18C	A, B, C*	-191.73	2.12E+06	20	313	2.11E+03	10.57	5	486.18	19.39	39.88
50-4	TP1-6C	A, B, C*	-193.20	2.20E+06	20	310	2.10E+03	10.50	5	512.40	6.10	11.90
50-4	TP2-6C	A, B, C*	-193.27	2.14E+06	19	297	2.08E+03	10.42	5	515.78	6.10	11.83
50-4	TP3-6C	A, B, C*	-193.13	2.10E+06	19	300	2.11E+03	10.56	5	519.23	6.03	11.61
63-4	TP3-18C	A, B, C*	-193.53	2.11E+06	19	297	2.11E+03	10.54	5	546.54	17.48	31.98
63-4	TP1-6C	A, B, C*	-190.87	2.08E+06	20	298	2.11E+03	10.53	5	545.48	5.89	10.79
63-4	TP2-6C	A, B, C*	-193.67	2.17E+06	19	317	2.11E+03	10.55	5	532.82	5.94	11.14
63-4	TP3-6C	A, B, C*	-193.87	2.08E+06	19	296	2.09E+03	10.44	5	523.92	5.98	11.41
71-3	TP1-18C	A, B, C*	-191.87	2.10E+06	19	301	2.08E+03	10.41	5	511.89	18.60	36.37
71-3	TP3-18C	A, B, C*	-194.87	2.06E+06	18	287	2.09E+03	10.45	5	499.19	18.78	37.62

EUT	Test Point	Components	Component A/D				Component B			Component C/C*		
			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)
71-3	TP1-6C	A, B, C*	-192.40	2.09E+06	19	302	2.09E+03	10.46	5	494.26	6.34	12.83
71-3	TP2-6C	A, B, C*	-194.20	2.14E+06	19	322	2.12E+03	10.60	5	574.31	5.53	9.63
71-3	TP3-6C	A, B, C*	-194.20	2.10E+06	18	302	2.12E+03	10.59	5	560.48	5.69	10.15
71-3	TP5-18C	A, B, C*	-193.00	2.04E+06	19	299	2.09E+03	10.47	5	493.10	17.81	36.12
Al Cal Plate	WV02	D, B, C*	-99.40	2.56E+05	10	156	2.10E+03	10.51	5	541.10	5.69	10.57
8-2	TP1-18C	D, B, C*	-98.67	2.37E+05	8	134	2.11E+03	10.56	5	527.65	18.20	34.50
8-2	TP2-18C	D, B, C*	-99.07	2.41E+05	8	138	2.12E+03	10.59	5	652.93	15.45	23.66
8-2	TP1-6C	D, B, C*	-98.67	2.39E+05	8	138	2.08E+03	10.42	5	508.67	6.23	12.23
Al Cal Plate	WV07	A/5, B, C*	-39.40	7.27E+04	14	238	2.14E+03	10.70	5	543.27	5.78	10.63
8-2	TP1-18C	A/5, B, C*	-38.33	6.27E+04	14	196	2.13E+03	10.65	5.002	508.00	18.89	37.19
8-2	TP2-18C	A/5, B, C*	-38.33	6.40E+04	16	200	2.13E+03	10.65	5	520.83	18.41	35.36
8-2	TP3-18C	A/5, B, C*	-38.80	6.55E+04	14	200	2.14E+03	10.72	5.002	513.41	18.61	36.24
8-2	TP1-6C	A/5, B, C*	-38.87	6.55E+04	14	200	2.13E+03	10.66	5	501.59	6.23	12.42
8-2	TP2-6C	A/5, B, C*	-38.93	6.51E+04	14	198	2.14E+03	10.68	5	506.83	6.16	12.15
8-2	TP3-6C	A/5, B, C*	-38.80	6.50E+04	14	200	2.14E+03	10.71	5.002	536.14	5.81	10.84
Al Cal Plate	WV02	AH, B, C*	-157.33	9.24E+05	16	200	2.14E+03	10.69	5	492.02	6.29	12.79
8-1	TP1-18C	AH, B, C*	-154.67	8.58E+05	14	170	2.13E+03	10.64	5	556.76	17.33	31.13
8-1	TP1-6C	AH, B, C*	-154.33	8.51E+05	14	170	2.04E+03	10.19	5	425.45	5.83	13.70
Al Cal Plate	WV05	A, B, C*	-199.40	2.38E+06	18	356	2.14E+03	10.69	5	531.58	5.97	11.23
50-5	TP2-6C	A, B, C*	-195.87	2.03E+06	18	276	2.11E+03	10.57	5	522.58	6.00	11.48

Appendix B – **Full Data Listing with Melt-Through Hole Data**

Solid Panel Data								
Panel ID	Lightning Test Zone	Test Point	Target Charge Transfer [C]	Charge Transfer [C]	Ignition	Panel Thickness (inches)	Area Expected (mm^2)	Area of Through Hole Observed (mm^2)
32-1	3	1	18	18.65	Yes	0.032	20.79	31.37
32-1	3	2	18	21.19	Yes	0.032	23.62	30.29
32-1	3	3	18	19.15	Yes	0.032	21.34	32.57
32-1	3	1	6	6.32	Yes	0.032	7.04	18.55
32-1	3	2	6	6.29	Yes	0.032	7.01	11.52
32-1	3	3	6	6.46	Yes	0.032	7.20	17.06
32-1	2A	2	18	17.61	Yes	0.032	19.63	39.16
32-1	2A	3	18	-	N/A	0.032	-	-
32-1	2A	1	6	6.13	Yes	0.032	6.83	18.20
32-1	2A	2	6	-	N/A	0.032	-	-
32-1	2A	3	6	-	N/A	0.032	-	-
32-2	1C	1	6	6.07	Yes	0.032	6.77	71.78
32-2	1C	2	6	-	N/A	0.032	-	-
32-2	1C	3	6	-	N/A	0.032	-	-
32-2	1A	1	18	16.73	yes	0.032	18.65	67.49
32-2	1A	2	18	-	N/A	0.032	-	-
32-2	1A	3	18	-	N/A	0.032	-	-
32-2	1A	4	6	8.12	Yes	0.032	9.05	50.90
40-1	3	1	18	18.75	Yes	0.04	14.82	20.59
40-1	3	2	18	19.61	Yes	0.04	15.50	21.57
40-1	3	3	18	19.58	Yes	0.04	15.48	22.23
40-1	3	1	6	6.18	Yes	0.04	4.88	2.04
40-1	3	3	6	6.1	Yes	0.04	4.82	4.37
40-1	3	4	6	5.73	Yes	0.04	4.53	0.00
40-2	2A	1	18	20.64	Yes	0.04	16.31	30.78
40-2	2A	2	18	-	N/A	0.04	-	-
40-2	2A	3	18	-	N/A	0.04	-	-
40-2	2A	1	6	6.5	Yes	0.04	5.14	0.00
40-2	2A	2	6	-	N/A	0.04	-	-
40-2	2A	3	6	-	N/A	0.04	-	-
40-3	1C	2	18	18.98	Yes	0.04	15.00	89.42
40-3	1C	3	18	-	N/A	0.04	-	-
40-3	1C	1	6	6.12	Yes	0.04	4.84	24.63
40-3	1C	2	6	-	N/A	0.04	-	-

Solid Panel Data								
Panel ID	Lightning Test Zone	Test Point	Target Charge Transfer [C]	Charge Transfer [C]	Ignition	Panel Thickness (inches)	Area Expected (mm^2)	Area of Through Hole Observed (mm^2)
40-3	1C	3	6	-	N/A	0.04	-	-
40-4	1A	1	18	18.37	Yes	0.04	14.52	35.89
40-4	1A	2	18	-	N/A	0.04	-	-
40-4	1A	3	18	-	N/A	0.04	-	-
40-4	1A	1	6	5.81	Yes	0.04	4.59	12.63
40-4	1A	2	6	-	N/A	0.04	-	-
40-4	1A	3	6	-	N/A	0.04	-	-
50-1	3	1	18	18.17	Yes	0.05	10.19	0.00
50-1	3	2	18	18.64	No	0.05	10.45	0.01
50-1	3	3	18	18.78	Yes	0.05	10.53	0.00
50-1	3	2	6	6.42	No	0.05	3.60	0.00
50-1	3	3	6	6	No	0.05	3.36	0.00
50-1	3	4	6	5.95	No	0.05	3.34	0.00
50-2	2A	1	18	17.86	Yes	0.05	10.01	30.68
50-2	2A	2	18	-	N/A	0.05	-	-
50-2	2A	3	18	-	N/A	0.05	-	-
50-2	2A	1	6	5.77	No	0.05	3.23	0.00
50-2	2A	2	6	6.25	No	0.05	3.50	0.00
50-2	2A	3	6	5.59	No	0.05	3.13	0.00
50-3	1C	1	18	18.83	Yes	0.05	10.56	25.16
50-3	1C	2	18	-	N/A	0.05	-	-
50-3	1C	3	18	-	N/A	0.05	-	-
50-3	1C	1	6	6.19	No	0.05	3.47	0.00
50-3	1C	2	6	6.29	No	0.05	3.53	0.00
50-3	1C	3	6	6.14	No	0.05	3.44	0.00
50-4	1A	1	18	19.38	Yes	0.05	10.86	23.67
50-4	1A	2	18	-	N/A	0.05	-	-
50-4	1A	3	18	-	N/A	0.05	-	-
50-4	1A	1	6	6.1	No	0.05	3.42	0.00
50-4	1A	2	6	6.1	No	0.05	3.42	0.00
50-4	1A	3	6	6.03	No	0.05	3.38	0.00
50-5	1A	2	6	6	Yes	1.05	0.03	0.00
50-5	1A	3	6	-	N/A	2.05	-	-
50-5	1A	4	6	-	N/A	3.05	-	-
63-1	3	1	18	18.26	Yes	0.063	7.17	1.86
63-1	3	3	18	19.6	Yes	0.063	7.70	0.10

Solid Panel Data								
Panel ID	Lightning Test Zone	Test Point	Target Charge Transfer [C]	Charge Transfer [C]	Ignition	Panel Thickness (inches)	Area Expected (mm^2)	Area of Through Hole Observed (mm^2)
63-1	3	4	18	21.04	No	0.063	8.26	0.00
63-1	3	1	6	6.15	No	0.063	2.42	0.00
63-1	3	2	6	5.9	No	0.063	2.32	0.00
63-1	3	3	6	6.03	No	0.063	2.37	0.00
63-2	2A	1	18	19.7	No	0.063	7.74	0.00
63-2	2A	2	18	18.92	No	0.063	7.43	5.35
63-2	2A	3	18	16.82	No	0.063	6.61	0.00
63-2	2A	1	6	6.72	No	0.063	2.64	0.00
63-2	2A	2	6	6.11	No	0.063	2.40	0.00
63-2	2A	3	6	5.86	No	0.063	2.30	0.00
63-3	1C	1	18	20.31	Yes	0.063	7.98	5.43
63-3	1C	2	18	-	N/A	0.063	-	-
63-3	1C	3	18	-	N/A	0.063	-	-
63-3	1C	1	6	6.23	No	0.063	2.45	0.00
63-3	1C	2	6	-	N/A	0.063	-	-
63-3	1C	3	6	-	N/A	0.063	-	-
63-4	1A	1	18	23.16	Yes	0.063	9.09	0.00
63-4	1A	3	18	17.48	Yes	0.063	6.86	23.24
63-4	1A	1	6	5.89	Yes	0.063	2.31	0.00
63-4	1A	2	6	5.94	Yes	0.063	2.33	0.00
63-4	1A	3	6	5.98	Yes	0.063	2.35	0.00
71-1	3	1	18	19.27	No	0.071	6.29	0.00
71-1	3	2	18	18.05	No	0.071	5.90	0.00
71-1	3	3	18	18.93	No	0.071	6.18	0.00
71-1	3	1	6	6.17	No	0.071	2.02	0.00
71-1	3	2	6	6.16	No	0.071	2.01	0.00
71-1	3	3	6	6.19	No	0.071	2.02	0.00
71-1	2A	1	18	18.65	No	0.071	6.09	3.53
71-1	2A	2	18	16.72	No	0.071	5.46	0.00
71-1	2A	3	18	19.43	No	0.071	6.35	1.54
71-1	2A	1	6	6.14	No	0.071	2.01	0.00
71-1	2A	2	6	5.92	No	0.071	1.93	0.00
71-1	2A	3	6	5.87	No	0.071	1.92	0.00
71-2	1C	1	18	18.84	No	0.071	6.15	0.00
71-2	1C	2	18	19.49	No	0.071	6.37	0.00
71-2	1C	5	18	17.95	No	0.071	5.86	0.00

Solid Panel Data								
Panel ID	Lightning Test Zone	Test Point	Target Charge Transfer [C]	Charge Transfer [C]	Ignition	Panel Thickness (inches)	Area Expected (mm^2)	Area of Through Hole Observed (mm^2)
71-2	1C	1	6	6.35	No	0.071	2.07	0.00
71-2	1C	2	6	-	N/A	0.071	-	-
71-2	1C	3	6	-	N/A	0.071	-	-
71-3	1A	1	18	18.6	No	0.071	6.08	0.00
71-3	1A	3	18	18.78	No	0.071	6.13	0.00
71-3	1A	5	18	17.81	yes	0.071	5.82	0.00
71-3	1A	1	6	6.34	No	0.071	2.07	0.00
71-3	1A	2	6	5.53	No	0.071	1.81	0.00
71-3	1A	3	6	5.69	Yes	0.071	1.86	0.00

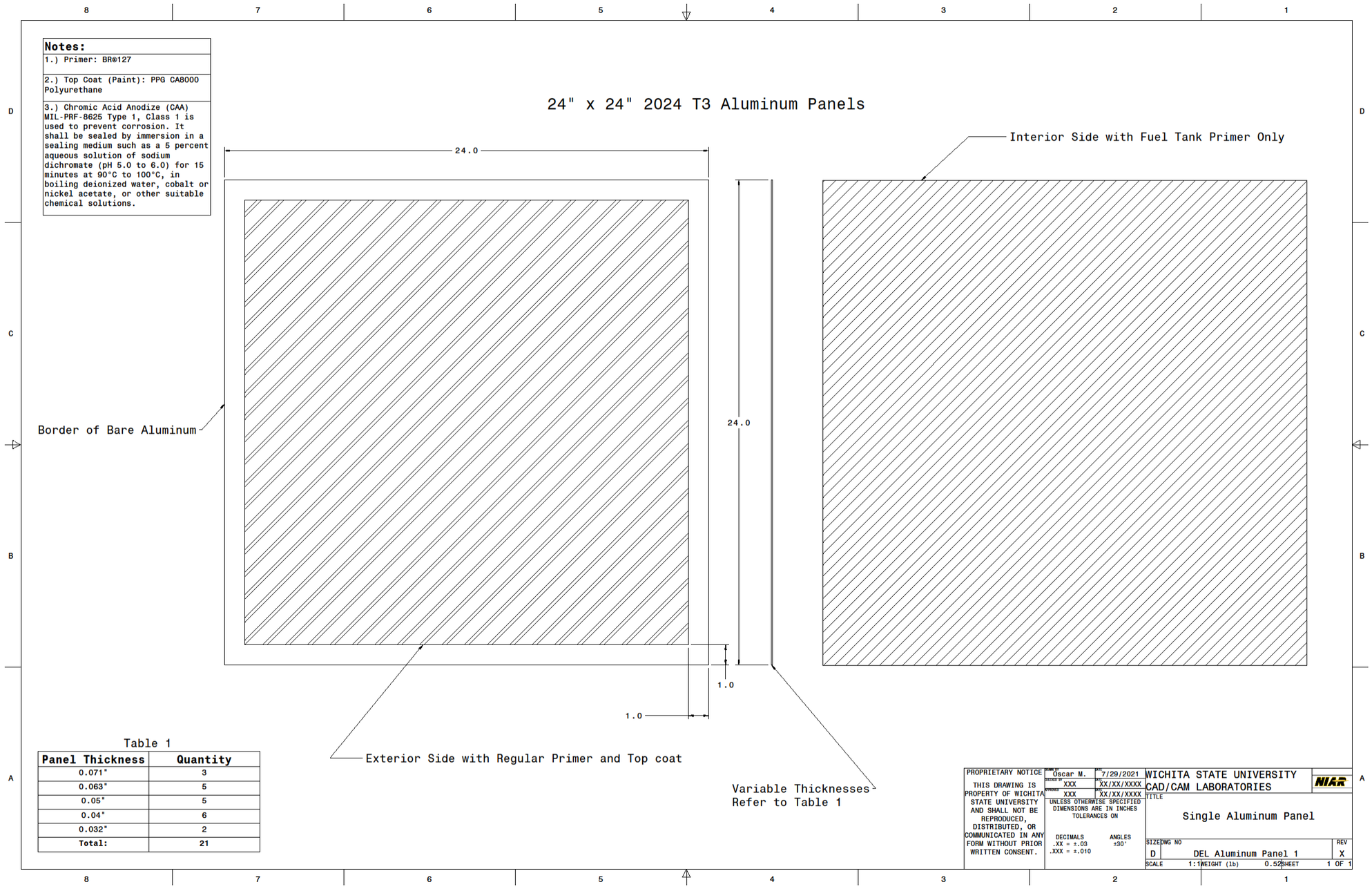
Metal Bond Panel Data							
Panel ID	Lightning Test Zone	Test Point	Target Charge Transfer [C]	Charge Transfer [C]	Ignition	Aluminum Sheet Thickness (half of panel thickness) (inches)	Area of Through Hole Observed (mm^2)
B32-1	3	1	18	18.84	No	0.032	0
B32-1	3	2	18	18.41	No	0.032	0
B32-1	3	3	18	18.18	No	0.032	0
B32-1	3	1	6	6.06	No	0.032	0
B32-1	3	2	6	5.78	No	0.032	0
B32-1	3	3	6	5.94	No	0.032	0
B32-1	2A	1	18	19.41	No	0.032	0
B32-1	2A	2	18	19.22	No	0.032	0
B32-1	2A	3	18	18.87	No	0.032	0
B32-1	2A	1	6	5.69	No	0.032	0
B32-1	2A	2	6	5.65	No	0.032	0
B32-1	2A	3	6	5.91	No	0.032	0
B32-2	1C	1	18	20.31	No	0.032	0
B32-2	1C	2	18	-	N/A	0.032	-
B32-2	1C	3	18	-	N/A	0.032	-
B32-2	1C	1	6	6.29	No	0.032	0
B32-2	1C	2	6	-	N/A	0.032	-
B32-2	1C	3	6	-	N/A	0.032	-
B32-2	1A	1	18	19.89	No	0.032	0
B32-2	1A	2	18	16.26	No	0.032	0
B32-2	1A	3	18	18.99	No	0.032	0

Metal Bond Panel Data							
Panel ID	Lightning Test Zone	Test Point	Target Charge Transfer [C]	Charge Transfer [C]	Ignition	Aluminum Sheet Thickness (half of panel thickness) (inches)	Area of Through Hole Observed (mm^2)
B32-2	1A	3	6	6.03	No	0.032	0
B32-2	1A	4	6	-	N/A	0.032	-
25-1	3	1	18	18.13	No	0.025	0
25-1	3	2	18	17.62	No	0.025	0
25-1	3	3	18	17.32	No	0.025	0
25-1	3	1	6	5.77	No	0.025	0
25-1	3	2	6	5.75	No	0.025	0
25-1	3	3	6	5.61	No	0.025	0
25-1	2A	1	18	18.53	No	0.025	0
25-1	2A	2	18	17.34	No	0.025	0
25-1	2A	3	18	17.75	No	0.025	0
25-1	2A	1	6	6.24	No	0.025	0
25-1	2A	2	6	6.08	No	0.025	0
25-1	2A	3	6	6.55	No	0.025	0
25-2	1C	1	18	20.37	No	0.025	0
25-2	1C	2	18	-	N/A	0.025	-
25-2	1C	3	18	-	N/A	0.025	-
25-2	1C	1	6	6.51	No	0.025	0
25-2	1C	2	6	-	N/A	0.025	-
25-2	1C	3	6	-	N/A	0.025	-
25-3	1A	3	18	19.86	No	0.025	0
25-3	1A	5	18	17.71	No	0.025	0
25-3	1A	6	18	23.19	No	0.025	0
25-3	1A	1	6	7.33	No	0.025	0
25-3	1A	2	6	6.58	No	0.025	0
25-3	1A	3	6	6.38	No	0.025	0
16-1	3	1	18	18.08	No	0.016	0
16-1	3	2	18	19.04	No	0.016	0
16-1	3	3	18	17.78	No	0.016	0
16-1	3	1	6	5.73	No	0.016	0
16-1	3	2	6	5.68	No	0.016	0
16-1	3	3	6	5.75	No	0.016	0
16-1	2A	1	18	17.57	No	0.016	0
16-1	2A	2	18	-	N/A	0.016	-
16-1	2A	3	18	-	N/A	0.016	-
16-1	2A	1	6	6.22	No	0.016	0

Metal Bond Panel Data							
Panel ID	Lightning Test Zone	Test Point	Target Charge Transfer [C]	Charge Transfer [C]	Ignition	Aluminum Sheet Thickness (half of panel thickness) (inches)	Area of Through Hole Observed (mm^2)
16-1	2A	2	6	-	N/A	0.016	-
16-1	2A	3	6	-	N/A	0.016	-
16-2	1C	2	18	19.13	No	0.016	0
16-2	1C	3	18	-	N/A	0.016	-
16-2	1C	1	6	5.9	No	0.016	0
16-2	1C	2	6	-	N/A	0.016	-
16-2	1C	3	6	-	N/A	0.016	-
16-3	1A	1	18	20.87	No	0.016	1590.431
16-3	1A	2	18	-	N/A	0.016	-
16-3	1A	3	18	-	N/A	0.016	-
16-3	1A	1	6	6.66	Yes	0.016	2827.433
16-3	1A	2	6	-	N/A	0.016	-
16-3	1A	3	6	-	N/A	0.016	-
12-1	3	1	18	19.22	No	0.012	0
12-1	3	2	18	17.95	No	0.012	0
12-1	3	3	18	18.43	No	0.012	0
12-1	3	1	6	5.8	No	0.012	0
12-1	3	2	6	5.74	No	0.012	0
12-1	3	3	6	5.98	No	0.012	0
12-1	2A	1	18	18.46	No	0.012	0
12-1	2A	2	18	17.73	No	0.012	0
12-1	2A	3	18	17.87	No	0.012	0
12-1	2A	1	6	6.2	No	0.012	0
12-1	2A	2	6	5.86	No	0.012	0
12-1	2A	3	6	6.62	No	0.012	0
12-2	1C	1	18	19.12	No	0.012	0
12-2	1C	2	18	18.14	No	0.012	0
12-2	1C	3	18	20.87	No	0.012	0
12-2	1C	1	6	6.33	No	0.012	0
12-2	1C	2	6	6.04	No	0.012	0
12-2	1C	3	6	6.36	No	0.012	0
12-3	1A	1	18	20.73	Yes	0.012	6361.725
12-3	1A	2	18	17.53	Yes	0.012	5674.502
12-3	1A	3	18	-	N/A	0.012	-
12-3	1A	2	6	6.04	Yes	0.012	5674.502
12-3	1A	3	6	-	N/A	0.012	-

Metal Bond Panel Data							
Panel ID	Lightning Test Zone	Test Point	Target Charge Transfer [C]	Charge Transfer [C]	Ignition	Aluminum Sheet Thickness (half of panel thickness) (inches)	Area of Through Hole Observed (mm^2)
8-2	3	1	18	18.89	No	0.008	0
8-2	3	2	18	18.41	No	0.008	0
8-2	3	3	18	18.61	No	0.008	0
8-2	3	1	6	6.23	No	0.008	0
8-2	3	2	6	6.16	No	0.008	0
8-2	3	3	6	5.81	No	0.008	0
8-2	2A	1	18	18.2	No	0.008	0
8-2	2A	2	18	15.45	Yes	0.008	1256.637
8-2	2A	3	18	-	N/A	0.008	-
8-2	2A	1	6	6.23	Yes	0.008	254.469
8-2	2A	2	6	-	N/A	0.008	-
8-2	2A	3	6	-	N/A	0.008	-
8-1	1C	1	18	17.33	Yes	0.008	1963.495
8-1	1C	2	18	-	N/A	0.008	-
8-1	1C	3	18	-	N/A	0.008	-
8-1	1C	1	6	5.83	Yes	0.008	3019.071
8-1	1C	2	6	-	N/A	0.008	-
8-1	1C	3	6	-	N/A	0.008	-

Appendix C – **Test Article Drawings**



Dual Panel Assembly

Notes:

1.) Primer: BR®127

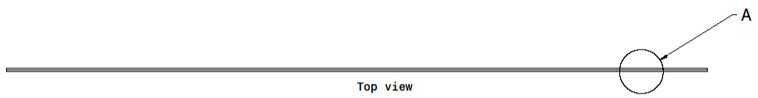
2.) Top Coat (Paint): PPG CA8000 Polyurethane

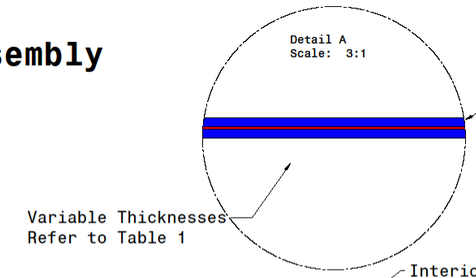
3.) Adhesive: FM73C Film

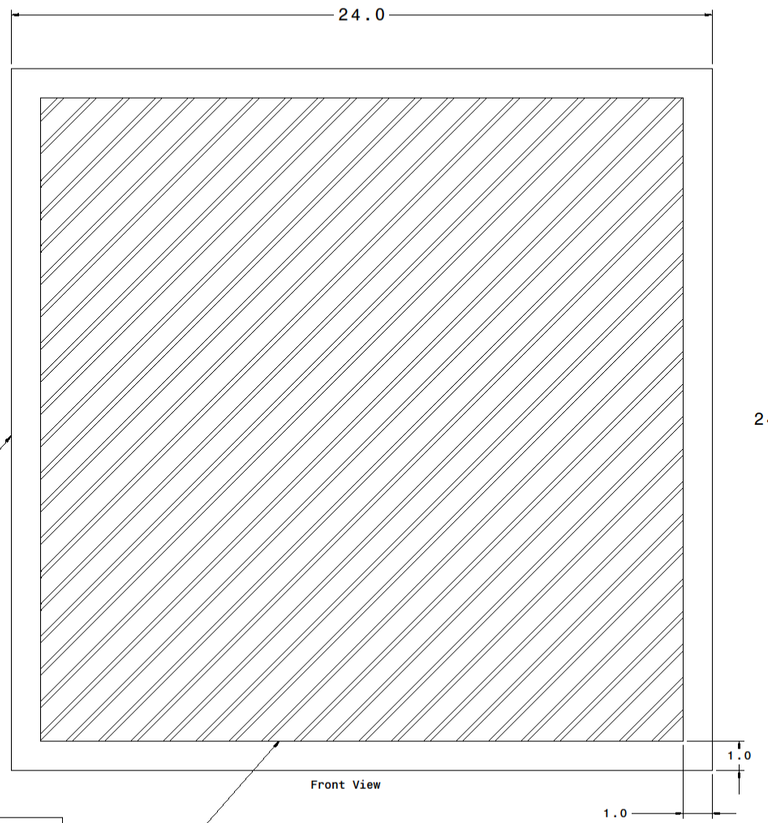
4.) Cure the FM73C film adhesive material at 245-260°F for a cure dwell time of 60-90 minutes at 50 psi with ramp rate of 0.5 -12 °F/min.

5.) 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

6.) Chromic Acid Anodize (CAA) MIL-PRF-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.







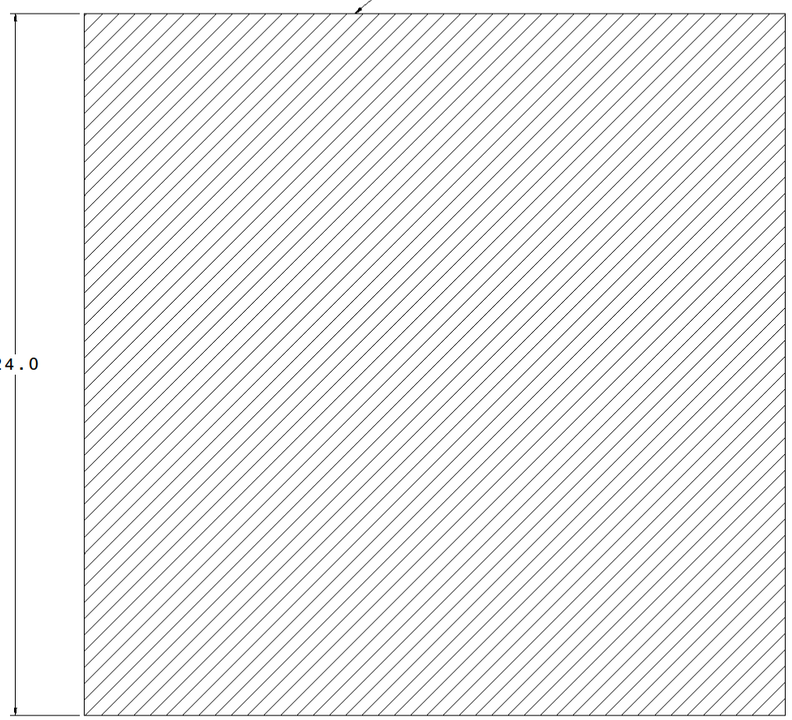


Table 1

Panel Thickness	Quantity
0.032"	2
0.025"	4
0.016"	3
0.012"	4
Total:	**13**

Exterior Side with Regular Primer and Top Coat

DRAWN Oscar M. 7/29/2021
CHECKED XXX XX/XX/XXXX
APPROVED XXX XX/XX/XXXX
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ON
DECIMALS .XX = ±.03 .XXX = ±.010
ANGLES ±30'

WICHITA STATE UNIVERSITY
CAD/CAM LABORATORIES

TITLE: Dual Aluminum Panel

SIZE D | DWG NO DEL Aluminum Panel 1 | REV X
SCALE 1:1 WEIGHT (lb) 0.52 SHEET 1 OF 1

Dual Panel Assembly

Notes:

1.) Primer: BR®127

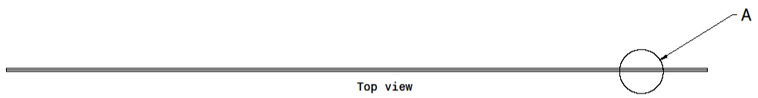
2.) Top Coat (Paint): PPG CA8000 Polyurethane

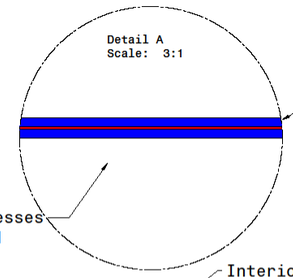
3.) Adhesive: FM73C Film

4.) 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 of 0.5 -12 °F/min.

5.) 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

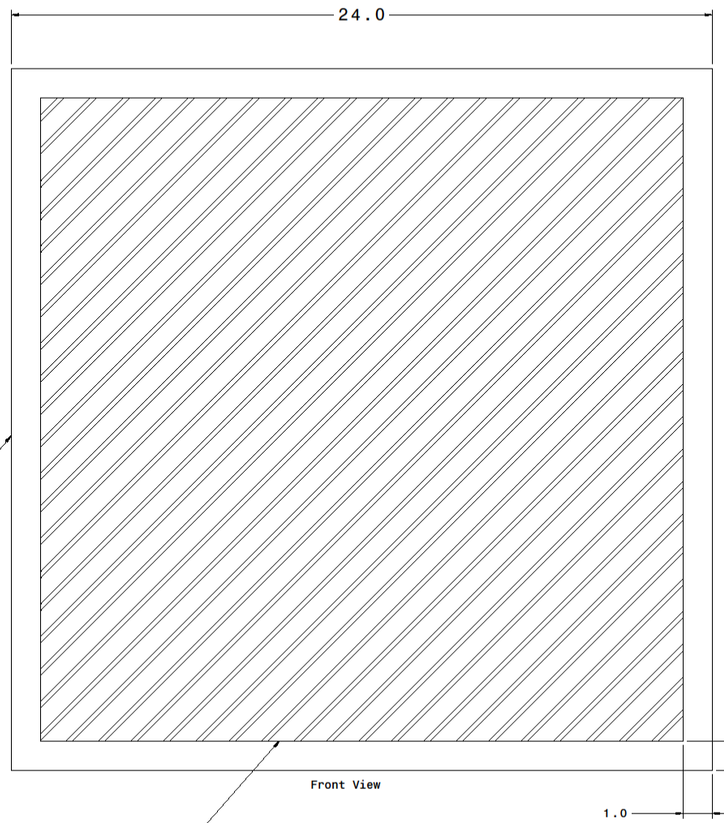
6.) Chromic Acid Anodize (CAA) MIL-PRF-8625 Type 1, Class 1 is used to prevent corrosion. It shall be sealed by immersion in a sealing medium such as a 5 percent aqueous solution of sodium dichromate (pH 5.0 to 6.0) for 15 minutes at 90°C to 100°C, in boiling deionized water, cobalt or nickel acetate, or other suitable chemical solutions.





In order from top to bottom:
Aluminum Sheet 1 (Blue)
FM73C Film Adhesive (Red)
Aluminum Sheet 2 (Blue)

Variable Thicknesses
Refer to Table 1



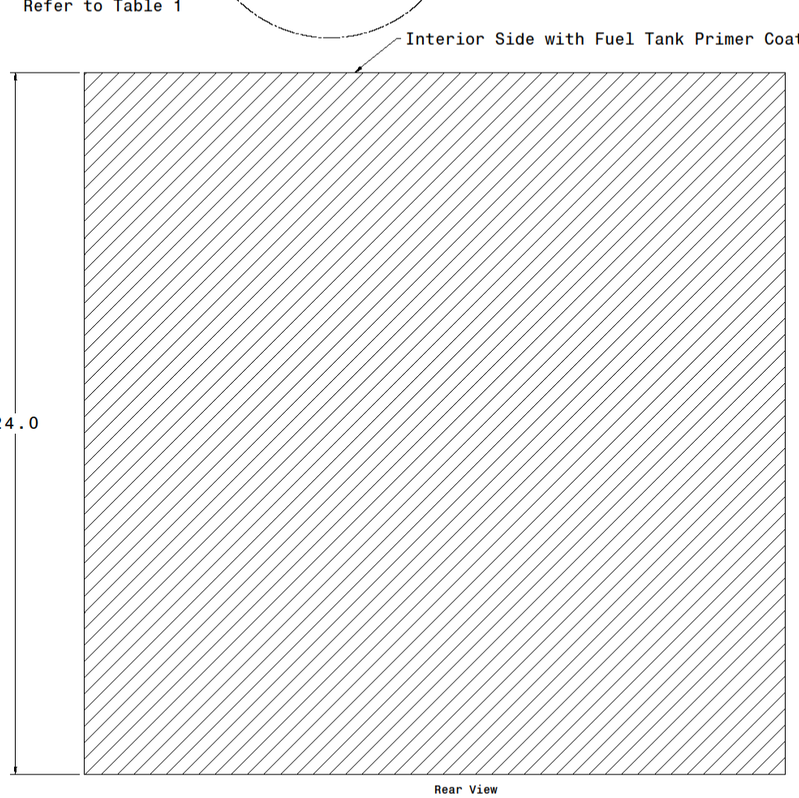


Table 1

Panel Thickness	Quantity
0.008"	4
Total:	4

Exterior Side with Regular Primer and Top Coat

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DRAWN Oscar M. 7/29/2021
CHECKED XXX XX/XX/XXXX
APPROVED XXX XX/XX/XXXX
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ON
DECIMALS .XX = ±.03 .XXX = ±.010
ANGLES ±30'

WICHITA STATE UNIVERSITY
CAD/CAM LABORATORIES

TITLE: Dual Aluminum Panel

SIZE D | DWG NO DEL Aluminum Panel 1 | REV X
SCALE 1:1 WEIGHT (lb) 0.52 SHEET 1 OF 1