NASA Technology Evaluation for Environmental Risk Mitigation
Kennedy Space Center, FL 32899

GSDO Program Hexavalent Chrome Alternatives

Final Pretreatments Test Report

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PREFACE

This test report is prepared by ITB, Inc. through the National Aeronautics and Space Administration (NASA) Technology Evaluation for Environmental Risk Mitigation Principal Center (TEERM) under Contract Number NNH09CF09B. The structure, format, and depth of technical content of the report will be determined by NASA TEERM in response to the specific requirements of this project.

ACKNOWLEDGMENTS

Thanks to Jerry Curran for the coordination and oversight of the ASTM B 117 salt spray testing and the KSC Beachfront testing. Thanks to Teddy Back for assembly of the test articles. Thanks to Rob Smith for taking and recording the DC resistance measurements.

EXECUTIVE SUMMARY

The replacement of hexavalent chromium in the processing of aluminum for aviation and aerospace applications remains a goal of great significance within the aviation and aerospace community. Aluminum is the major manufacturing material of structures and components in both the aircraft (military and commercial) and space flight arena; consequently, the processing and maintenance of this material against degradation and corrosion is of prime importance. For years, hexavalent chromium has been a widely used element within applied coating systems because of its self-healing and corrosion resistant properties. Occupational Safety and Health Administration (OSHA) studies have concluded that hexavalent chromium (hex chrome) is carcinogenic and poses significant risk to human health. On May 5, 2011, amendments to the Defense Federal Acquisition Regulation Supplement (DFARS) were issued in the Federal Register. Subpart 223.73 prohibits contracts from requiring hexavalent chromium in deliverables unless certain exceptions apply. These exceptions include authorization from a general or flag officer and members of the Senior Executive Service from a Program Executive Office, and unmodified legacy systems. Otherwise, Subpart 252.223-7008 provides the contract clause prohibiting contractors from using or delivering hexavalent chromium in a concentration greater than 0.1 percent by weight for all new contracts and to be included down to subcontractors for supplies, maintenance and repair services, and construction materials. National Aeronautics and Space Administration (NASA), Department of Defense (DoD), and industry stakeholders continue to search for alternatives to hex chrome in coatings applications that meet their performance requirements in corrosion protection, cost, operability, and health and safety, while typically specifying that performance must be equal to or greater than existing systems.

Hexavalent chrome free pretreatments should be considered for use on Ground Support Equipment (GSE) and Electrical Ground Support Equipment (EGSE). Both of the hexavalent chrome free pretreatments (Metalast TCP HF and SurTec 650C) evaluated by this project met, and in some instances exceeded, the requirements of MIL-DTL-5541 “Chemical Conversion Coatings on Aluminum and Aluminum Alloys”. For DC resistance measurements, both Metalast TCP HF and SurTec 650C met initial requirements following assembly and in many cases continued to maintain passing readings for the duration of testing.

Based on the results of this project, NASA specifications, drawings and drawing notes should be modified to list hexavalent chrome free pretreatments as an option for use.

1 Introduction

1.1 Background

The NASA TEERM Ground Support Development and Operations (GSDO) Program Hexavalent Chrome Alternatives Project evaluated and tested non-chromated coating systems (pretreatment, primer, and topcoat) as replacements for hexavalent chrome coatings used on Ground Support Equipment (GSE) and Electrical Ground Support Equipment (EGSE). Promising coatings had been identified from previous NASA TEERM Projects; TEERM Non-Chrome Coating System Project, TEERM Hex-Chrome Free Coating Alternatives for Aerospace, TEERM Hex-Chrome Free Coatings for Electronics Application and the NASA/ESA Hexavalent Chrome Alternatives Collaboration.

For this particular phase of the project, hexavalent chrome free pretreatments were evaluated for electrical bonding properties per "Hexavalent Chrome Free Coatings for Electronics Applications, Joint Test Protocol (JTP), Electrical Connectors; January 2012."

1.2 Objective

The overall objective of the TEERM Ground Systems Development and Operations (GSDO) Program Hexavalent Chrome Alternatives Project is to evaluate and test fully non-chromated coating systems (pretreatment, primer and topcoat) as well as several pretreatment and pretreatment plus primer systems as replacements for hexavalent chrome coatings currently in use for aircraft and aerospace applications, including avionics and electronics applications. Successful implementation of acceptable coatings from testing will depend on programmatic requirements in addition to the basic coatings performance requirements tested as a part of this task.

2 Test Articles

This section outlines the preparation of the test panels from alloy selection through pretreatment application.

2.1 Alloys

The alloys used in this project were selected because of their common use in avionics and electronics housing applications. All test panels were procured mill finished without mill markings. Mill finish is as supplied from the mill (raw material manufacturer); the surface is not polished and will most likely have a dull matte appearance. Test panel size is called out in the test description sections. The following alloys were selected for this project:

- 5052-H32
- 6061-T6

2.2 Pretreatment/Conversion Coating Systems

The pretreatment/conversion coating systems that were evaluated for this project are listed in Table 1. The hexavalent chrome free pretreatments selected for this project were agreed upon by the stakeholders of the Hexavalent Chrome Free Coatings for Electronics Applications Project.

Table 1 - Pretreatment/Conversion Coating Systems

Pretreatment/Conversion Coating Systems	**Processing Location**
Alodine 1200S Chromated Pre-treatment	Corrosion Technology Lab
Metalast TCP HF Non-Chromated Pre-treatment	Corrosion Technology Lab
SurTec 650C Non-Chromated Pre-treatment	Corrosion Technology Lab

2.3 Panel Preparation

The following test panel preparation procedure was developed using vendor recommendations as well as lessons learned from previous NASA TEERM managed projects. Test panels were processed on May 6, 2013.

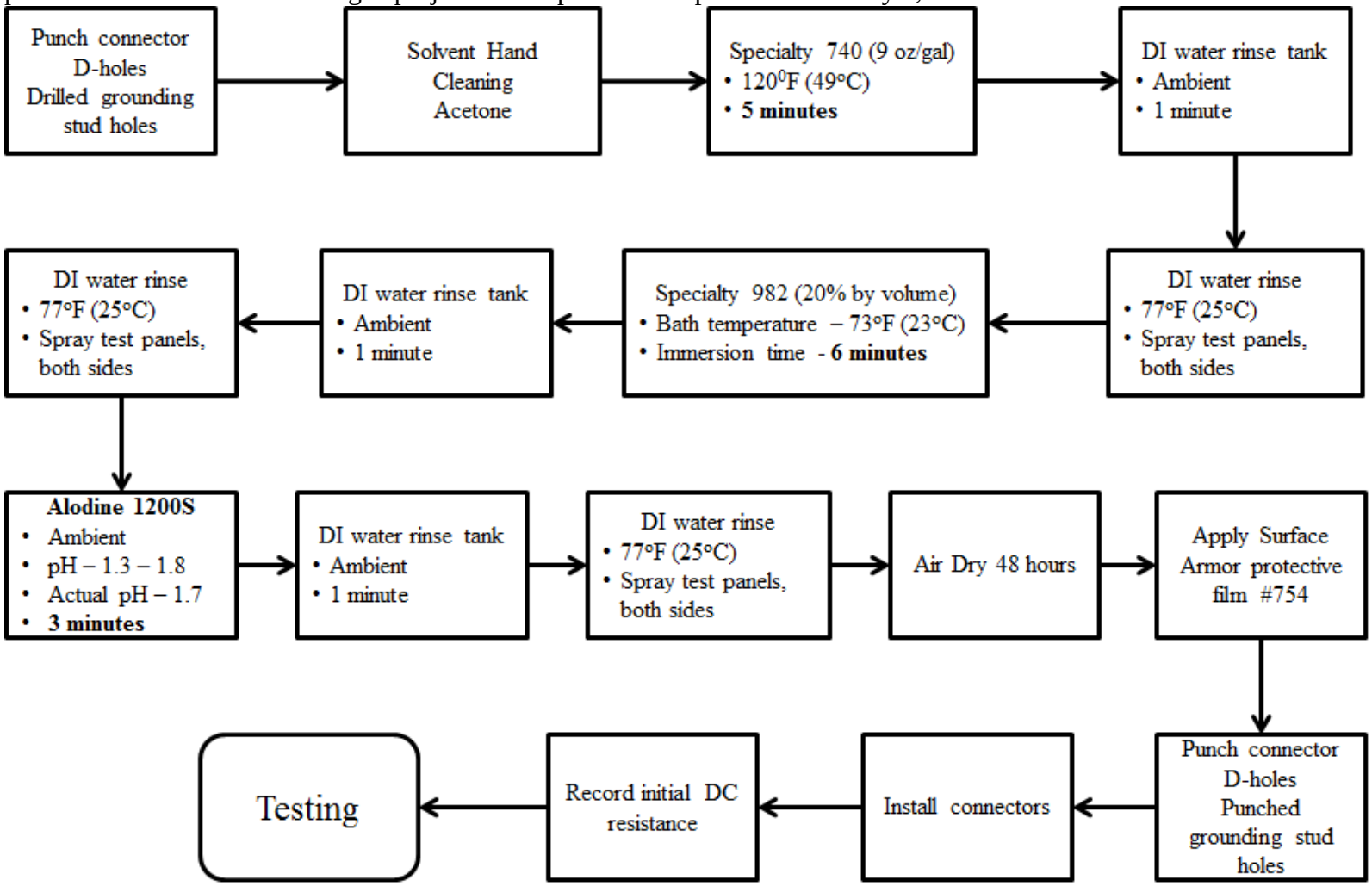


Figure 1 - Test Panel Preparation, Alodine 1200S

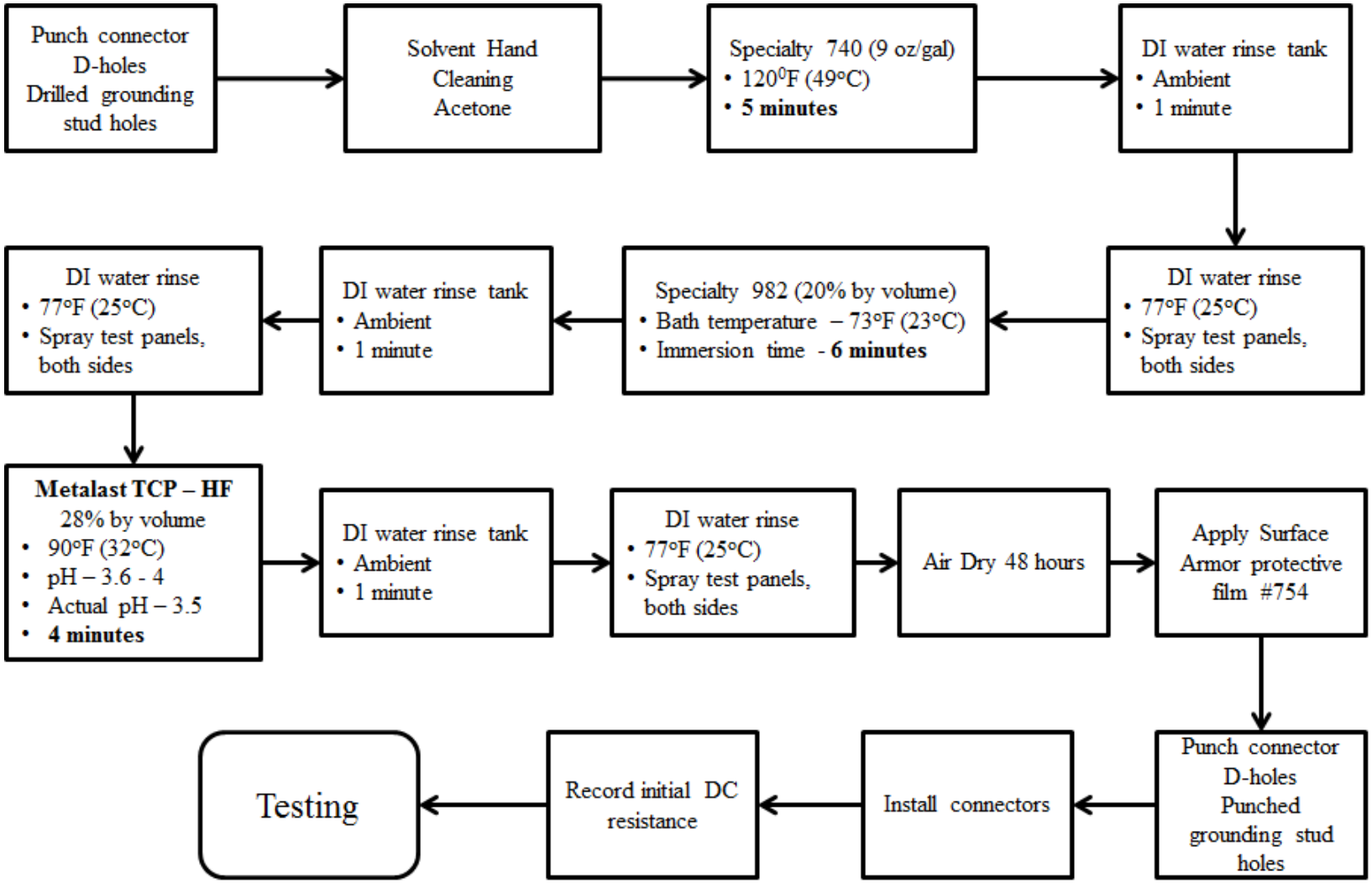


Figure 2 – Test Panel Preparation, Metalast TCP-HF

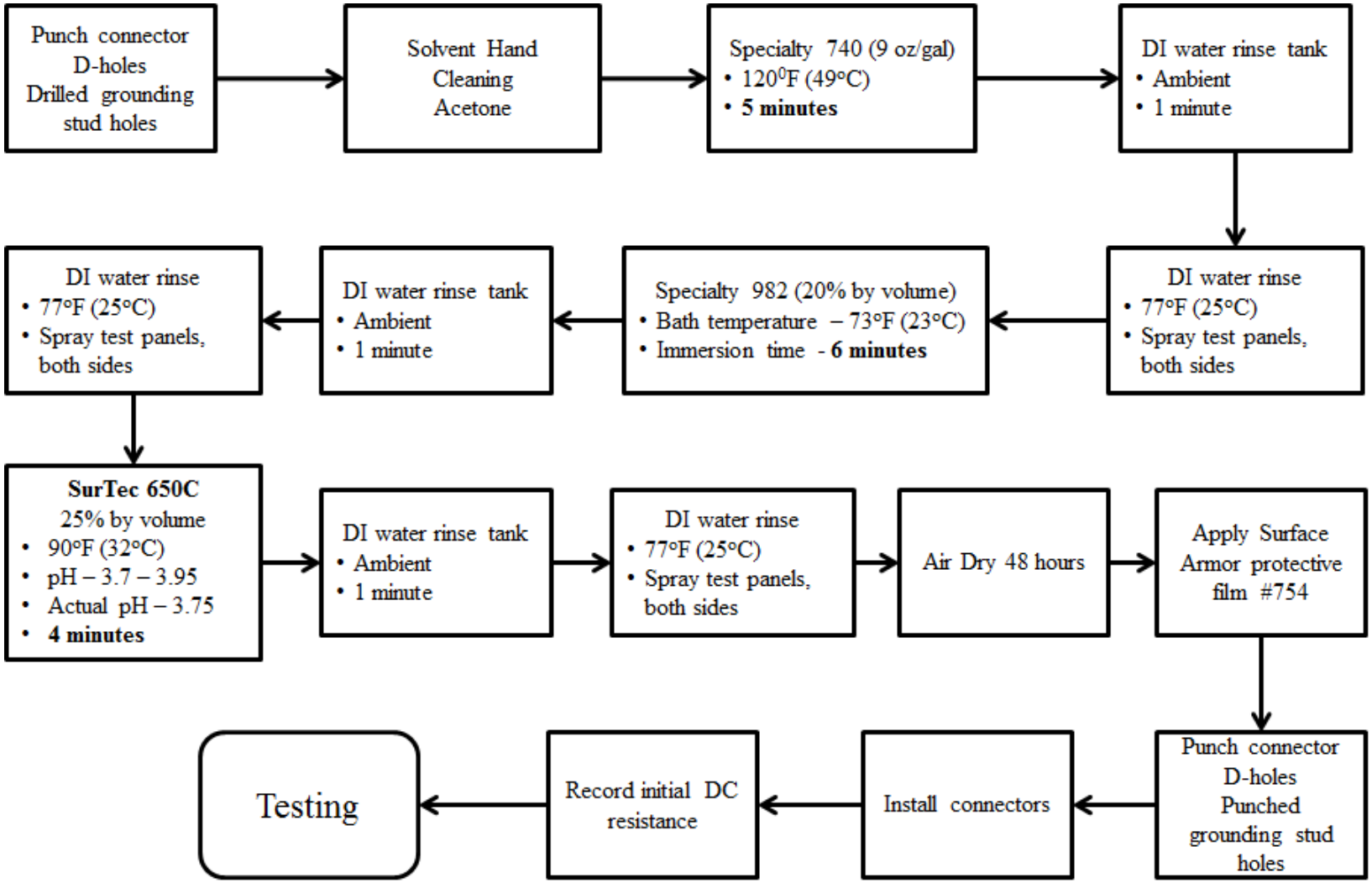


Figure 3 - Test Panel Preparation, SurTec 650C

2.4 Test Panel Count/Numbering

The test panels were sorted by alloy and exposure scenario. Test panels were prepared with and without connectors and grounding studs.

2.4.1 Alodine 1200S; Test Panels with Connectors

Pretreatment	Panel #	Substrate	Test
Alodine 1200S	Al 50 - 001	5052-H32	Beach
Alodine 1200S	Al 50 - 002	5052-H32	Beach

Pretreatment	Panel #	Substrate	Test
Alodine 1200S	Al 50 - 003	5052-H32	Stored

Pretreatment	Panel #	Substrate	Test
Alodine 1200S	Al 60 - 001	6061-T6	Beach
Alodine 1200S	Al 60 - 002	6061-T6	Beach

Pretreatment	Panel #	Substrate	Test
Alodine 1200S	Al 60 - 003	6061-T6	Stored

2.4.2 Alodine 1200S; Test Panels without Connectors

Pretreatment	Panel #	Substrate	Test
Alodine 1200S	Al 50 - 004	5052-H32	ASTM B 117
Alodine 1200S	Al 50 - 005	5052-H32	ASTM B 117
Alodine 1200S	Al 50 - 006	5052-H32	ASTM B 117

Pretreatment	Panel #	Substrate	Test
Alodine 1200S	Al 60 - 004	6061-T6	ASTM B 117
Alodine 1200S	Al 60 - 005	6061-T6	ASTM B 117
Alodine 1200S	Al 60 - 006	6061-T6	ASTM B 117

2.4.3 Metalast TCP HF; Test Panels with Connectors

Pretreatment	Panel #	Substrate	Test
Metalas TCP HF	M 50 - 001	5052-H32	Beach
Metalas TCP HF	M 50 - 002	5052-H32	Beach

Pretreatment	Panel #	Substrate	Test
Metalas TCP HF	M 50 - 003	5052-H32	Stored

Pretreatment	Panel #	Substrate	Test
Metalas TCP HF	M 60 - 001	6061-T6	Beach
Metalas TCP HF	M 60 - 002	6061-T6	Beach

Pretreatment	Panel #	Substrate	Test
Metalas TCP HF	M 60 - 003	6061-T6	Stored

2.4.4 Metalast TCP HF; Test Panels without Connectors

Pretreatment	Panel #	Substrate	Test
Metalas TCP HF	M 50 - 004	5052-H32	ASTM B 117
Metalas TCP HF	M 50 - 005	5052-H32	ASTM B 117
Metalas TCP HF	M 50 - 006	5052-H32	ASTM B 117

Pretreatment	Panel #	Substrate	Test
Metalas TCP HF	M 60 - 004	6061-T6	ASTM B 117
Metalas TCP HF	M 60 - 005	6061-T6	ASTM B 117
Metalas TCP HF	M 60 - 006	6061-T6	ASTM B 117

2.4.5 SurTec 650C; Test Panels with Connectors

Pretreatment	Panel #	Substrate	Test
SurTec 650C	S 50 - 001	5052-H32	Beach
SurTec 650C	S 50 - 002	5052-H32	Beach

Pretreatment	Panel #	Substrate	Test
SurTec 650C	S 50 - 003	5052-H32	Stored

Pretreatment	Panel #	Substrate	Test
SurTec 650C	S 60 - 001	6061-T6	Beach
SurTec 650C	S 60 - 002	6061-T6	Beach

Pretreatment	Panel #	Substrate	Test
SurTec 650C	S 60 - 003	6061-T6	Stored

2.4.6 SurTec 650C; Test Panels without Connectors

Pretreatment	Panel #	Substrate	Test
SurTec 650C	S 50 - 004	5052-H32	ASTM B 117
SurTec 650C	S 50 - 005	5052-H32	ASTM B 117
SurTec 650C	S 50 - 006	5052-H32	ASTM B 117

Pretreatment	Panel #	Substrate	Test
SurTec 650C	S 60 - 004	6061-T6	ASTM B 117
SurTec 650C	S 60 - 005	6061-T6	ASTM B 117
SurTec 650C	S 60 - 006	6061-T6	ASTM B 117

2.5 Test Article Fabrication prior to Pretreatment

The KSC Corrosion Test Lab drilled and punched holes in all of the test articles for connector hole B and grounding stud hole A (see Figure 4). The hole diameters were:

- Connector D-hole = Figure 4
- Grounding stud hole = 0.25” +/- 0.010” inch

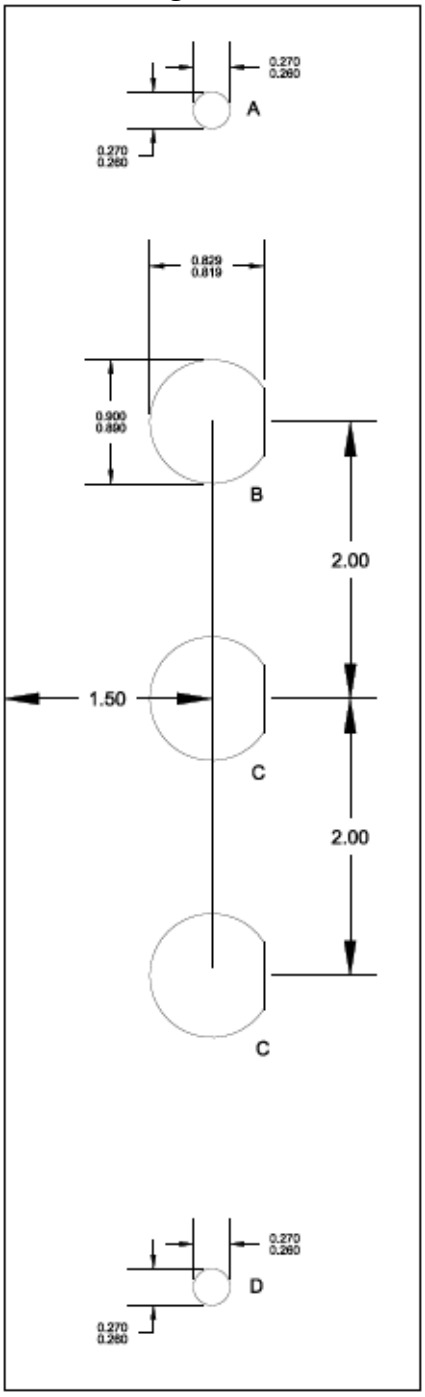


Figure 4 - Test Article Fabrication prior to Pretreatment

2.6 Test Article Fabrication Following Pretreatment

The KSC Corrosion Test Lab punched holes in all of the test articles for connector holes C and grounding stud location D (see Figure 5). The hole diameters were:

- Connector D-hole = see Figure 5
- Grounding stud hole = 0.26” +/- 0.010” inch

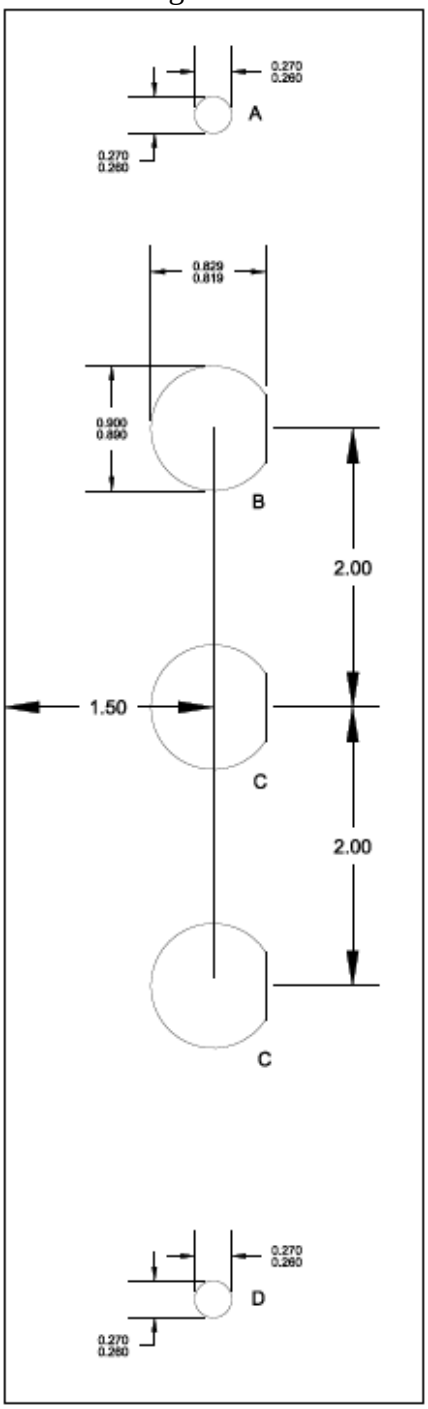


Figure 5 - Test Article Fabrication after Pretreatment

2.7 Test Article Fabrication, Connector and Grounding Stud Installation

The KSC Corrosion Test Lab assembled the test articles per the following criteria:

- The connector receptacles consisted of part number: MS3474W12 – 10S
- The grounding studs consisted of cadmium plated serrated hex flange bolts (0.5" x .25") with 20 threads per inch. Nuts used to secure the screws to the test articles were cadmium plated serrated hex flange and star tooth locking nuts.
- The area around the connector holes and grounding studs was not sanded or altered prior to installation of the connectors or grounding studs per KSC-E-166C, figure 10 "clean to bare metal 1/8-inch larger than connector unless mounting area is finished with conductive coating."
- The test panels were cleaned with acetone and gauze prior to assembly to remove machine oil from the hole punching process.
- When installing grounding stud A and connectors B and C-1 non-conductive CERAN HVA grease was used per KSC Standard Drawing Notes; "Apply a thin, continuous coating of grease (CERAN HVA) to faying surfaces. After installing connectors, remove excess grease with a clean, dry, lint-free rag."
- When installing grounding stud D and connector C-2 non-conductive CERAN HVA grease was not used.
- The connector jam nuts were torqued to 35 inch pounds.
- The grounding stud serrated hex flange locking and star tooth nuts were torqued to 35 inch pounds.

3 Testing; Test Panels with Connectors

Testing was conducted at the KSC Corrosion Technology Laboratory and Beachside Corrosion Laboratory as well as the Engineering Development Laboratory (see Table 2).

Table 2 – Testing with Connectors

Test	Test Method	Evaluation Criteria	Location
DC Resistance	NASA-STD-4003	NASA-STD-4003	KSC EDL
Ambient Storage	N/A	NASA-STD-4003	KSC Corrosion Lab
Marine Environment	ASTM D 1014	NASA-STD-4003	KSC Corrosion Lab

3.1 DC Resistance

This test was used to determine what effect pretreatments would have on the impedance path from the connector backshell to the equipment case.

3.1.1 Test Procedure

DC resistance was measured between connector shells to grounding studs per NASA-STD-4003, Electrical Bonding for NASA Launch Vehicles, Spacecraft, Payloads, and Flight Equipment, section 4.3.1. The DC resistance from backshell to case (grounding stud) shall not exceed 2.5 milliohms. Readings that exceed 2.5 milliohms were recorded as failed.

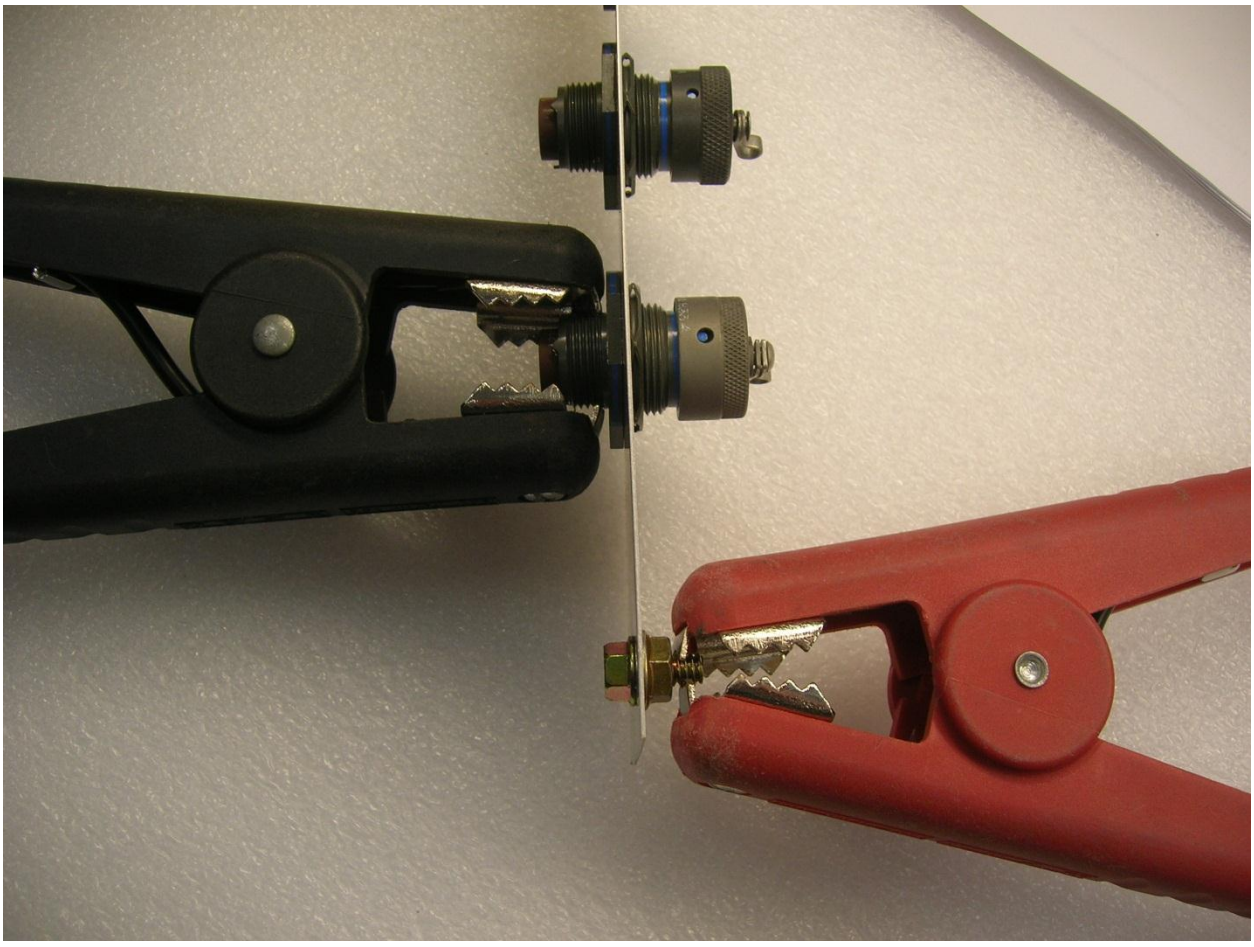


Figure 6 - DC Resistance Measured Between Connector Shells and Grounding Studs

3.1.2 Evaluation Procedure

An AEMC Instruments 6250 Micro Ohmmeter in calibration was used to measure the DC resistance from the connector backshell to the grounding studs on the test panels. Each measurement was taken three times with the readings being recorded in Appendix A.

DC resistance measurements were taken on all test articles with connectors installed prior to testing. Connectors with initial DC resistance readings greater than 2.5 milliohms were loosened

and again torqued to 35 inch pounds. If the resistance readings continued to be above 2.5 milliohms, the connectors were deemed failed.

3.2 Ambient Storage

This test was used to evaluate if pretreatments exposed to typical storage conditions will affect the impedance path from the connector backshell to the equipment case over time.

3.2.1 Test Procedure

Test panels were stored in a temperature controlled room, either in a laboratory or office.

3.2.2 Evaluation Procedure

DC resistance was measured between connector shells to grounding studs per NASA-STD-4003, Electrical Bonding for NASA Launch Vehicles, Spacecraft, Payloads, and Flight Equipment, section 4.3.1. The DC resistance from backshell to case (grounding stud) shall not exceed 2.5 milliohms. Readings that exceeded 2.5 milliohms were recorded as failed. Any signs of corrosion or other irregularities were noted as they were observed once testing was complete.

DC resistance measurements were taken after 35 and 70 days of storage.

3.3 Marine Environment

This test evaluated the performance of the test and control coatings during outdoor exposure in a marine environment. Accelerated testing was useful for comparing the performance of coatings under accelerated conditions; however, correlations to actual service performance were difficult due to different corrosion mechanisms prevalent in the outdoor versus accelerated situations. Outdoor exposure in the environment of performance, therefore, is a critical test necessary to determine the effect actual weather patterns and real-world exposure have on the coatings of interest. Comparing data collected from atmospheric and accelerated testing gave insight into anticipated performance of a coating system before being field tested.

3.3.1 Test Procedure

Atmospheric exposure testing follows ASTM D 1014 (Standard Practice for Conducting Exterior Exposure Tests of Paints and Coatings on Metal Substrates).

Test articles were installed horizontally at the KSC Beach Front Corrosion Lab, located at latitude 28.594°N, longitude -80.582°W, and approximately 100 feet (30 meters) from the high tide line. Testing followed KSC testing procedures for fasteners, exposure angle, and inspection intervals unless otherwise noted.

3.3.2 Evaluation Procedure

DC resistance was measured between connector shells to grounding studs per NASA-STD-4003, Electrical Bonding for NASA Launch Vehicles, Spacecraft, Payloads, and Flight Equipment, section 4.3.1. The DC resistance from backshell to case shall not exceed 2.5 milliohms. Readings that exceed 2.5 milliohms were recorded as failed.

DC resistance measurements were taken after 35 and 70 days of exposure.

4 Testing; Test Panels without Connectors

Testing was conducted at the KSC Corrosion Technology Laboratory and Beachside Corrosion Laboratory

Table 3 – Testing without Connectors

Test	Test Method	Evaluation Criteria	Location
Salt Spray Resistance	ASTM B 117	MIL-DTL-5541	KSC Corrosion Lab

4.1 Salt Spray Resistance

This test was used to rapidly evaluate both the performance of a coating or coating system and how well it prevents corrosion. Salt Spray Resistance is a requirement MIL-DTL-5541 "Chemical Conversion Coatings on Aluminum and Aluminum Alloys."

4.1.1 Test Procedure

Test panels were subjected to a 5 percent NaCl salt spray, pH-adjusted to a range of 6.5 – 7.2, in accordance with ASTM B 117 (Standard Practice for Operating a Salt Spray (Fog) Apparatus).

4.1.2 Evaluation Procedure

Once testing was complete, if signs of corrosion appeared on the test articles, the following criteria were used for evaluation. Per MIL-DTL-5541; at the end of 168 hours of exposure to the 5 percent salt spray test, test specimens shall meet the following corrosion resistance requirements:

- No more than 5 isolated spots or pits (see 6.9), none larger than 0.031 inch in diameter, per test specimen. Areas within 0.25 inch from the edges, identification markings, and holding points during processing or salt spray exposure shall be excluded. Loss of color shall not be cause for rejection.
- No more than 15 isolated spots or pits, none larger than 0.031 inch in diameter, on the combined surface area of all five test specimens, subjected to the salt spray test.

5 Results

Results from this project were analyzed following 35 and 70 days of exposure.

5.1 Salt Spray Resistance

Test panels were evaluated for corrosion every 168 hours of testing. For this project, test panels that continued to have passing results were left in testing for a total of 672 hours. Table 4 and Table 5 show the results from salt spray testing. The hexavalent chrome free alternative Metalast TCP HF performed as well as the hexavalent chrome baseline Alodine 1200S on 5052-H32 test panels. Hexavalent chrome free SurTec 650C did not perform as expected on 5052-H32. After passing 168 hours of salt spray testing, the SurTec 650C pretreatment broke down and failed significantly after 336 hours of salt spray testing. As seen in Appendix E, large pits were observed on the SurTec 650C test panels. This failure mechanism had not been previously observed during NASA TEERM testing of SurTec 650C. If feasible, the test panels should be more closely evaluated, possibly with a scanning electron microscope (SEM) in an attempt to better understand why the SurTec 650C failed.

The hexavalent chrome free alternatives Metalast TCP HF and SurTec 650C performed as well as the hexavalent chrome baseline Alodine 1200S on 6061-T6 test panels. Overall, SurTec 650C performed slightly better than Metalast TCP HF and Alodine 1200S.

Table 4 – Combined Salt Spray Data; 5052-H32 Test Panels

Pretreatment	Panel #	Substrate	@168	@336	@504	@672	Total
Alodine 1200S	Al 50 - 004	5052-H32	0	0	0	1	1
	Al 50 - 005		0	0	0	0	0
	Al 50 - 006		0	0	0	1	1
Metalast TCP HF	M 50 - 004	5052-H32	0	0	1	1	2
	M 50 - 005		0	0	0	0	0
	M 50 - 006		0	0	0	0	0
SurTec 650C	S 50 - 004	5052-H32	0	9	x	x	9
	S 50 - 005		0	15	x	x	15
	S 50 - 006		0	10	x	x	10

Table 5 - Combined Salt Spray Data; 6061-T6 Test Panels

Pretreatment	Panel #	Substrate	@168	@336	@504	@672	Total
Alodine 1200S	Al 60 - 004	6061-T6	1	3	0	0	4
	Al 60 - 005		2	3	0	0	5
	Al 60 - 006		1	0	0	0	1
Metalast TCP HF	M 60 - 004	6061-T6	1	1	0	1	3
	M 60 - 005		2	0	0	1	3
	M 60 - 006		2	0	3	0	5
SurTec 650C	S 60 - 004	6061-T6	0	0	0	2	2
	S 60 - 005		0	0	0	0	0
	S 60 - 006		0	0	0	1	1

5.2 35 Days of Exposure at the KSC Beachfront

Following 35 days of exposure at the KSC Beachfront, all of the test articles were removed from the beach and taken to the KSC Beachfront laboratory so DC resistance measurements could be collected. DC resistance data is given in Appendix A. Appendix B provides a breakout of the data by pretreatment, test panel alloy and exposure condition.

Table 6 combines the breakout data from 35 days of exposure at the KSC Beachfront. Test articles with Alodine 1200S, the baseline pretreatment, performed worse than expected. There was an expectation that test articles with Alodine 1200S would have maintained passing results

for the duration of exposure. In reviewing the pictures of the test articles with Alodine 1200S in Appendix C, corrosion was limited on the exterior of the connectors and grounding studs.

In review of Table 6, test articles with Metalast TCP HF had consistent results by connector mounting procedure regardless of how the grounding studs were mounted. Passing results were maintained for the duration of exposure when the connector D-hole was punched into the test panels after the application of Metalast TCP HF regardless of how the grounding studs were mounted. However, when the connector D-hole was punched into the test panel prior to pretreatment application, mixed results were recorded for the 5052-H32 test panels and failing results were recorded for the 6061-T6 test panels regardless of how the grounding studs were mounted. The lack of CERAN HVA grease during installation of the connectors resulted in failing DC resistance measurements following the 35 days of exposure at the KSC Beachfront regardless of how the grounding studs were mounted. It was suspected that corrosion contributed to the failing DC resistance measurements.

Test articles with SurTec 650C had very consistent results by connector mounting procedure regardless of how the grounding studs were mounted. Passing results were maintained for the duration of exposure when the connector D-hole was punched into the test panels after the application of SurTec 650C regardless of how the grounding studs were mounted. However, when the connector D-hole was punched into the test panels prior to pretreatment application mixed results were recorded for the 5052-H32 test panels and the 6061-T6 test panels regardless of how the grounding studs were mounted. The lack of CERAN HVA grease during installation of the connectors resulted in mixed DC resistance measurements following the 35 days of exposure at the KSC Beachfront. DC resistance measurements with grounding stud A were mixed for the 5052-H32 test panels and failed for the 6061-T6 test panels. DC resistance measurements with grounding stud D were mixed for the 5052-H32 and 6061-T6 test panels. It was suspected that corrosion contributed to the failing DC resistance measurements.

Table 6 – Combined Breakout Data; 35 Days of Exposure at the KSC Beachfront

DC resistance readings from test panels following 35 days of exposure at the KSC Beachfront

Ground	Connector	Alodine 1200S				Metalast TCP HF				SurTec 650C			
		5052-H32		6061-T6		5052-H32		6061-T6		5052-H32		6061-T6	
		Pass	**Fail**	**Pass**	**Fail**	**Pass**	**Fail**	**Pass**	**Fail**	**Pass**	**Fail**	**Pass**	**Fail**
Stud A	B	0	2	1	1	1	1	0	2	1	1	1	1
	Hole punched prior to pretreatment												
	CERAN HVA grease used during install												
	C-1	1	1	0	2	2	0	2	0	2	0	2	0
	Hole punched after pretreatment												
Hole drilled prior to pretreatment	CERAN HVA grease used during install												
	C-2	1	1	1	1	0	2	0	2	1	1	0	2
CERAN HVA grease used during install	Hole punched after pretreatment												
	No CERAN HVA grease used during install												
Stud D	B	0	2	2	0	1	1	0	2	1	1	1	1
	Hole punched prior to pretreatment												
	CERAN HVA grease used during install												
	C-1	2	0	0	2	2	0	2	0	2	0	2	0
	Hole punched after pretreatment												
Hole punched after pretreatment	CERAN HVA grease used during install												
	C-2	1	1	1	1	0	2	0	2	1	1	1	1
No CERAN HVA grease used during install	Hole punched after pretreatment												
	No CERAN HVA grease used during install												

Connector C-2 with Alodine 1200S failed initial reading on test panel Al 50 - 002

5.3 35 Days of Ambient Office Storage

Following 35 days of ambient office storage, all of the test articles were taken to the Engineering Development Laboratory so DC resistance measurements could be collected. DC resistance data is given in Appendix A. Appendix B provides a breakout of the data by pretreatment, test panel alloy and exposure condition.

Table 7 combines the breakout data from 35 days of ambient office storage. Test articles with Alodine 1200S, the baseline pretreatment, performed worse than expected. There was an expectation that test articles with Alodine 1200S would have maintained passing results for the duration of storage. Further analysis and review were required once testing had completed 70 days of storage to explain why failing DC resistance measurements were being observed on all but one of the connectors. The one exception was the connector installed with the CERAN HVA grease stored in an ambient environment.

In review of Table 7, test articles with Metalast TCP HF had consistent results by connector mounting procedure regardless of how the grounding studs were mounted. Passing results were maintained for the duration of storage for all of the combinations of connector and grounding stud mounting procedures.

Test articles with SurTec 650C had very consistent results for the 5052-H32 test panels. Passing results were maintained for the duration of storage for all of the combinations of connector and grounding stud mounting procedures on the 5052-H32 test panels. The 6061-T6 test panels maintained passing DC resistance measurements only were the connector D-holes were punched into the test panels prior to pretreatments application regardless of how the grounding studs were mounted.

Table 7 – Combined Breakout Data; 35 days of Ambient Office Storage

DC resistance readings from test panels following 35 days of ambient office storage

Ground	Connector	Alodine 1200S				Metalast TCP HF				SurTec 650C			
		5052-H32		6061-T6		5052-H32		6061-T6		5052-H32		6061-T6	
		Pass	**Fail**	**Pass**	**Fail**	**Pass**	**Fail**	**Pass**	**Fail**	**Pass**	**Fail**	**Pass**	**Fail**
Stud A	B	0	1	0	1	1	0	1	0	1	0	1	0
	Hole punched prior to pretreatment												
	CERAN HVA grease used during install												
	C-1	0	1	0	1	1	0	1	0	1	0	0	1
	Hole punched after pretreatment												
Hole drilled prior to pretreatment	CERAN HVA grease used during install												
	C-2	1	0	1	0	1	0	1	0	1	0	0	1
CERAN HVA grease used during install	Hole punched after pretreatment												
	No CERAN HVA grease used during install												
Stud D	B	0	1	0	1	1	0	1	0	1	0	1	0
	Hole punched prior to pretreatment												
	CERAN HVA grease used during install												
	C-1	0	1	1	0	1	0	1	0	1	0	0	1
	Hole punched after pretreatment												
Hole punched after pretreatment	CERAN HVA grease used during install												
	C-2	1	0	1	0	1	0	1	0	1	0	0	1
No CERAN HVA grease used during install	Hole punched after pretreatment												
	No CERAN HVA grease used during install												

Connector B with Alodine 1200S failed initial reading on test panel Al 50 - 003

5.4 70 Days of Exposure at the KSC Beachfront

Following 70 days of exposure at the KSC Beachfront, all of the test articles were removed from the beach and taken to the KSC Beachfront laboratory so DC resistance measurements could be collected. DC resistance data is given in Appendix A. Appendix B provides a breakout of the data by pretreatment, test panel alloy and exposure condition.

Table 8 combines the breakout data from 70 days of exposure at the KSC Beachfront. Test articles with Alodine 1200S, the baseline pretreatment, continued to have failing results. Following 70 days of KSC Beachfront exposure, only one of six connectors had DC resistance readings that were passing on 5052-H32 test articles, connector location C-1 on test article Al 50 – 002. Connector C-1 had the connector hole punched into the test panel after pretreatment application and CERAN HVA grease was used while installing the connector. This particular connector had passing DC resistance readings regardless of the grounding stud installation procedure. For the 6061-T6 test articles, only two DC resistance readings met passing criteria. Readings between connector location B and grounding stud D on test articles Al 60 – 001 and Al 60 – 002 maintained passing DC resistance results following 70 days of exposure at the KSC Beachfront. Connector B had the connector hole punched into the test panel prior to pretreatment and CERAN HVA grease was used while installing the connector. Grounding stud D had the mounting hole punched into the test panel after pretreatment application and did not have CERAN HVA grease applied during installation. In reviewing the pictures of the Alodine 1200S test article in Appendix C, corrosion was limited on the exterior of the connectors and grounding studs. In reviewing the pictures of the disassembled test articles in Appendix D, there was no sign of corrosion between the mounting surfaces of the connector and the test panel for connector locations B and C-1, connectors installed with CERAN HVA grease. Some limited corrosion was observed on the mounting surfaces of connector C-2, connectors that did not have CERAN HVA grease applied during assembly. For the grounding studs, there was no sign of corrosion on the internal surfaces of grounding stud A which was installed with CERAN HVA grease. For grounding stud D, corrosion was observed on the exterior of the star tooth nuts. Corrosion was also observed on the inside of the lower teeth of the star tooth nuts which were against the test panel surface. Corrosion was observed in that area for all of the grounding studs with star tooth nuts. Grounding stud D was installed without the application of CERAN HVA grease.

In review of Table 8, test articles with Metalast TCP HF had consistent results by connector mounting procedure regardless of how the grounding studs were mounted. For the 5052-H32 test articles, connector location B on M 50 – 001 maintained passing DC resistance readings for the duration of the test regardless of the grounding stud installation procedure. For connector location B, the connector hole was punched into the test panel prior to pretreatment application and CERAN HVA grease was used during connector installation. Connector location C-1 on test articles M 50 – 001 and M 50 – 002 had DC resistance readings that went from passing 35 days of exposure to having failed readings following 70 days of exposure regardless of the grounding stud installation procedure. For the 6061-T6 test articles, change only occurred with connector C-1 on test article M 60 – 001. For that particular connector, the results went from passing 35 days of exposure to having failed DC resistance readings following 70 days of exposure

regardless of the grounding stud installation procedure. In reviewing the pictures of the Metalast TCP-HF test articles in Appendix C, corrosion was limited on the exterior of the connectors and grounding studs. In reviewing the pictures of the disassembled test articles in Appendix D, there was no sign of corrosion between the mounting surfaces of the connector and the test panel for connector locations B and C-1, connectors installed with CERAN HVA grease. Some limited corrosion was observed on the mounting surfaces of connector C-2, connectors that did not have CERAN HVA grease applied during assembly. For the grounding studs, there was no sign of corrosion on the internal surfaces of grounding stud A which was installed with CERAN HVA grease. For grounding stud D, corrosion was observed on the exterior of the star tooth nuts. Corrosion was also observed on the inside of the lower teeth of the star tooth nuts which were against the test panel surface. Corrosion was observed in that area for all of the grounding studs with star tooth nuts. Grounding stud D was installed without the application of CERAN HVA grease.

Test articles with SurTec 650C had very consistent results by connector mounting procedure and grounding stud installation. For the 5052-H32 test articles, connector location C-2 on test article S 50 – 001 the DC resistance readings went from passing 35 days of exposure to having failed readings following 70 days of exposure regardless of the grounding stud installation procedure. Connector location C-1 on test articles S 50 - 001 and S 50 – 002 maintained passing DC resistance readings for the duration of testing. Connector location B on test article S 50 – 002 had DC resistance readings that went from passing 35 days of exposure to having failed readings following 70 days of exposure regardless of the grounding stud installation procedure. Connector location B on test article S 50 -001 had DC resistance readings that went from failing 35 days of exposure to having passing readings following 70 days of exposure regardless of the grounding stud installation procedure. In reviewing the disassembled test article, there is no obvious visual indication as to why the DC resistance readings for connector location B would go from failing to passing over the duration of testing. For the 6061-T6 test articles, the results following 70 days of exposure at the KSC Beachfront site were very consistent to the results following 35 days of exposure. The one exception was a failed DC resistance reading on test article S 60 – 002 connector location C-2 to grounding stud D. All other DC resistance readings remained the same regarding pass/fail criteria. In reviewing the pictures of the SurTec 650C test articles in Appendix C, corrosion was limited on the exterior of the connectors and grounding studs. In reviewing the pictures of the disassembled test articles in Appendix D, there was no sign of corrosion between the mounting surfaces of the connector and the test panel for connector locations B and C-1, connectors installed with CERAN HVA grease. Some limited corrosion was observed on the mounting surfaces of connector C-2, connectors that did not have CERAN HVA grease applied during assembly. For the grounding studs, there was no sign of corrosion on the internal surfaces of grounding stud A which was installed with CERAN HVA grease. For grounding stud D, corrosion was observed on the exterior of the star tooth nuts. Corrosion was also observed on the inside of the lower teeth of the star tooth nuts which were against the test panel surface. Corrosion was observed in that area for all of the grounding studs with star tooth nuts. Grounding stud D was installed without the application of CERAN HVA grease.

Table 8 - Combined Breakout Data; 70 Days of Exposure at the KSC Beachfront

DC resistance readings from test panels following 70 days of exposure at the KSC Beachfront

Ground	Connector	Alodine 1200S				Metalast TCP HF				SurTec 650C			
		5052-H32		6061-T6		5052-H32		6061-T6		5052-H32		6061-T6	
		Pass	**Fail**	**Pass**	**Fail**	**Pass**	**Fail**	**Pass**	**Fail**	**Pass**	**Fail**	**Pass**	**Fail**
Stud A	B	0	2	0	2	1	1	0	2	1	1	1	1
	Hole punched prior to pretreatment												
	CERAN HVA grease used during install												
	C-1	1	1	0	2	0	2	1	1	2	0	2	0
Hole drilled prior to pretreatment	Hole punched after pretreatment												
	CERAN HVA grease used during install												
	C-2	0	2	0	2	0	2	0	2	0	2	0	2
CERAN HVA grease used during install	Hole punched after pretreatment												
	No CERAN HVA grease used during install												
Stud D	B	0	2	2	0	1	1	0	2	1	1	1	1
	Hole punched prior to pretreatment												
	CERAN HVA grease used during install												
	C-1	1	1	0	2	0	2	1	1	2	0	2	0
Hole punched after pretreatment	Hole punched after pretreatment												
	CERAN HVA grease used during install												
	C-2	0	2	0	2	0	2	0	2	0	2	0	2
No CERAN HVA grease used during install	Hole punched after pretreatment												
	No CERAN HVA grease used during install												

Connector C-2 with Alodine 1200S failed initial reading on test panel Al 50 - 002

5.5 70 Days of Ambient Office Storage

Following 70 days of ambient office storage, the test articles were taken to the KSC Beachfront laboratory so DC resistance measurements could be collected. DC resistance data is given in Appendix A. Appendix B provides a breakout of the data by pretreatment, test panel alloy and exposure condition.

Table 9 combines the breakout data from 70 days of ambient office storage. For the 5052-H32 test article with Alodine 1200S, all of the DC resistance readings remained the same regarding pass/fail criteria. For the 6061-T6 test article, the results following 70 days of ambient office storage were very consistent to the results following 35 days of storage. The one exception was a failed DC resistance reading on test article S 60 – 003 connector location C-2 to grounding stud A. As seen in Appendix C, no visual changes were observed on the test articles over the duration of testing. Since no visual changes were observed on the exterior of the test articles, the test articles were not disassembled for inspection of the bonding surfaces.

In reviewing Table 9, 5052-H32 test article with Metalast TCP HF, all of the DC resistance readings were fails following 70 days of ambient office storage. This was a reversal from the results following 35 days of ambient office storage when all of the DC resistance readings were passing. There are no visual indications as to why the readings would go from passing to failing over the duration of testing. For the 6061-T6 test article, the results following 70 days of ambient office storage were the same as the results following 35 days of storage. As seen in Appendix C, no visual changes were observed on the test articles over the duration of testing. Since no visual changes were observed on the exterior of the test articles, the test articles were not disassembled for inspection of the bonding surfaces.

The test article with SurTec 650C on 5052-H32 had DC resistance readings that remained the same regarding pass/fail criteria. For the 6061-T6 test article, the results following 70 days of ambient office storage were very consistent to the results following 35 days of storage. The one exception was connector C-2 that had failing DC resistance readings following 35 days of ambient office storage but had passing results following 70 days of storage. There are no visual indications as to why the readings would go from passing to failing over the duration of testing. As seen in Appendix C, no visual changes were observed on the test articles over the duration of testing. Since no visual changes were observed on the exterior of the test articles, the test articles were not disassembled for inspection of the bonding surfaces.

Table 9 - Combined Breakout Data; 70 days of Ambient Office Storage

DC resistance readings from test panels following 70 days of ambient office storage

Ground	Connector	Alodine 1200S				Metalast TCP HF				SurTec 650C			
		5052-H32		6061-T6		5052-H32		6061-T6		5052-H32		6061-T6	
		Pass	**Fail**	**Pass**	**Fail**	**Pass**	**Fail**	**Pass**	**Fail**	**Pass**	**Fail**	**Pass**	**Fail**
Stud A	B												
	Hole punched prior to pretreatment	0	1	0	1	0	1	1	0	1	0	1	0
	CERAN HVA grease used during install												
	C-1												
	Hole punched after pretreatment	0	1	0	1	0	1	1	0	1	0	0	1
Hole drilled prior to pretreatment	CERAN HVA grease used during install												
	C-2												
CERAN HVA grease used during install	Hole punched after pretreatment	1	0	0	1	0	1	1	0	1	0	1	0
	No CERAN HVA grease used during install												
Stud D	B												
	Hole punched prior to pretreatment	0	1	0	1	0	1	1	0	1	0	1	0
	CERAN HVA grease used during install												
	C-1												
	Hole punched after pretreatment	0	1	1	0	0	1	1	0	1	0	0	1
Hole punched after pretreatment	CERAN HVA grease used during install												
	C-2												
No CERAN HVA grease used during install	Hole punched after pretreatment	1	0	1	0	0	1	1	0	1	0	1	0
	No CERAN HVA grease used during install												

Connector B with Alodine 1200S failed initial reading on test panel Al 50 - 003

6 Conclusions

In review of the data generated during this project, hexavalent chrome free pretreatments should be considered for use on Ground Support Equipment (GSE) and Electrical Ground Support Equipment (EGSE). Following salt spray testing with 5052-H32, the hexavalent chrome free pretreatments passed the required 168 hours of testing. Metalast TCP HF greatly surpassed the specification by passing 672 hours. For 6061-T6, both of the hexavalent chrome free pretreatments greatly surpassed the specification by passing 672 hours. Based on the results of salt spray testing, both of the hexavalent chrome free pretreatments meet the requirements of MIL-DTL-5541 "Chemical Conversion Coatings on Aluminum and Aluminum Alloys."

For electrical bonding, the hexavalent chrome free pretreatments performed as well as and in some cases better than the hexavalent chrome baseline. Following 35 days of exposure at the KSC Beachfront, Metalast TCP HF and SurTec 650C test articles outperformed Alodine 1200S for connector location C-1. Connector location C-1 is considered the typical procedure for installing connectors. Following 70 days of exposure at the KSC Beachfront, SurTec 650C continued to perform very well for connector location C-1, continuing to outperform Alodine 1200S.

Overall, the number of connectors and test articles was limited for the DC resistance evaluation. In order to get more distinct data trends, a larger sample size would be required.

7 Recommendations

Based on the performance of the hexavalent chrome free pretreatments evaluated in this project, NASA specifications, drawings and drawing notes should be modified to list hexavalent chrome free pretreatments as an option for use. It may be necessary to modify NASA-STD-5008B, "Protective Coating of Carbon Steel, Stainless Steel, and Aluminum on Launch Structures, Facilities, and Ground Support Equipment" to include a section on hexavalent chrome free pretreatments.

This project only evaluated connectors with a cadmium finish. Connectors with cadmium and chromium free finishes need to be evaluated as well. Several cadmium and chromium free finishes are currently available. Work completed by NAVAIR has shown that cadmium and chromium free connectors can meet performance requirements for corrosion resistance. Additional work needs to be done with cadmium and chromium free connectors to ensure they meet NASA electrical bonding requirements.

There is a need to evaluate how well primers and topcoats will perform over hexavalent chrome free pretreatments. Primers and topcoats could be selected from NASA-STD-5008B, "Protective Coating of Carbon Steel, Stainless Steel, and Aluminum on Launch Structures, Facilities, and Ground Support Equipment; section 4.5.2.2." New coating technologies and products should also be evaluated for testing. Hexavalent chrome free coatings that meet or exceed testing standards should be considered for implementation.

Appendix A: DC Resistance Readings

AEMC Instruments 6250 Micro Ohmmeter

- Model: AEMC Instruments Micro-ohmmeter
- Metrology: M89175
- Calibration date: 5/7/2012
- Calibration due date: 9/7/2013

The DC resistance from backshell to case shall not exceed 2.5 milliohms.

Alodine 1200S

					Initial	35 days	70 days
Pretreatment	**Panel #**	**Substrate**	**Test**	**Grounding stud A**	**Average**	**Average**	**Average**
Alodine 1200S	Al 50 - 001	5052-H32	Beach	Connector B	1.3850	9.1707	11.9133
				Connector C-1	0.7646	2.7057	5.8193
				Connector C-2	0.8047	1.8770	3.8770
				Grounding stud D	*	0.9985	1.0763
				Connector B	1.0162	7.8450	8.9077
				Connector C-1	0.3181	2.1733	5.2903
				Connector C-2	0.2267	1.6373	3.3480
Alodine 1200S	Al 50 - 002	5052-H32	Beach	Grounding stud A			
				Connector B	1.5985	25.5797	12.1677
				Connector C-1	0.3813	1.0292	1.4343
				Connector C-2	3.3059	9.2367	15.6357
				Grounding stud D	*	0.6016	0.5733
				Connector B	1.6092	30.7220	13.1803
				Connector C-1	0.2960	0.9343	1.3220
				Connector C-2	4.2364	8.0200	15.4633
Alodine 1200S	Al 50 - 003	5052-H32	Stored	Grounding stud A			
				Connector B	0.3341	13.6783	15.2297
				Connector C-1	0.6059	4.3146	6.3560
				Connector C-2	0.6814	1.7453	0.5433
				Grounding stud D	*	0.5544	0.5303
				Connector B	2.9204	8.2047	15.6643
				Connector C-1	0.4795	4.1967	6.2377
				Connector C-2	0.4906	1.5465	0.3440
Alodine 1200S	Al 60 - 001	6061-T6	Beach	Grounding stud A			
				Connector B	1.3479	2.5959	2.9367
				Connector C-1	1.5331	12.1003	26.1203
				Connector C-2	1.6506	5.0783	7.2303
				Grounding stud D	*	2.3748	2.4803
				Connector B	0.2957	0.7789	0.9687
				Connector C-1	0.3907	10.5247	26.4320
				Connector C-2	1.8686	3.1082	4.7690
Alodine 1200S	Al 60 - 002	6061-T6	Beach	Grounding stud A			
				Connector B	0.5995	2.2975	2.6157
				Connector C-1	0.6637	6.4550	8.4940
				Connector C-2	0.7269	1.5479	13.7170
				Grounding stud D	*	0.6631	0.6280
				Connector B	0.5186	2.1763	2.4103
				Connector C-1	0.5291	6.2967	8.8707
				Connector C-2	0.4822	1.4030	11.3977
Alodine 1200S	Al 60 - 003	6061-T6	Stored	Grounding stud A			
				Connector B	1.6031	5.0313	6.1453
				Connector C-1	1.6318	2.5952	3.0223
				Connector C-2	1.6647	2.4727	2.8783
				Grounding stud D	*	2.5019	2.6827
				Connector B	1.0729	3.1671	3.9167
				Connector C-1	0.2995	0.5970	0.7150
				Connector C-2	0.2536	0.3840	0.4877

* Stud to stud following 35 & 70 days of exposure

Metalast TCP-HF

					Initial	35 days	70 days
Pretreatment	**Panel #**	**Substrate**	**Test**	Grounding stud A	**Average**	**Average**	**Average**
Metalas TCP HF	M 50 - 001	5052-H32	Beach	Connector B	0.3483	1.3567	1.5060
				Connector C-1	0.4413	2.2237	4.9350
				Connector C-2	0.5828	49.6600	10.3077
				Grounding stud D	*	0.5089	0.4977
				Connector B	0.3871	1.5457	1.6970
				Connector C-1	0.3924	2.2806	4.3860
				Connector C-2	0.4289	40.5567	10.3363
Metalas TCP HF	M 50 - 002	5052-H32	Beach	Grounding stud A			
				Connector B	0.8284	46.5533	8.3693
				Connector C-1	0.4500	1.8076	4.5067
				Connector C-2	0.6307	27.6097	9.0337
				Grounding stud D	*	0.4081	0.3713
				Connector B	0.9188	44.5733	8.8090
				Connector C-1	0.4418	1.8459	4.4620
				Connector C-2	0.4864	27.0967	10.4153
Metalas TCP HF	M 50 - 003	5052-H32	Stored	Grounding stud A			
				Connector B	0.5303	2.0185	2.7523
				Connector C-1	0.4301	2.0630	2.9727
				Connector C-2	0.7838	2.1023	10.5107
				Grounding stud D	*	0.4326	0.3640
				Connector B	0.5295	2.0912	2.7900
				Connector C-1	0.3803	2.0425	2.8693
				Connector C-2	0.6810	2.2561	8.7147
Metalas TCP HF	M 60 - 001	6061-T6	Beach	Grounding stud A			
				Connector B	0.7258	8.6300	10.6630
				Connector C-1	0.4969	1.9686	2.9063
				Connector C-2	0.8747	13.9233	20.1500
				Grounding stud D	*	0.7406	0.7157
				Connector B	0.5585	9.6533	28.6877
				Connector C-1	0.2441	1.6621	2.6463
				Connector C-2	0.5331	13.7833	14.7650
Metalas TCP HF	M 60 - 002	6061-T6	Beach	Grounding stud A			
				Connector B	0.8105	21.0327	7.2247
				Connector C-1	0.2646	0.7690	1.0213
				Connector C-2	0.4110	4.9454	13.7820
				Grounding stud D	*	0.4094	0.4557
				Connector B	0.8960	33.0300	7.0847
				Connector C-1	0.2317	0.7267	0.9913
				Connector C-2	0.2927	5.0775	13.5780
Metalas TCP HF	M 60 - 003	6061-T6	Stored	Grounding stud A			
				Connector B	0.3150	1.5326	2.1097
				Connector C-1	0.3810	0.8360	1.0197
				Connector C-2	0.4052	0.5893	0.6853
				Grounding stud D	*	0.5180	0.5123
				Connector B	0.3094	1.4808	2.0590
				Connector C-1	0.2618	0.6718	0.8597
				Connector C-2	0.2132	0.3522	0.4537

* Stud to stud following 35 & 70 days of exposure

SurTec 650C

					Initial	35 days	70 days
Pretreatment	**Panel #**	**Substrate**	**Test**	Grounding stud A	**Average**	**Average**	**Average**
SurTec 650C	S 50 - 001	5052-H32	Beach	Connector B	0.4008	3.9539	1.3793
				Connector C-1	0.4337	0.7630	1.3277
				Connector C-2	0.5142	0.9387	8.5413
				Grounding stud D	*	0.7689	0.8010
				Connector B	0.3753	4.5240	1.2000
				Connector C-1	0.2773	1.0486	1.0137
				Connector C-2	0.2581	1.0895	8.0483
SurTec 650C	S 50 - 002	5052-H32	Beach	Grounding stud A			
				Connector B	0.2906	2.2122	3.9237
				Connector C-1	0.2645	0.5232	0.6923
				Connector C-2	0.6140	8.0433	7.6567
				Grounding stud D	*	0.4685	0.4773
				Connector B	0.3810	2.2733	4.0090
				Connector C-1	0.2965	0.5540	0.7257
				Connector C-2	0.5293	41.9433	7.9577
SurTec 650C	S 50 - 003	5052-H32	Stored	Grounding stud A			
				Connector B	0.4195	1.3230	1.7760
				Connector C-1	0.3809	1.5248	2.1040
				Connector C-2	0.4412	0.7743	1.0657
				Grounding stud D	*	0.5866	0.5707
				Connector B	0.5033	1.3935	1.7743
				Connector C-1	0.3756	1.4997	1.9837
				Connector C-2	0.3081	0.6083	0.8013
SurTec 650C	S 60 - 001	6061-T6	Beach	Grounding stud A			
				Connector B	0.1827	0.3417	0.4150
				Connector C-1	0.3265	1.0405	1.1973
				Connector C-2	0.3673	3.4685	7.1750
				Grounding stud D	*	0.4697	0.4090
				Connector B	0.3079	0.4623	0.5267
				Connector C-1	0.3584	1.0674	1.2107
				Connector C-2	0.3365	3.4447	7.1307
SurTec 650C	S 60 - 002	6061-T6	Beach	Grounding stud A			
				Connector B	1.6120	28.8700	8.6787
				Connector C-1	0.3389	1.1426	1.7120
				Connector C-2	0.5253	2.5754	3.2493
				Grounding stud D	*	0.4353	0.4340
				Connector B	1.6663	20.3100	9.1103
				Connector C-1	0.3127	1.0948	1.6773
				Connector C-2	0.4046	2.4533	3.1457
SurTec 650C	S 60 - 003	6061-T6	Stored	Grounding stud A			
				Connector B	0.3300	1.8155	2.2407
				Connector C-1	0.3711	3.7863	7.0543
				Connector C-2	0.9788	10.8320	0.9130
				Grounding stud D	*	0.4000	0.3543
				Connector B	0.4051	1.8937	2.3030
				Connector C-1	0.3573	3.8378	7.0300
				Connector C-2	0.9348	14.4970	1.1140

* Stud to stud following 35 & 70 days of exposure

Appendix B: DC Resistance Data Breakout

Alodine 1200S Beachfront Test Articles – 5052-H32 (35 days)

DC resistance readings from 5052-H32 test panels following 35 days of exposure at the KSC Beachfront

Alodine 1200S

Ground	Connector	Pass	Fail
Stud A	B	0	2
	Hole punched prior to pretreatment		
	CERAN HVA grease used during install		
	C-1	1	1
	Hole punched after pretreatment		
Hole drilled prior to pretreatment	CERAN HVA grease used during install		
	C-2*	1	1
CERAN HVA grease used during install	Hole punched after pretreatment		
	No CERAN HVA grease used during install		
Stud D	B	0	2
	Hole punched prior to pretreatment		
	CERAN HVA grease used during install		
	C-1	2	0
	Hole punched after pretreatment		
Hole punched after pretreatment	CERAN HVA grease used during install		
	C-2*	1	1
No CERAN HVA grease used during install	Hole punched after pretreatment		
	No CERAN HVA grease used during install		

* Failed initial reading on test panel Al 50 - 002

Alodine 1200S Beachfront Test Articles – 5052-H32 (70 days)

DC resistance readings from 5052-H32 test panels following 70 days of exposure at the KSC Beachfront

Alodine 1200S

Ground	Connector	Pass	Fail
Stud A	B	0	2
	Hole punched prior to pretreatment		
	CERAN HVA grease used during install		
	C-1	1	1
	Hole punched after pretreatment		
Hole drilled prior to pretreatment	CERAN HVA grease used during install		
	C-2*	0	2
CERAN HVA grease used during install	Hole punched after pretreatment		
	No CERAN HVA grease used during install		
Stud D	B	0	2
	Hole punched prior to pretreatment		
	CERAN HVA grease used during install		
	C-1	1	1
	Hole punched after pretreatment		
Hole punched after pretreatment	CERAN HVA grease used during install		
	C-2*	0	2
No CERAN HVA grease used during install	Hole punched after pretreatment		
	No CERAN HVA grease used during install		

* Failed initial reading on test panel Al 50 - 002

Alodine 1200S Ambient Office Storage Test Articles – 5052-H32 (35 days)

DC resistance readings from 5052-H32 test panels following 35 days of ambient office storage			
Alodine 1200S			
Ground	**Connector**	**Pass**	**Fail**
Stud A	B Hole punched prior to pretreatment CERAN HVA grease used during install	0	1
	C-1 Hole punched after pretreatment CERAN HVA grease used during install	0	1
Hole drilled prior to pretreatment CERAN HVA grease used during install	C-2 Hole punched after pretreatment No CERAN HVA grease used during install	1	0
Stud D	B* Hole punched prior to pretreatment CERAN HVA grease used during install	0	1
	C-1 Hole punched after pretreatment CERAN HVA grease used during install	0	1
Hole punched after pretreatment No CERAN HVA grease used during install	C-2 Hole punched after pretreatment No CERAN HVA grease used during install	1	0

* Failed initial reading on test panel Al 50 - 003

Alodine 1200S Ambient Office Storage Test Articles – 5052-H32 (70 days)

DC resistance readings from 5052-H32 test panels following 70 days of ambient office storage			
Alodine 1200S			
Ground	**Connector**	**Pass**	**Fail**
Stud A	B	0	1
	Hole punched prior to pretreatment		
	CERAN HVA grease used during install		
	C-1	0	1
	Hole punched after pretreatment		
Hole drilled prior to pretreatment	CERAN HVA grease used during install		
	C-2	1	0
CERAN HVA grease used during install	Hole punched after pretreatment		
	No CERAN HVA grease used during install		
Stud D	B*	0	1
	Hole punched prior to pretreatment		
	CERAN HVA grease used during install		
	C-1	0	1
	Hole punched after pretreatment		
Hole punched after pretreatment	CERAN HVA grease used during install		
	C-2	1	0
No CERAN HVA grease used during install	Hole punched after pretreatment		
	No CERAN HVA grease used during install		

* Failed initial reading on test panel Al 50 - 003

Alodine 1200S Beachfront Test Articles – 6061-T6 (35 days)

DC resistance readings from 6061-T6 test panels following 35 days of exposure at the KSC Beachfront			
Alodine 1200S			
Ground	**Connector**	**Pass**	**Fail**
Stud A	B	1	1
	Hole punched prior to pretreatment		
	CERAN HVA grease used during install		
	C-1	0	2
Hole drilled prior to pretreatment	Hole punched after pretreatment		
	CERAN HVA grease used during install		
	C-2	1	1
CERAN HVA grease used during install	Hole punched after pretreatment		
	No CERAN HVA grease used during install		
Stud D	B	2	0
	Hole punched prior to pretreatment		
	CERAN HVA grease used during install		
	C-1	0	2
Hole punched after pretreatment	Hole punched after pretreatment		
	CERAN HVA grease used during install		
	C-2	1	1
No CERAN HVA grease used during install	Hole punched after pretreatment		
	No CERAN HVA grease used during install		

Alodine 1200S Beachfront Test Articles – 6061-T6 (70 days)

DC resistance readings from 6061-T6 test panels following 70 days of exposure at the KSC Beachfront			
Alodine 1200S			
Ground	**Connector**	**Pass**	**Fail**
Stud A	B	0	2
	Hole punched prior to pretreatment		
	CERAN HVA grease used during install		
	C-1	0	2
	Hole punched after pretreatment		
Hole drilled prior to pretreatment	CERAN HVA grease used during install		
	C-2	0	2
CERAN HVA grease used during install	Hole punched after pretreatment		
	No CERAN HVA grease used during install		
Stud D	B	2	0
	Hole punched prior to pretreatment		
	CERAN HVA grease used during install		
	C-1	0	2
	Hole punched after pretreatment		
Hole punched after pretreatment	CERAN HVA grease used during install		
	C-2	0	2
No CERAN HVA grease used during install	Hole punched after pretreatment		
	No CERAN HVA grease used during install		

Alodine 1200S Ambient Office Storage Test Articles – 6061-T6 (35 days)

DC resistance readings from 6061-T6 test panels following 35 days of ambient office storage			
Alodine 1200S			
Ground	**Connector**	**Pass**	**Fail**
Stud A	B Hole punched prior to pretreatment CERAN HVA grease used during install	0	1
	C-1 Hole punched after pretreatment CERAN HVA grease used during install	0	1
Hole drilled prior to pretreatment	C-2 Hole punched after pretreatment No CERAN HVA grease used during install	1	0
CERAN HVA grease used during install			
Stud D	B Hole punched prior to pretreatment CERAN HVA grease used during install	0	1
	C-1 Hole punched after pretreatment CERAN HVA grease used during install	1	0
Hole punched after pretreatment	C-2 Hole punched after pretreatment No CERAN HVA grease used during install	1	0
No CERAN HVA grease used during install			

Alodine 1200S Ambient Office Storage Test Articles – 6061-T6 (70 days)

DC resistance readings from 6061-T6 test panels following 70 days of ambient office storage			
Alodine 1200S			
Ground	**Connector**	**Pass**	**Fail**
Stud A	B Hole punched prior to pretreatment CERAN HVA grease used during install	0	1
Hole drilled prior to pretreatment	C-1 Hole punched after pretreatment CERAN HVA grease used during install	0	1
CERAN HVA grease used during install	C-2 Hole punched after pretreatment No CERAN HVA grease used during install	0	1
Stud D	B Hole punched prior to pretreatment CERAN HVA grease used during install	0	1
Hole punched after pretreatment	C-1 Hole punched after pretreatment CERAN HVA grease used during install	1	0
No CERAN HVA grease used during install	C-2 Hole punched after pretreatment No CERAN HVA grease used during install	1	0

Metalast TCP HF Beachfront Test Articles – 5052-H32 (35 days)

DC resistance readings from 5052-H32 test panels following 35 days of exposure at the KSC Beachfront			
Metalast TCP HF			
Ground	**Connector**	**Pass**	**Fail**
Stud A	B	1	1
	Hole punched prior to pretreatment		
	CERAN HVA grease used during install		
	C-1	2	0
	Hole punched after pretreatment		
Hole drilled prior to pretreatment	CERAN HVA grease used during install		
	C-2	0	2
CERAN HVA grease used during install	Hole punched after pretreatment		
	No CERAN HVA grease used during install		
Stud D	B	1	1
	Hole punched prior to pretreatment		
	CERAN HVA grease used during install		
	C-1	2	0
	Hole punched after pretreatment		
Hole punched after pretreatment	CERAN HVA grease used during install		
	C-2	0	2
No CERAN HVA grease used during install	Hole punched after pretreatment		
	No CERAN HVA grease used during install		

Metalast TCP HF Beachfront Test Articles – 5052-H32 (70 days)

DC resistance readings from 5052-H32 test panels following 70 days of exposure at the KSC Beachfront			
Metalast TCP HF			
Ground	**Connector**	**Pass**	**Fail**
Stud A	B Hole punched prior to pretreatment CERAN HVA grease used during install	1	1
Hole drilled prior to pretreatment	C-1 Hole punched after pretreatment CERAN HVA grease used during install	0	2
CERAN HVA grease used during install	C-2 Hole punched after pretreatment No CERAN HVA grease used during install	0	2
Stud D	B Hole punched prior to pretreatment CERAN HVA grease used during install	1	1
Hole punched after pretreatment	C-1 Hole punched after pretreatment CERAN HVA grease used during install	0	2
No CERAN HVA grease used during install	C-2 Hole punched after pretreatment No CERAN HVA grease used during install	0	2

Metalast TCP HF Ambient Office Storage Test Articles – 5052-H32 (35 days)

DC resistance readings from 5052-H32 test panels following 35 days of ambient office storage			
Metalast TCP HF			
Ground	**Connector**	**Pass**	**Fail**
Stud A	B	1	0
	Hole punched prior to pretreatment		
	CERAN HVA grease used during install		
	C-1	1	0
	Hole punched after pretreatment		
Hole drilled prior to pretreatment	CERAN HVA grease used during install		
	C-2	1	0
CERAN HVA grease used during install	Hole punched after pretreatment		
	No CERAN HVA grease used during install		
Stud D	B	1	0
	Hole punched prior to pretreatment		
	CERAN HVA grease used during install		
	C-1	1	0
	Hole punched after pretreatment		
Hole punched after pretreatment	CERAN HVA grease used during install		
	C-2	1	0
No CERAN HVA grease used during install	Hole punched after pretreatment		
	No CERAN HVA grease used during install		

Metalast TCP HF Ambient Office Storage Test Articles – 5052-H32 (70 days)

DC resistance readings from 5052-H32 test panels following 70 days of ambient office storage			
Metalast TCP HF			
Ground	**Connector**	**Pass**	**Fail**
Stud A	B Hole punched prior to pretreatment CERAN HVA grease used during install	0	1
Hole drilled prior to pretreatment	C-1 Hole punched after pretreatment CERAN HVA grease used during install	0	1
CERAN HVA grease used during install	C-2 Hole punched after pretreatment No CERAN HVA grease used during install	0	1
Stud D	B Hole punched prior to pretreatment CERAN HVA grease used during install	0	1
Hole punched after pretreatment	C-1 Hole punched after pretreatment CERAN HVA grease used during install	0	1
No CERAN HVA grease used during install	C-2 Hole punched after pretreatment No CERAN HVA grease used during install	0	1

Metalast TCP HF Beachfront Test Articles – 6061-T6 (35 days)

DC resistance readings from 6061-T6 test panels following 35 days of exposure at the KSC Beachfront			
Metalast TCP HF			
Ground	**Connector**	**Pass**	**Fail**
Stud A	B	0	2
	Hole punched prior to pretreatment		
	CERAN HVA grease used during install		
	C-1	2	0
Hole drilled prior to pretreatment	Hole punched after pretreatment		
	CERAN HVA grease used during install		
	C-2	0	2
CERAN HVA grease used during install	Hole punched after pretreatment		
	No CERAN HVA grease used during install		
Stud D	B	0	2
	Hole punched prior to pretreatment		
	CERAN HVA grease used during install		
	C-1	2	0
Hole punched after pretreatment	Hole punched after pretreatment		
	CERAN HVA grease used during install		
	C-2	0	2
No CERAN HVA grease used during install	Hole punched after pretreatment		
	No CERAN HVA grease used during install		

Metalast TCP HF Beachfront Test Articles – 6061-T6 (70 days)

DC resistance readings from 6061-T6 test panels following 70 days of exposure at the KSC Beachfront			
Metalast TCP HF			
Ground	**Connector**	**Pass**	**Fail**
Stud A	B	0	2
	Hole punched prior to pretreatment		
	CERAN HVA grease used during install		
	C-1	1	1
	Hole punched after pretreatment		
Hole drilled prior to pretreatment	CERAN HVA grease used during install		
	C-2	0	2
CERAN HVA grease used during install	Hole punched after pretreatment		
	No CERAN HVA grease used during install		
Stud D	B	0	2
	Hole punched prior to pretreatment		
	CERAN HVA grease used during install		
	C-1	1	1
	Hole punched after pretreatment		
Hole punched after pretreatment	CERAN HVA grease used during install		
	C-2	0	2
No CERAN HVA grease used during install	Hole punched after pretreatment		
	No CERAN HVA grease used during install		

Metalast TCP HF Ambient Office Storage Test Articles – 6061-T6 (35 days)

DC resistance readings from 6061-T6 test panels following 35 days of ambient office storage			
Metalast TCP HF			
Ground	**Connector**	**Pass**	**Fail**
Stud A	B	1	0
	Hole punched prior to pretreatment		
	CERAN HVA grease used during install		
	C-1	1	0
	Hole punched after pretreatment		
Hole drilled prior to pretreatment	CERAN HVA grease used during install		
	C-2	1	0
CERAN HVA grease used during install	Hole punched after pretreatment		
	No CERAN HVA grease used during install		
Stud D	B	1	0
	Hole punched prior to pretreatment		
	CERAN HVA grease used during install		
	C-1	1	0
	Hole punched after pretreatment		
Hole punched after pretreatment	CERAN HVA grease used during install		
	C-2	1	0
No CERAN HVA grease used during install	Hole punched after pretreatment		
	No CERAN HVA grease used during install		

Metalast TCP HF Ambient Office Storage Test Articles – 6061-T6 (70 days)

DC resistance readings from 6061-T6 test panels following 70 days of ambient office storage			
Metalast TCP HF			
Ground	**Connector**	**Pass**	**Fail**
Stud A	B	1	0
	Hole punched prior to pretreatment		
	CERAN HVA grease used during install		
	C-1	1	0
	Hole punched after pretreatment		
Hole drilled prior to pretreatment	CERAN HVA grease used during install		
	C-2	1	0
CERAN HVA grease used during install	Hole punched after pretreatment		
	No CERAN HVA grease used during install		
Stud D	B	1	0
	Hole punched prior to pretreatment		
	CERAN HVA grease used during install		
	C-1	1	0
	Hole punched after pretreatment		
Hole punched after pretreatment	CERAN HVA grease used during install		
	C-2	1	0
No CERAN HVA grease used during install	Hole punched after pretreatment		
	No CERAN HVA grease used during install		

SurTec 650C Beachfront Test Articles – 5052-H32 (35 days)

DC resistance readings from 5052-H32 test panels following 35 days of exposure at the KSC Beachfront			
SurTec 650C			
Ground	**Connector**	**Pass**	**Fail**
Stud A	B	1	1
	Hole punched prior to pretreatment		
	CERAN HVA grease used during install		
	C-1	2	0
	Hole punched after pretreatment		
Hole drilled prior to pretreatment	CERAN HVA grease used during install		
	C-2	1	1
CERAN HVA grease used during install	Hole punched after pretreatment		
	No CERAN HVA grease used during install		
Stud D	B	1	1
	Hole punched prior to pretreatment		
	CERAN HVA grease used during install		
	C-1	2	0
	Hole punched after pretreatment		
Hole punched after pretreatment	CERAN HVA grease used during install		
	C-2	1	1
No CERAN HVA grease used during install	Hole punched after pretreatment		
	No CERAN HVA grease used during install		

SurTec 650C Beachfront Test Articles – 5052-H32 (70 days)

DC resistance readings from 5052-H32 test panels following 70 days of exposure at the KSC Beachfront			
SurTec 650C			
Ground	**Connector**	**Pass**	**Fail**
Stud A	B	1	1
	Hole punched prior to pretreatment		
	CERAN HVA grease used during install		
	C-1	2	0
	Hole punched after pretreatment		
Hole drilled prior to pretreatment	CERAN HVA grease used during install		
	C-2	0	2
CERAN HVA grease used during install	Hole punched after pretreatment		
	No CERAN HVA grease used during install		
Stud D	B	1	1
	Hole punched prior to pretreatment		
	CERAN HVA grease used during install		
	C-1	2	0
	Hole punched after pretreatment		
Hole punched after pretreatment	CERAN HVA grease used during install		
	C-2	0	2
No CERAN HVA grease used during install	Hole punched after pretreatment		
	No CERAN HVA grease used during install		

SurTec 650C Ambient Office Storage Test Articles – 5052-H32 (35 days)

DC resistance readings from 5052-H32 test panels following 35 days of ambient office storage			
SurTec 650C			
Ground	**Connector**	**Pass**	**Fail**
Stud A	B Hole punched prior to pretreatment CERAN HVA grease used during install	1	0
	C-1 Hole punched after pretreatment CERAN HVA grease used during install	1	0
Hole drilled prior to pretreatment			
	C-2 Hole punched after pretreatment No CERAN HVA grease used during install	1	0
CERAN HVA grease used during install			
Stud D	B Hole punched prior to pretreatment CERAN HVA grease used during install	1	0
	C-1 Hole punched after pretreatment CERAN HVA grease used during install	1	0
Hole punched after pretreatment			
	C-2 Hole punched after pretreatment No CERAN HVA grease used during install	1	0
No CERAN HVA grease used during install			

SurTec 650C Ambient Office Storage Test Articles – 5052-H32 (70 days)

DC resistance readings from 5052-H32 test panels following 70 days of ambient office storage			
SurTec 650C			
Ground	**Connector**	**Pass**	**Fail**
Stud A	B	1	0
	Hole punched prior to pretreatment		
	CERAN HVA grease used during install		
	C-1	1	0
	Hole punched after pretreatment		
Hole drilled prior to pretreatment	CERAN HVA grease used during install		
	C-2	1	0
CERAN HVA grease used during install	Hole punched after pretreatment		
	No CERAN HVA grease used during install		
Stud D	B	1	0
	Hole punched prior to pretreatment		
	CERAN HVA grease used during install		
	C-1	1	0
	Hole punched after pretreatment		
Hole punched after pretreatment	CERAN HVA grease used during install		
	C-2	1	0
No CERAN HVA grease used during install	Hole punched after pretreatment		
	No CERAN HVA grease used during install		

SurTec 650C Beachfront Test Articles – 6061-T6 (35 days)

DC resistance readings from 6061-T6 test panels following 35 days of exposure at the KSC Beachfront			
SurTec 650C			
Ground	**Connector**	**Pass**	**Fail**
Stud A	B	1	1
	Hole punched prior to pretreatment		
	CERAN HVA grease used during install		
	C-1	2	0
	Hole punched after pretreatment		
Hole drilled prior to pretreatment	CERAN HVA grease used during install		
	C-2	0	2
	Hole punched after pretreatment		
CERAN HVA grease used during install	No CERAN HVA grease used during install		
Stud D	B	1	1
	Hole punched prior to pretreatment		
	CERAN HVA grease used during install		
	C-1	2	0
	Hole punched after pretreatment		
Hole punched after pretreatment	CERAN HVA grease used during install		
	C-2	1	1
	Hole punched after pretreatment		
No CERAN HVA grease used during install	No CERAN HVA grease used during install		

SurTec 650C Beachfront Test Articles – 6061-T6 (70 days)

DC resistance readings from 6061-T6 test panels following 70 days of exposure at the KSC Beachfront			
SurTec 650C			
Ground	**Connector**	**Pass**	**Fail**
Stud A	B	1	1
	Hole punched prior to pretreatment		
	CERAN HVA grease used during install		
	C-1	2	0
	Hole punched after pretreatment		
Hole drilled prior to pretreatment	CERAN HVA grease used during install		
	C-2	0	2
CERAN HVA grease used during install	Hole punched after pretreatment		
	No CERAN HVA grease used during install		
Stud D	B	1	1
	Hole punched prior to pretreatment		
	CERAN HVA grease used during install		
	C-1	2	0
	Hole punched after pretreatment		
Hole punched after pretreatment	CERAN HVA grease used during install		
	C-2	0	2
No CERAN HVA grease used during install	Hole punched after pretreatment		
	No CERAN HVA grease used during install		

SurTec 650C Ambient Office Storage Test Articles – 6061-T6 (35 days)

DC resistance readings from 6061-T6 test panels following 35 days of ambient office storage			
SurTec 650C			
Ground	**Connector**	**Pass**	**Fail**
Stud A	B	1	0
	Hole punched prior to pretreatment		
	CERAN HVA grease used during install		
	C-1	0	1
	Hole punched after pretreatment		
Hole drilled prior to pretreatment	CERAN HVA grease used during install		
	C-2	0	1
CERAN HVA grease used during install	Hole punched after pretreatment		
	No CERAN HVA grease used during install		
Stud D	B	1	0
	Hole punched prior to pretreatment		
	CERAN HVA grease used during install		
	C-1	0	1
	Hole punched after pretreatment		
Hole punched after pretreatment	CERAN HVA grease used during install		
	C-2	0	1
No CERAN HVA grease used during install	Hole punched after pretreatment		
	No CERAN HVA grease used during install		

SurTec 650C Ambient Office Storage Test Articles – 6061-T6 (70 days)

DC resistance readings from 6061-T6 test panels following 70 days of ambient office storage			
SurTec 650C			
Ground	**Connector**	**Pass**	**Fail**
Stud A	B Hole punched prior to pretreatment CERAN HVA grease used during install	1	0
Hole drilled prior to pretreatment	C-1 Hole punched after pretreatment CERAN HVA grease used during install	0	1
CERAN HVA grease used during install	C-2 Hole punched after pretreatment No CERAN HVA grease used during install	1	0
Stud D	B Hole punched prior to pretreatment CERAN HVA grease used during install	1	0
Hole punched after pretreatment	C-1 Hole punched after pretreatment CERAN HVA grease used during install	0	1
No CERAN HVA grease used during install	C-2 Hole punched after pretreatment No CERAN HVA grease used during install	1	0

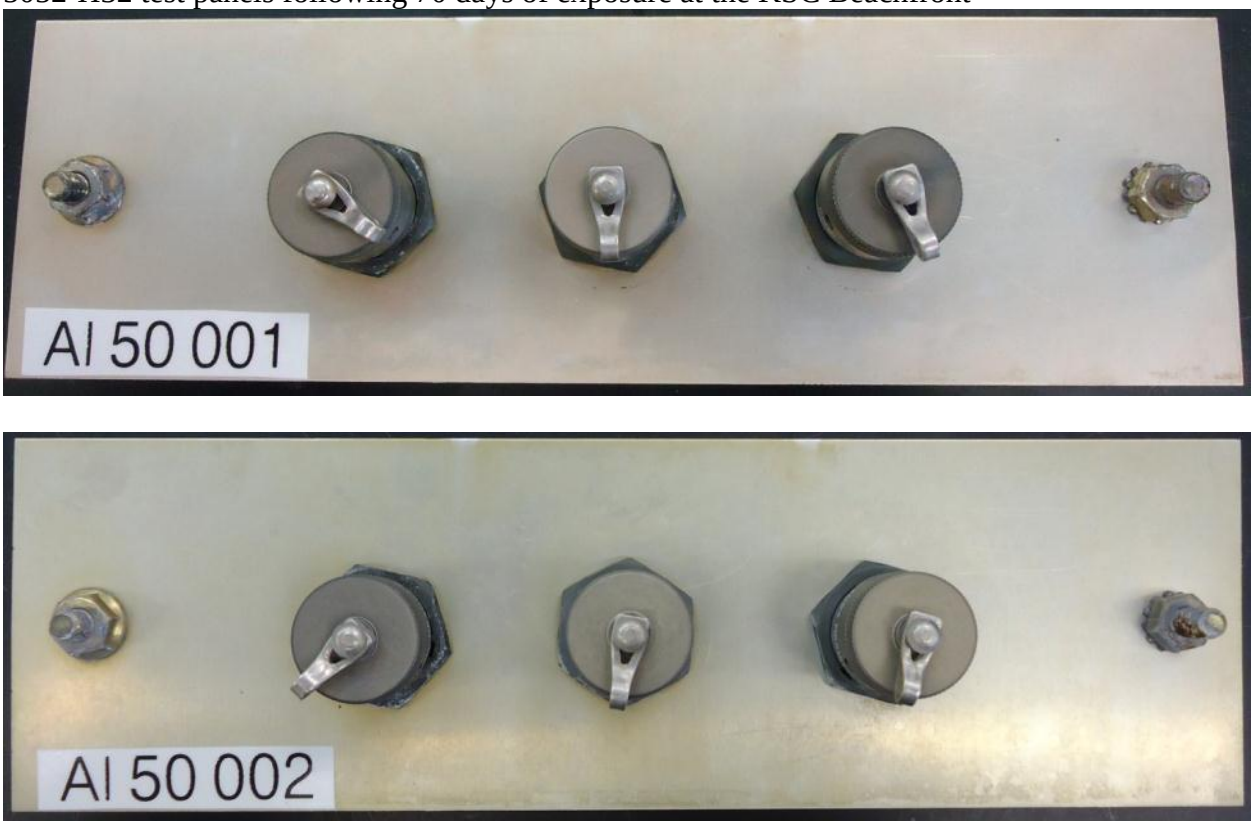
Appendix C: Test Article Pictures

Alodine 1200S

5052-H32 test panels following 35 days of exposure at the KSC Beachfront

5052-H32 test panels following 35 days of ambient office storage

5052-H32 test panels following 70 days of exposure at the KSC Beachfront

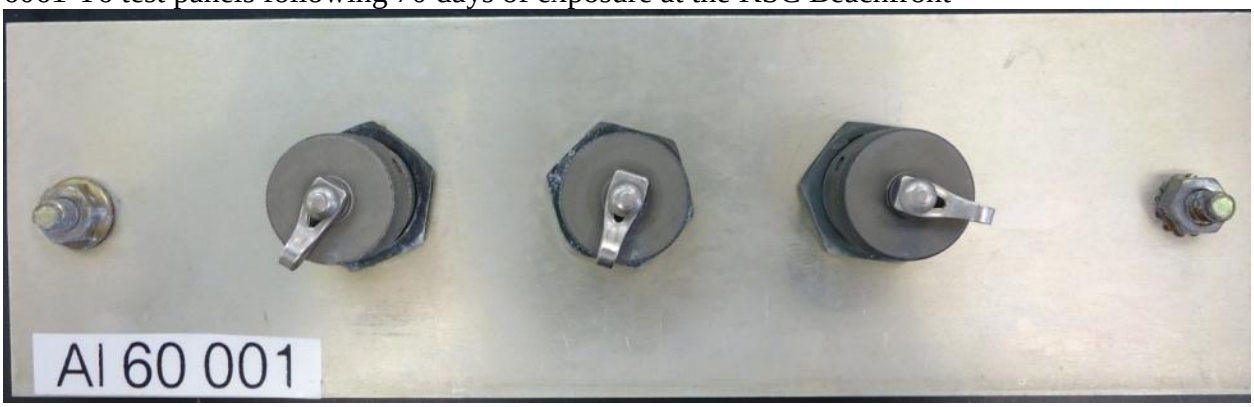


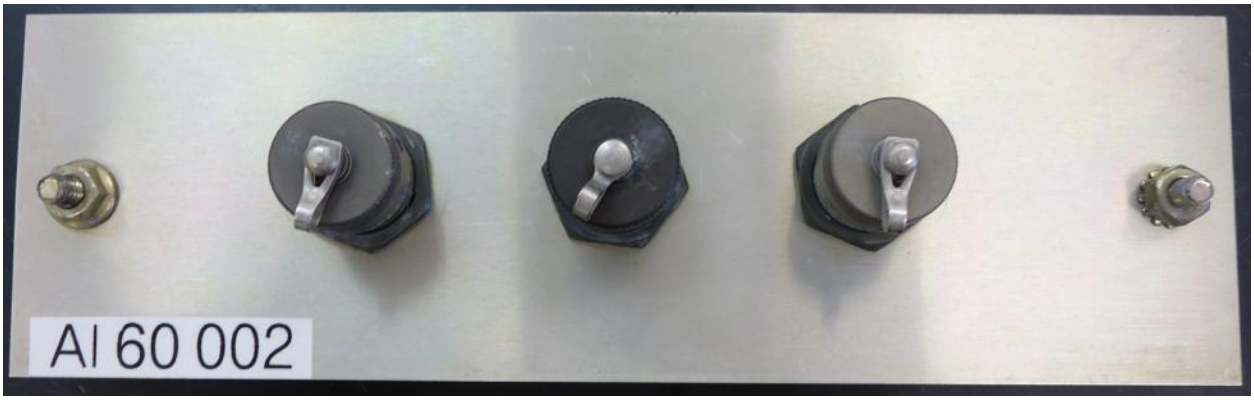
5052-H32 test panels following 70 days of ambient office storage

6061-T6 test panels following 35 days of exposure at the KSC Beachfront

6061-T6 test panels following 35 days of ambient office storage

6061-T6 test panels following 70 days of exposure at the KSC Beachfront

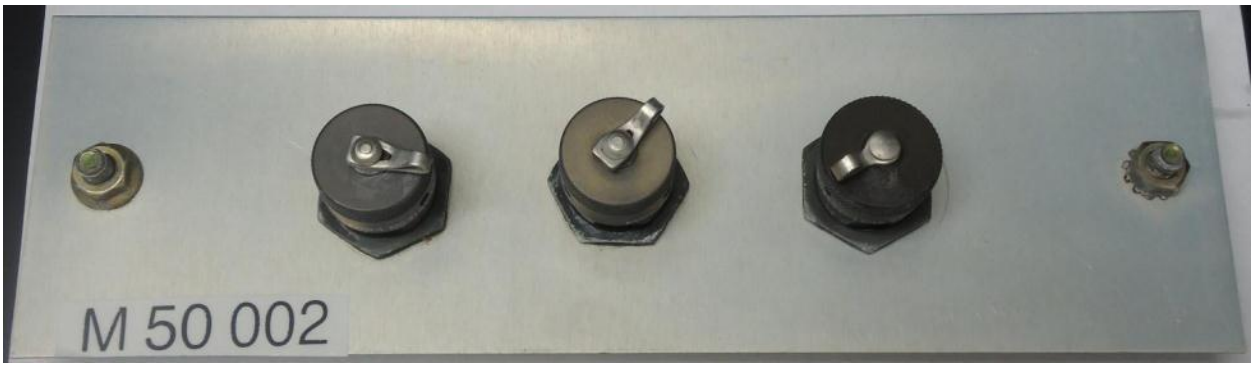




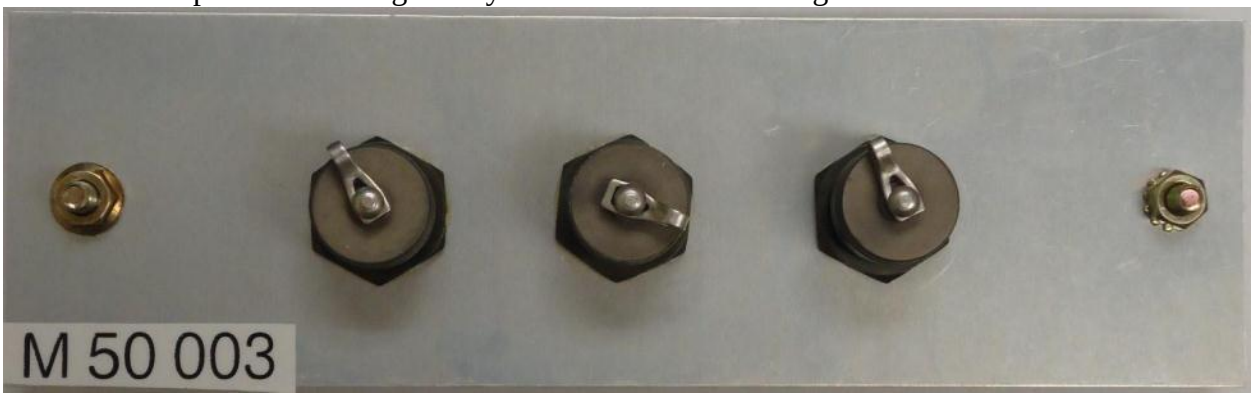
6061-T6 test panels following 70 days of ambient office storage

Metalast TCP HF

5052-H32 test panels following 35 days of exposure at the KSC Beachfront



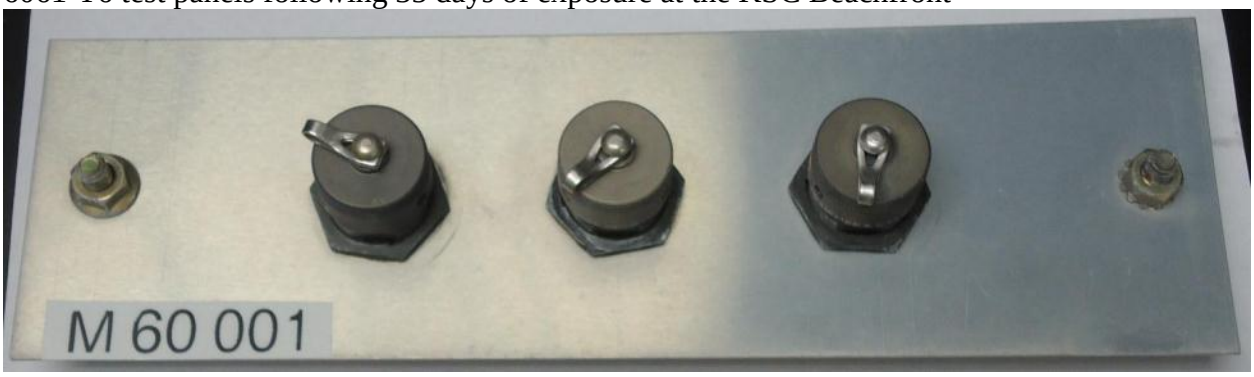
5052-H32 test panels following 35 days of ambient office storage

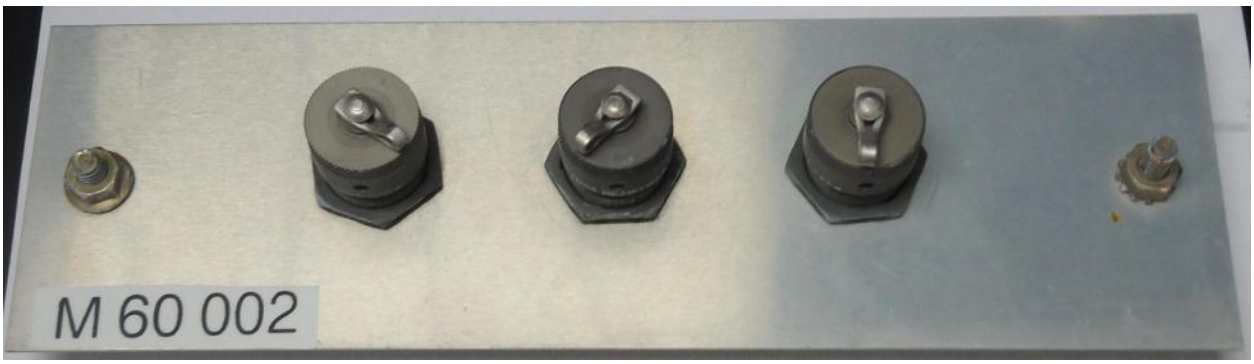


5052-H32 test panels following 70 days of exposure at the KSC Beachfront

5052-H32 test panels following 70 days of ambient office storage

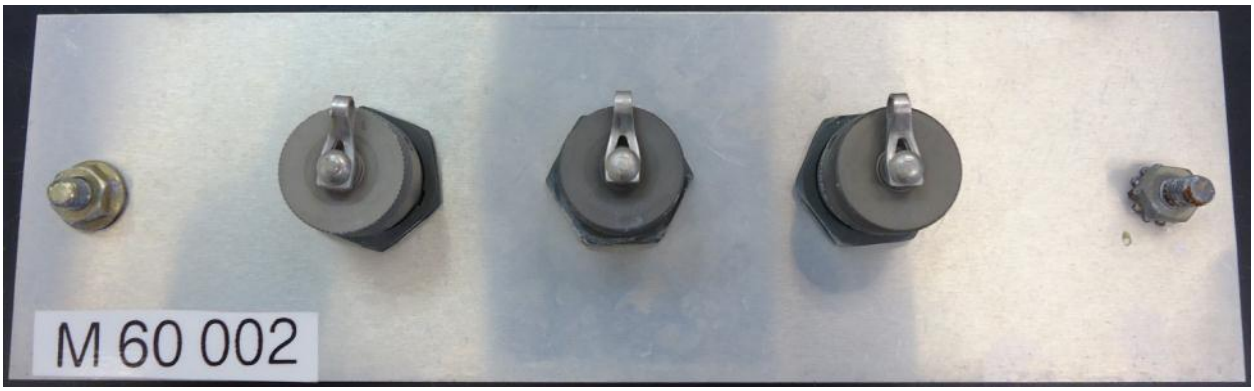
6061-T6 test panels following 35 days of exposure at the KSC Beachfront





6061-T6 test panels following 35 days of ambient office storage

6061-T6 test panels following 70 days of exposure at the KSC Beachfront



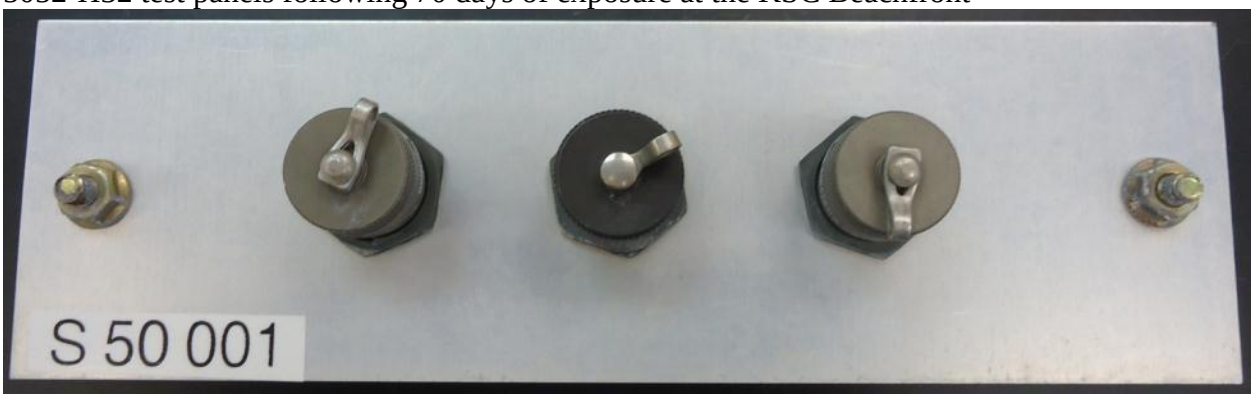
6061-T6 test panels following 70 days of ambient office storage

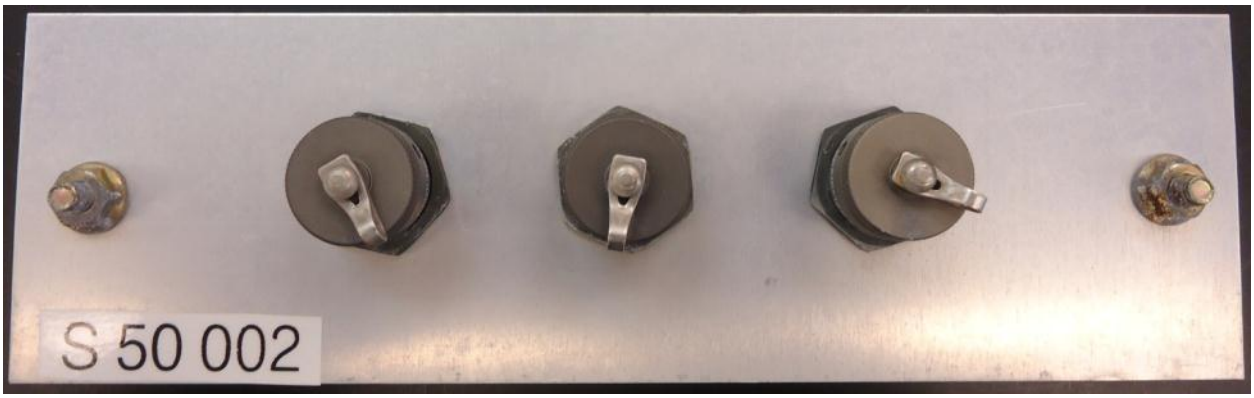
SurTec 650C

5052-H32 test panels following 35 days of exposure at the KSC Beachfront

5052-H32 test panels following 35 days of ambient office storage

5052-H32 test panels following 70 days of exposure at the KSC Beachfront



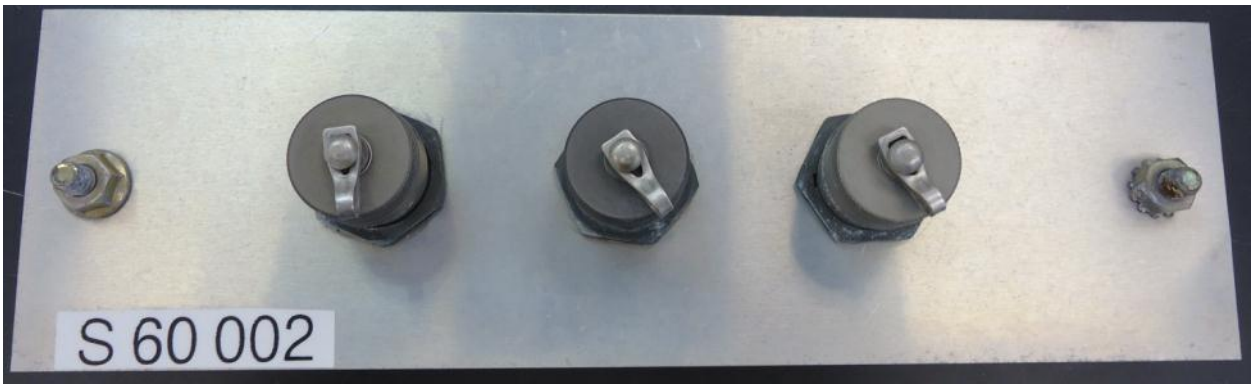


5052-H32 test panels following 70 days of ambient office storage

6061-T6 test panels following 35 days of exposure at the KSC Beachfront

6061-T6 test panels following 35 days of ambient office storage

6061-T6 test panels following 70 days of exposure at the KSC Beachfront

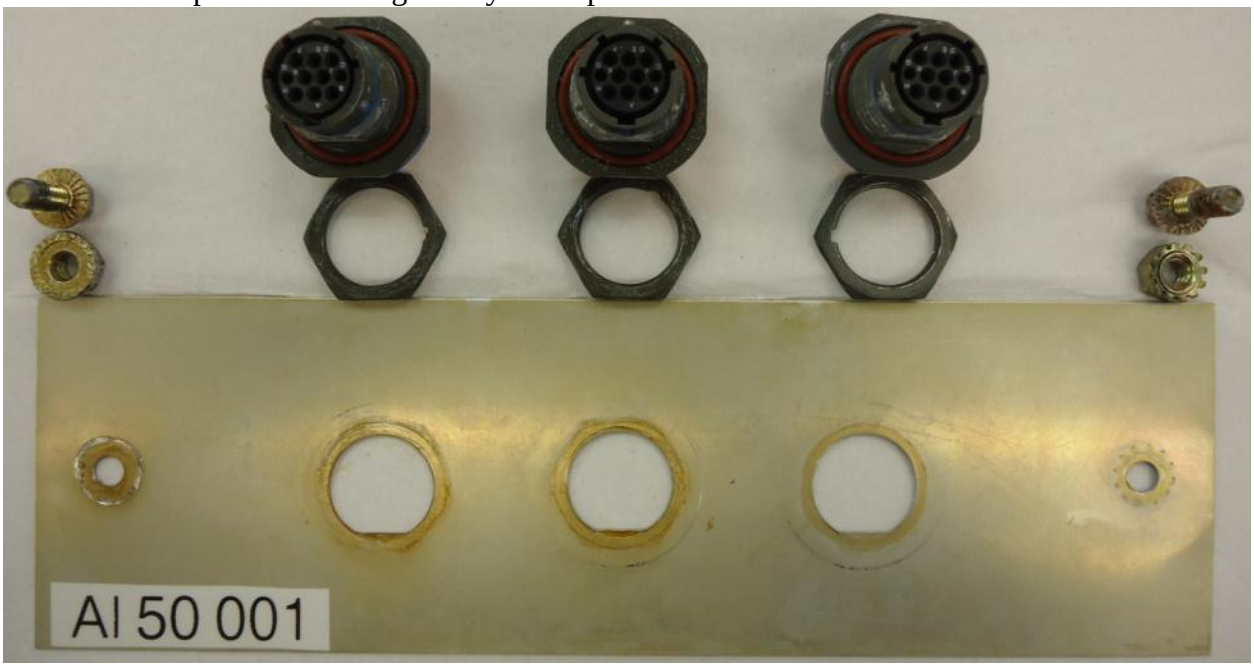


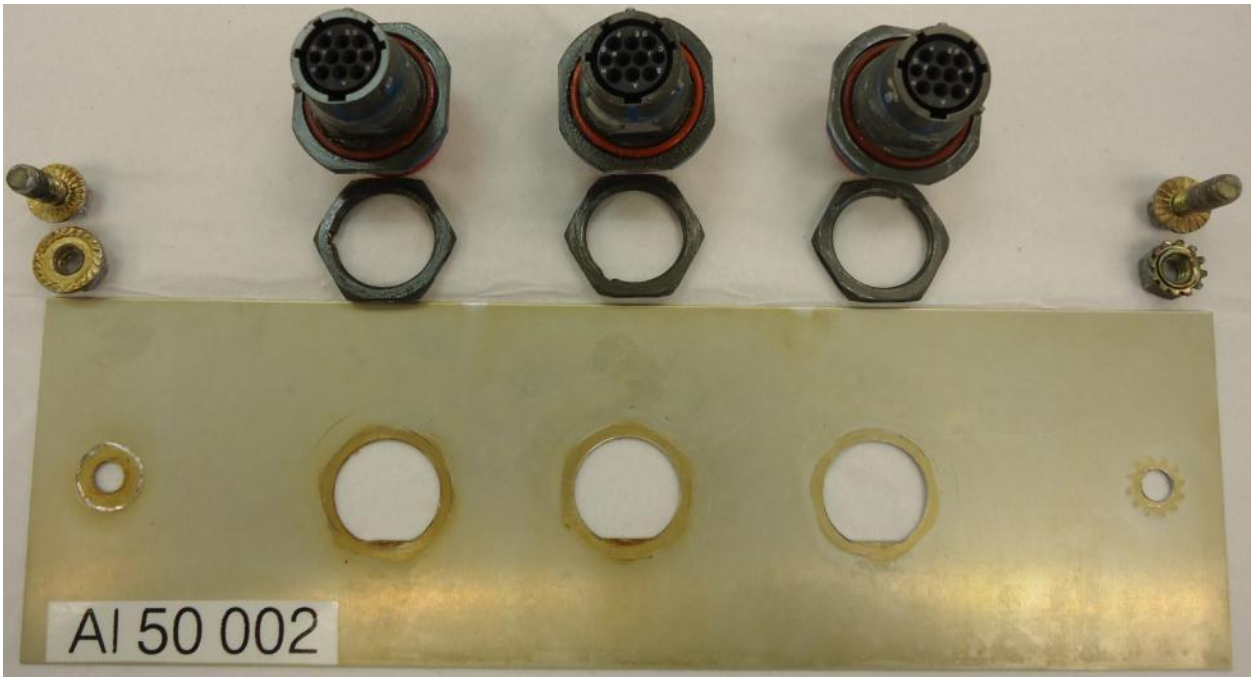
6061-T6 test panels following 70 days of ambient office storage

Appendix D: Test Vehicle Disassembly

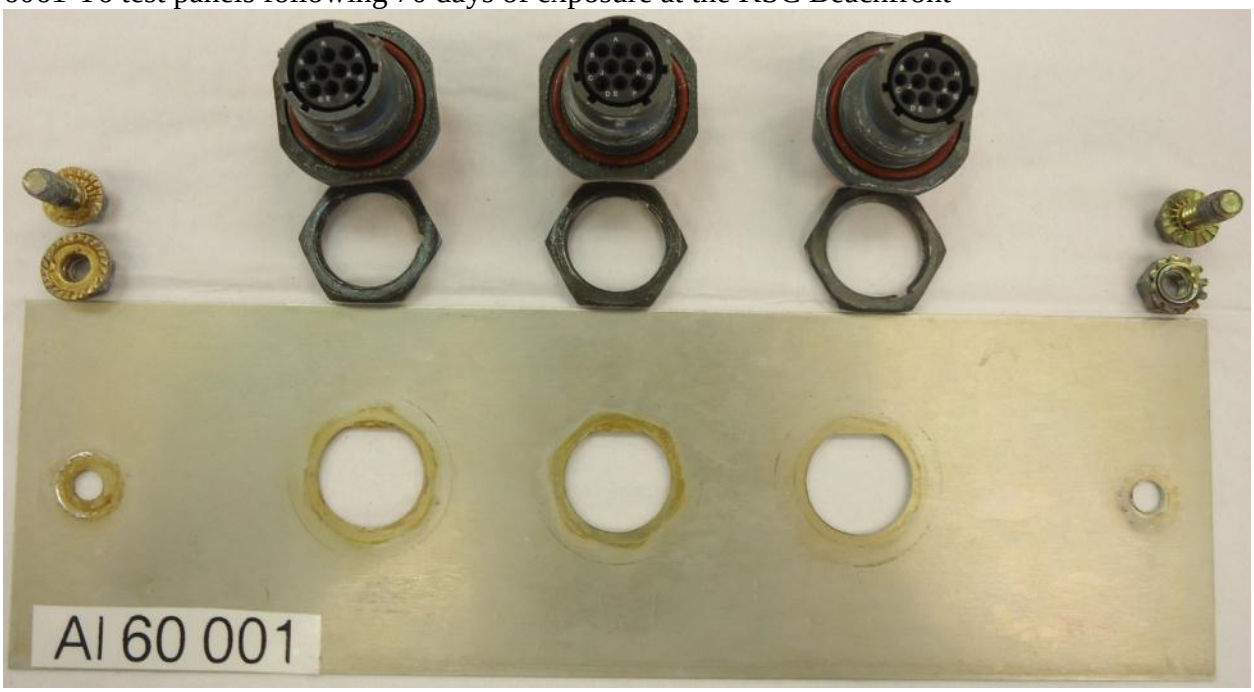
Alodine 1200S

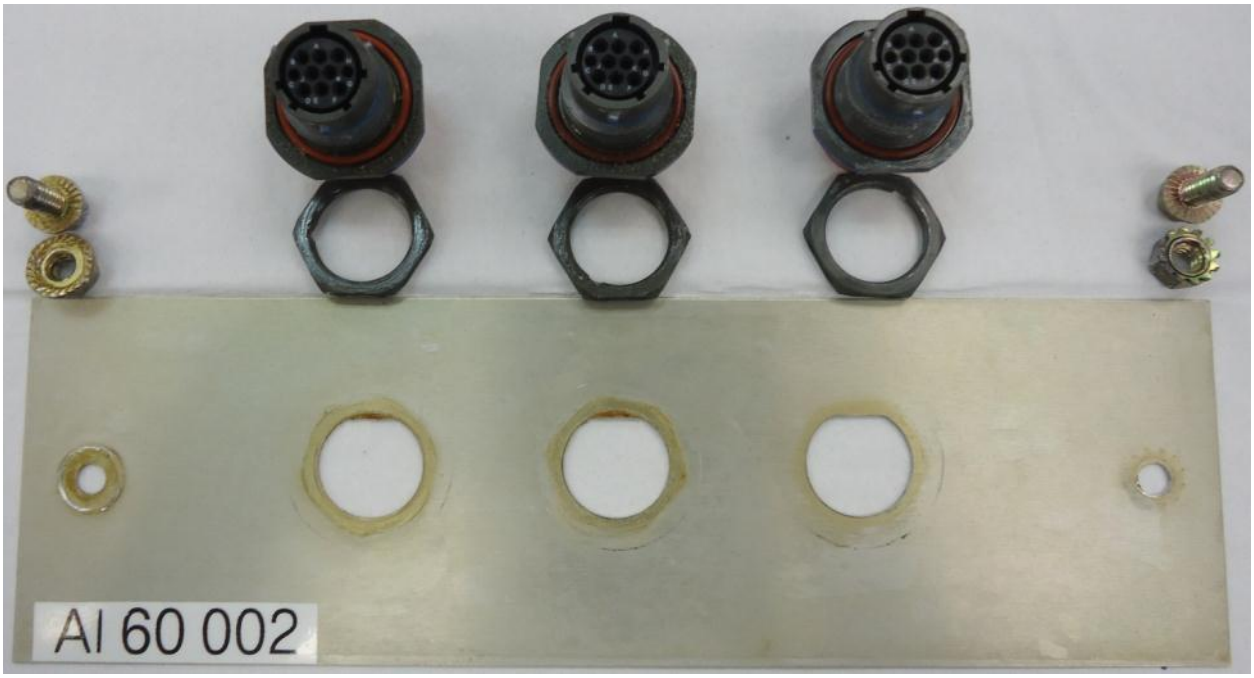
5052-H32 test panels following 70 days of exposure at the KSC Beachfront





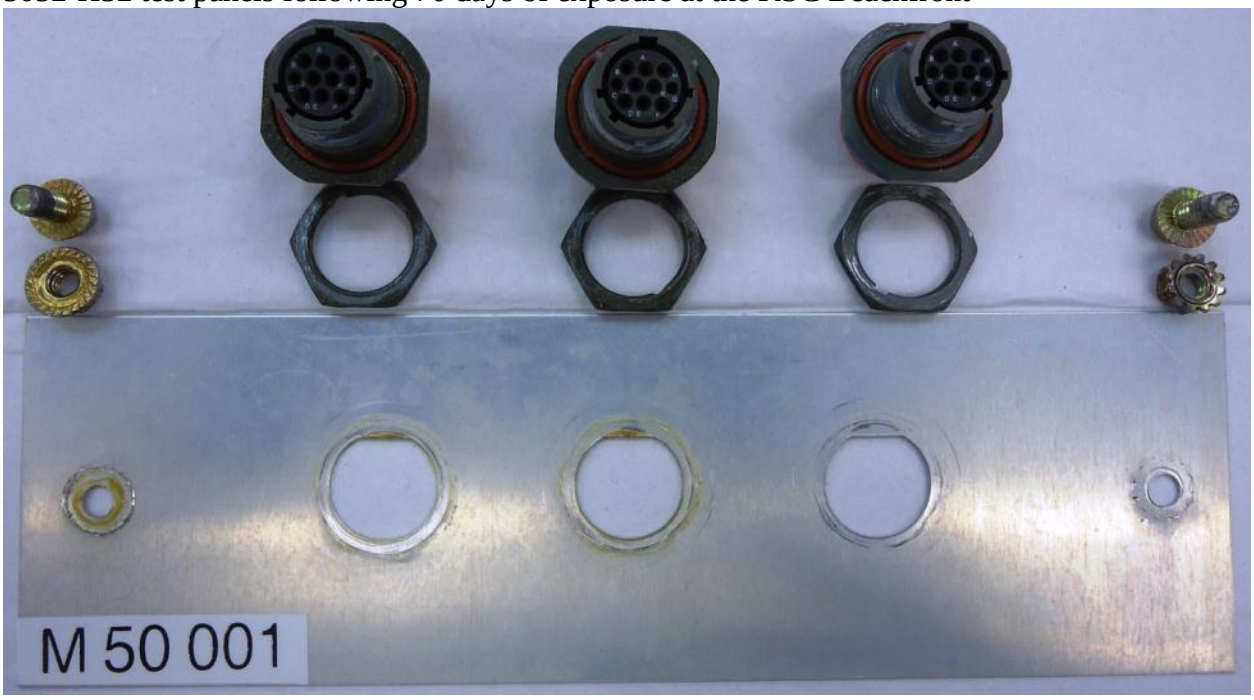
6061-T6 test panels following 70 days of exposure at the KSC Beachfront

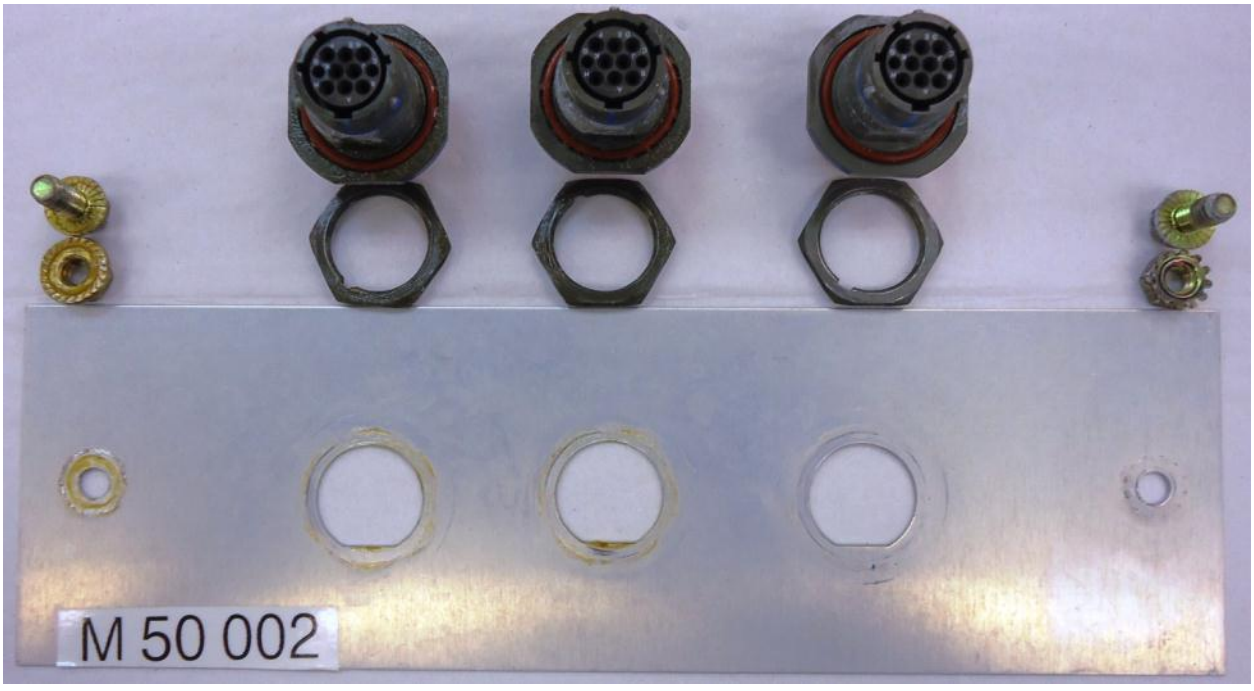




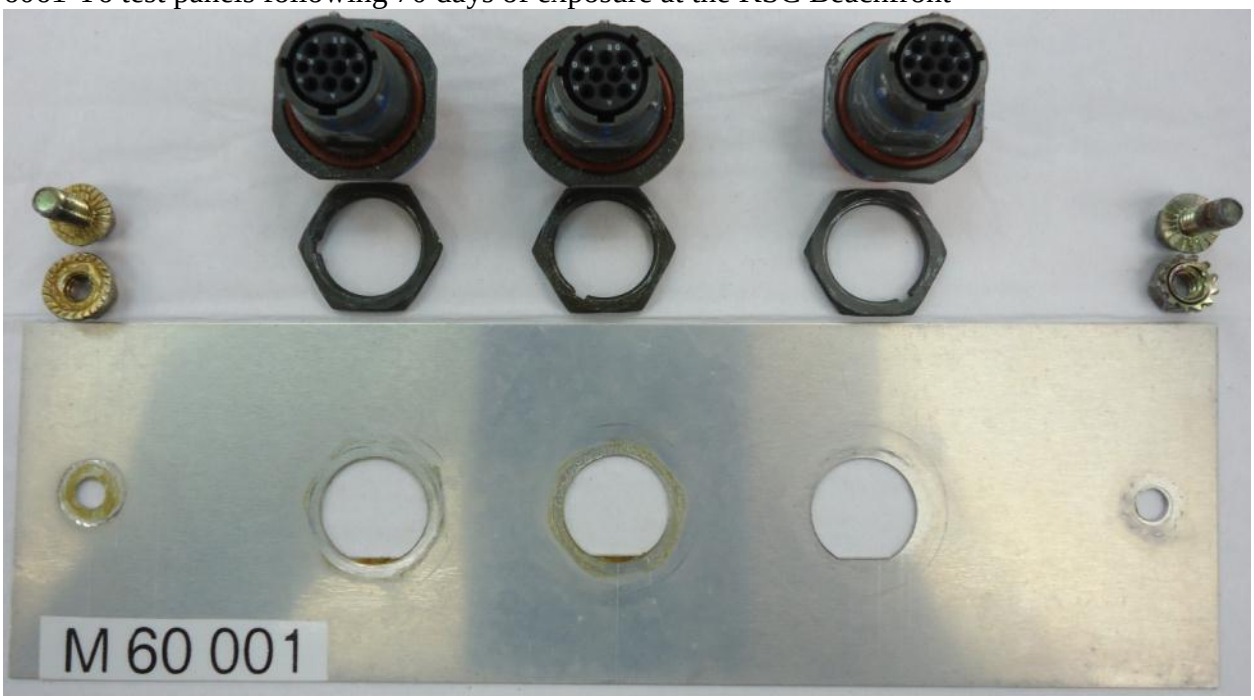
Metalast TCP HF

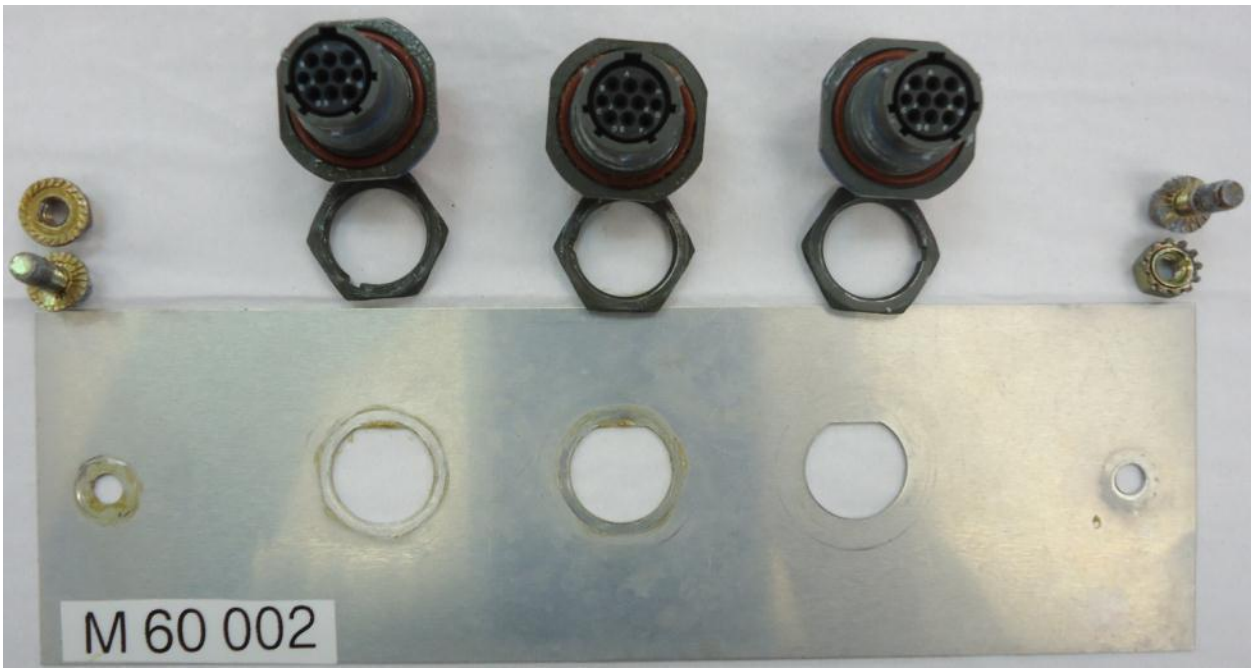
5052-H32 test panels following 70 days of exposure at the KSC Beachfront





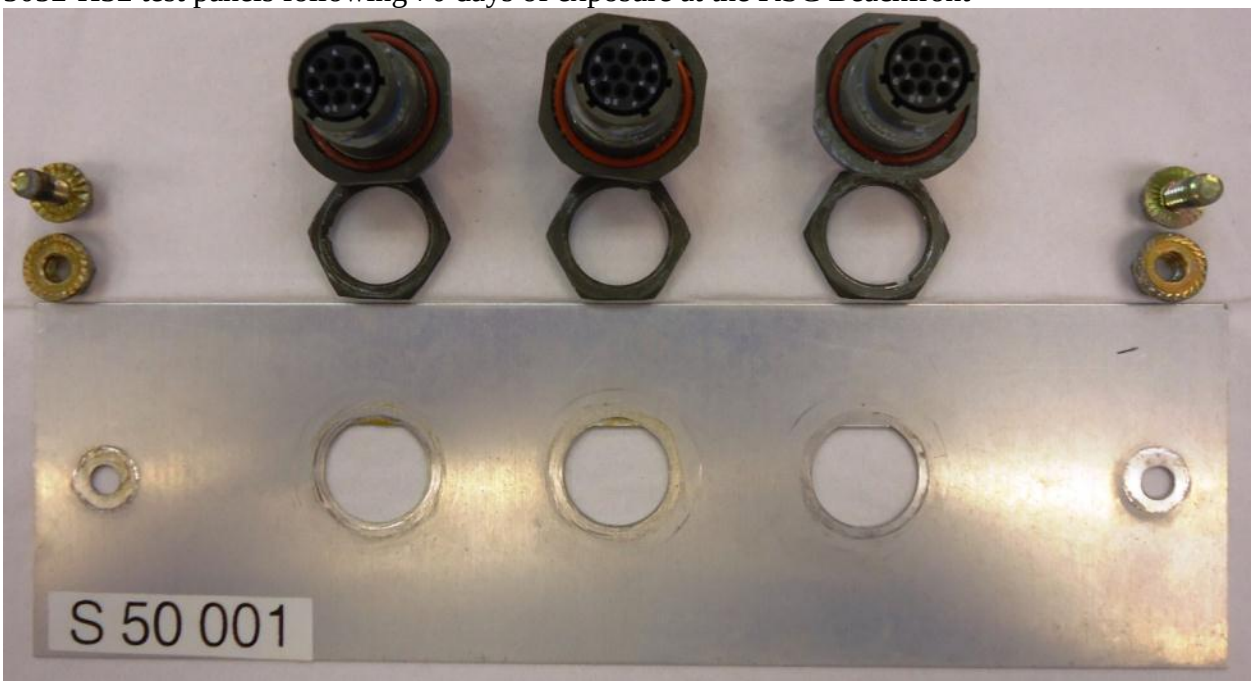
6061-T6 test panels following 70 days of exposure at the KSC Beachfront

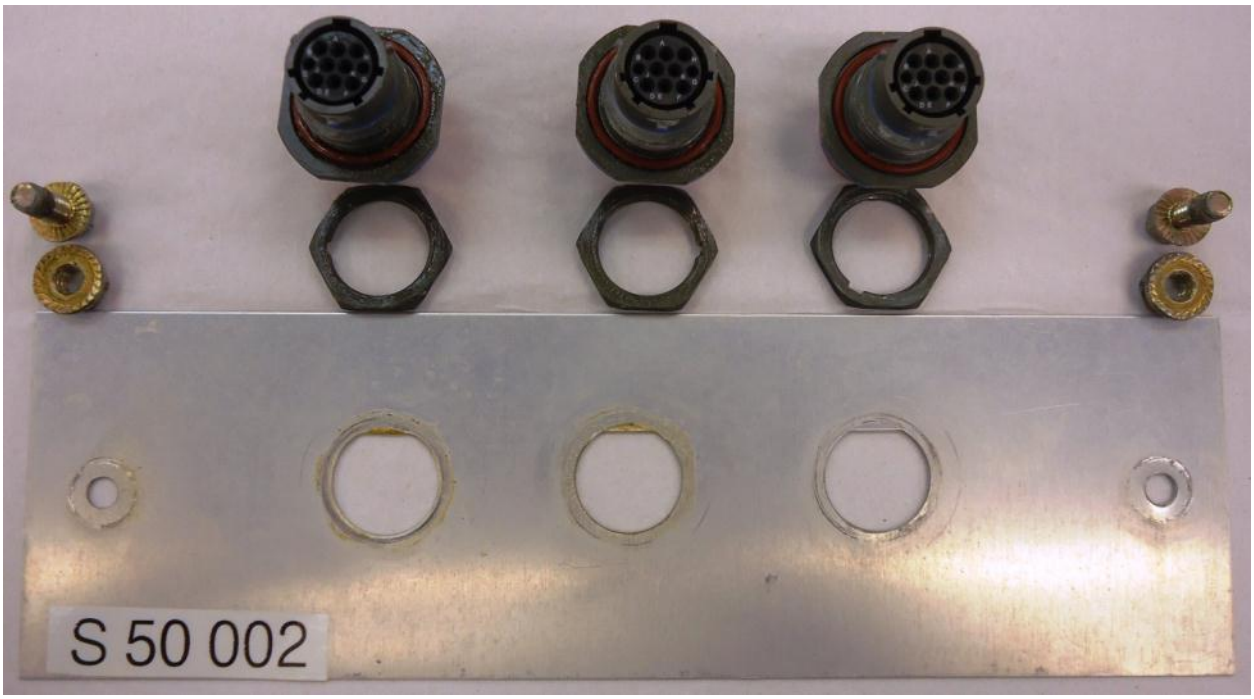




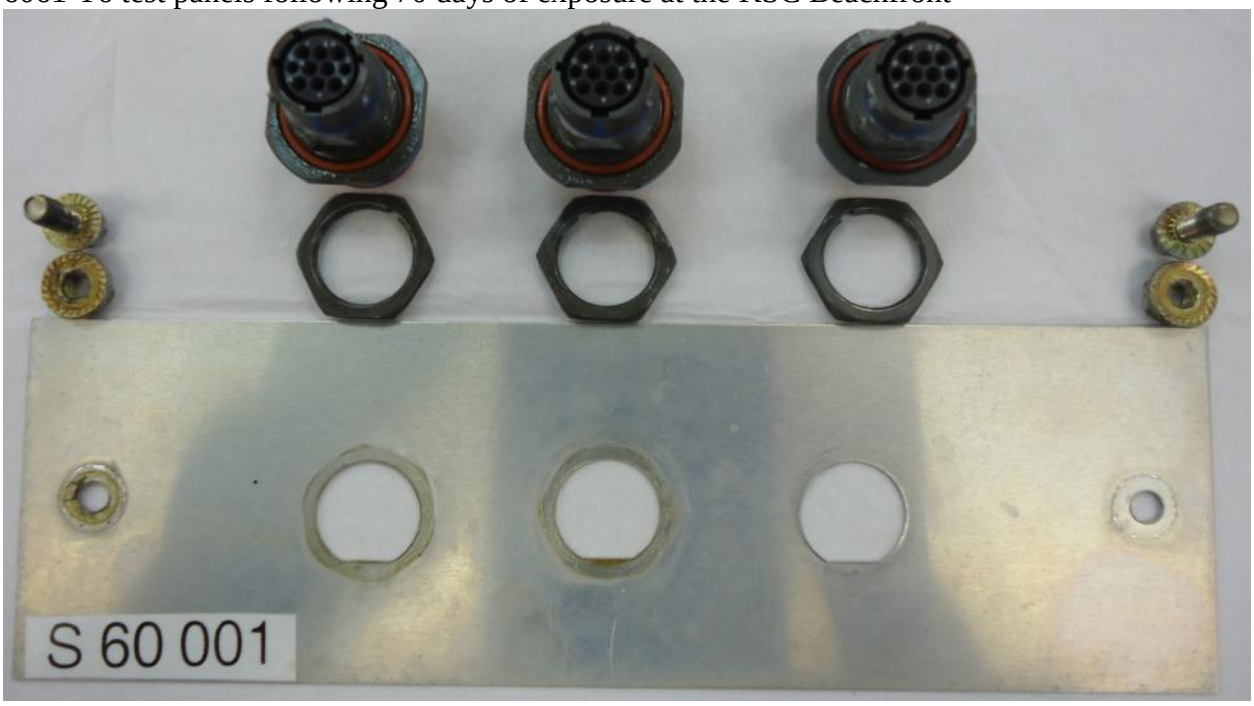
SurTec 650C

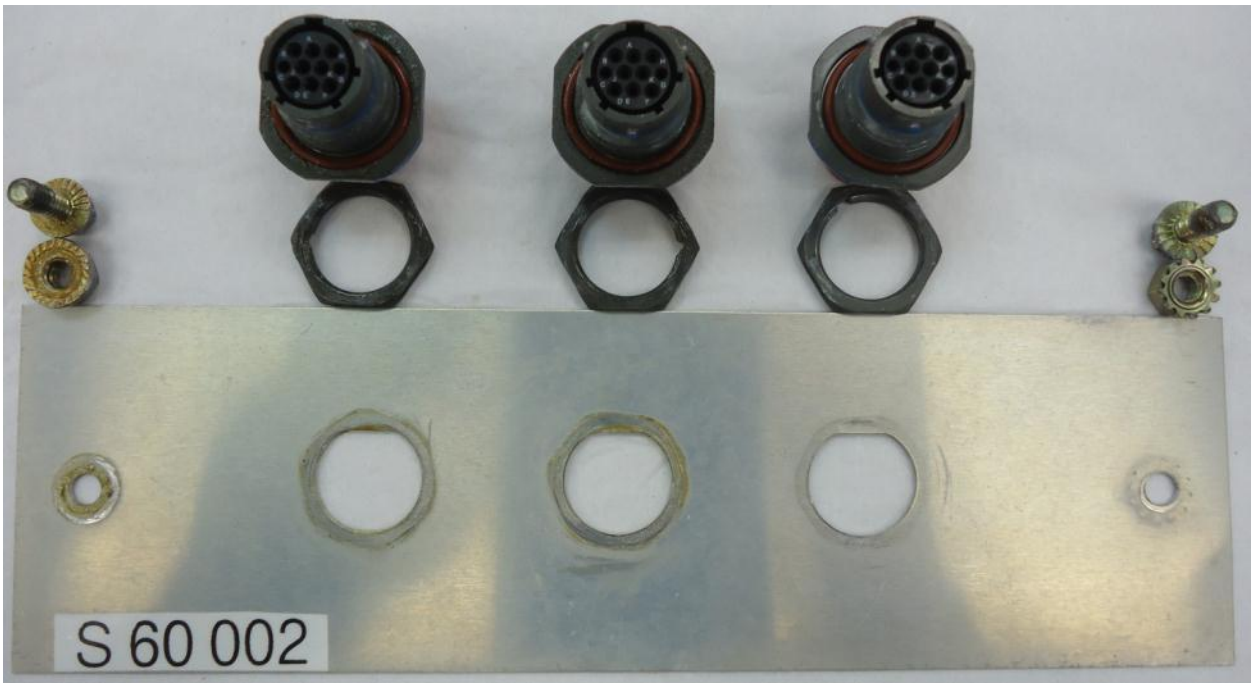
5052-H32 test panels following 70 days of exposure at the KSC Beachfront





6061-T6 test panels following 70 days of exposure at the KSC Beachfront

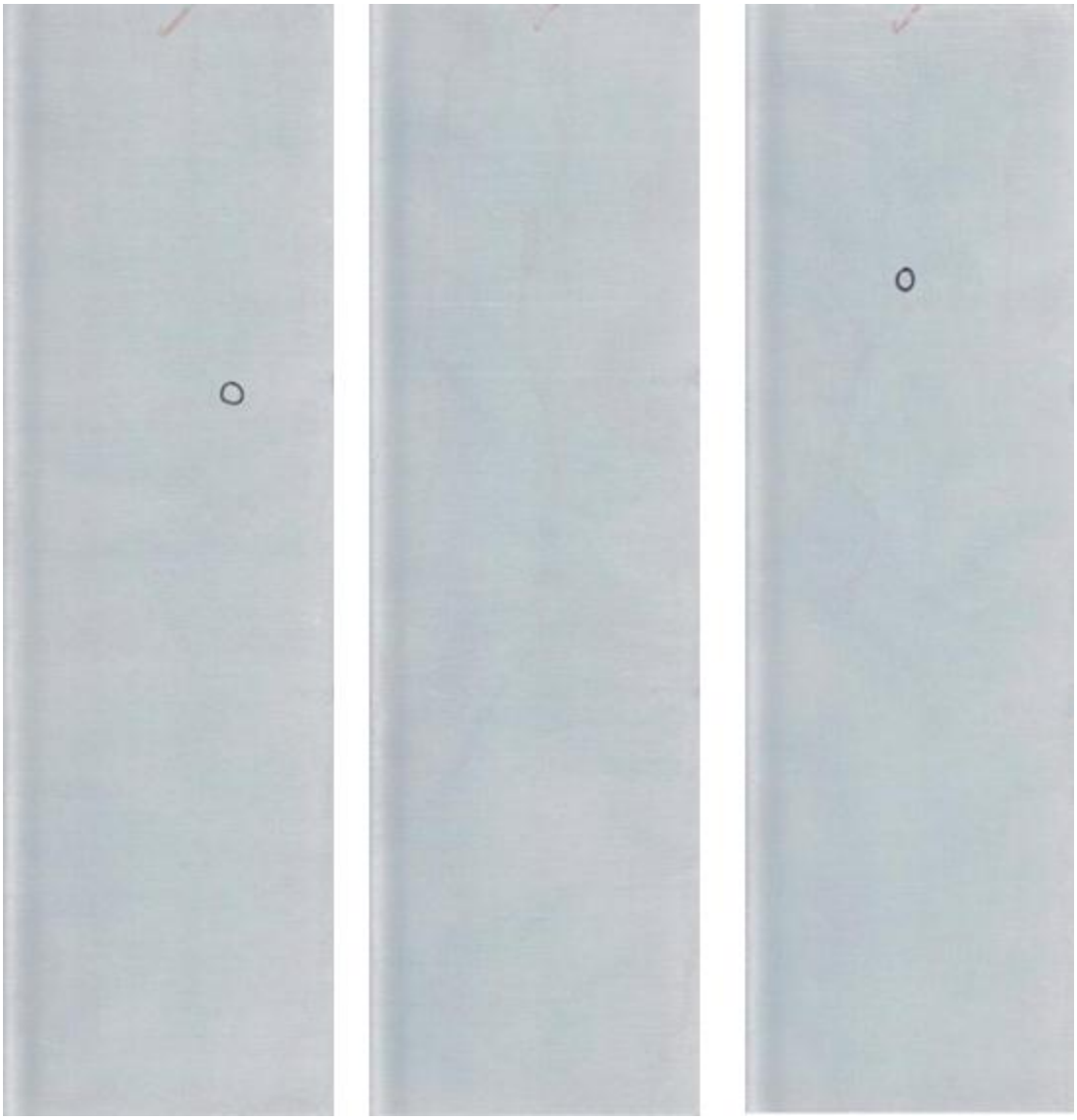




Appendix E: ASTM B 117 Salt Spray Results

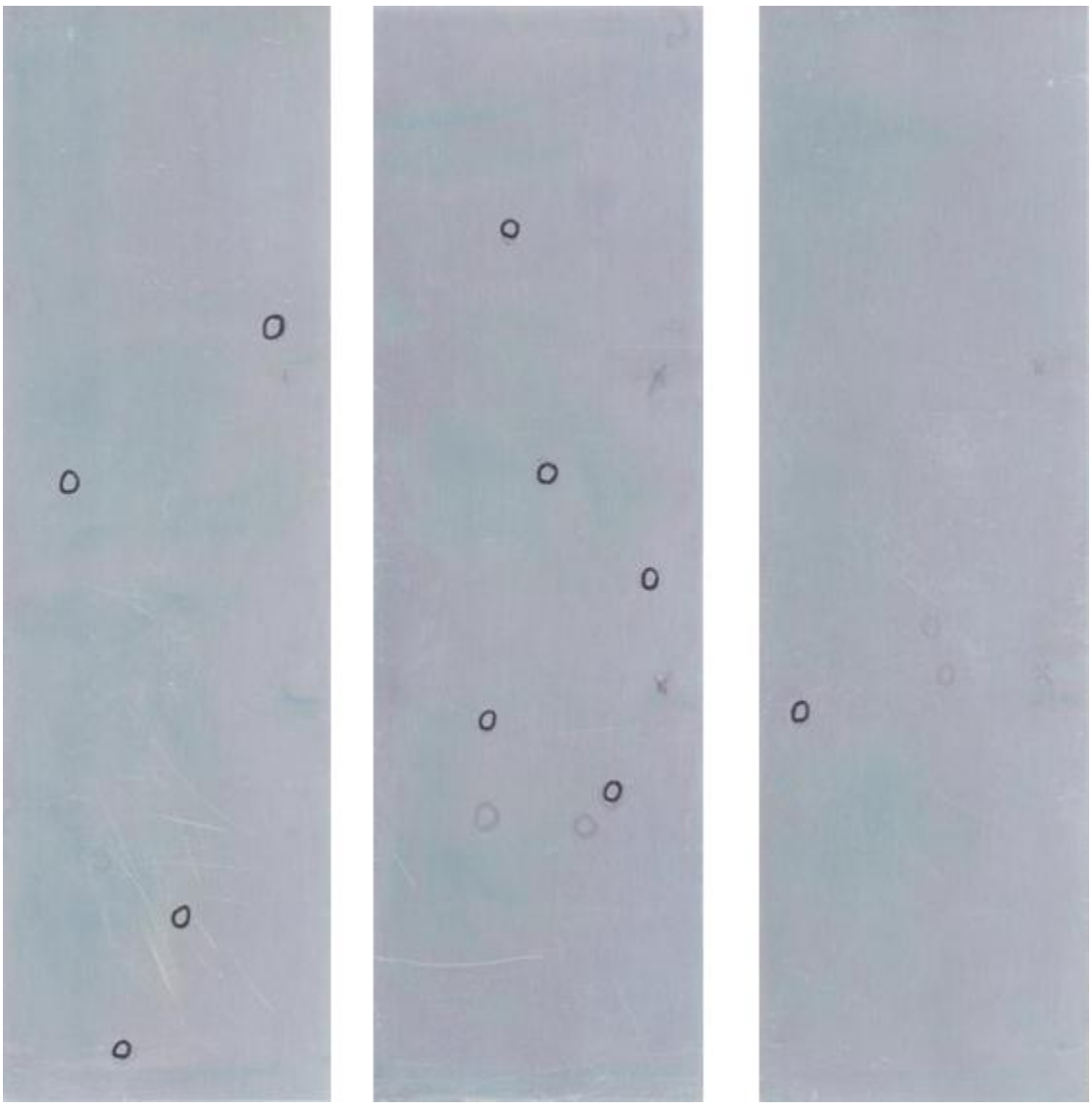
Alodine 1200S
5052-H32

Pretreatment	Panel #	Substrate	@168	@336	@504	@672	Total
Alodine 1200S	Al 50 - 004	5052-H32	0	0	0	1	1
Alodine 1200S	Al 50 - 005	5052-H32	0	0	0	0	0
Alodine 1200S	Al 50 - 006	5052-H32	0	0	0	1	1



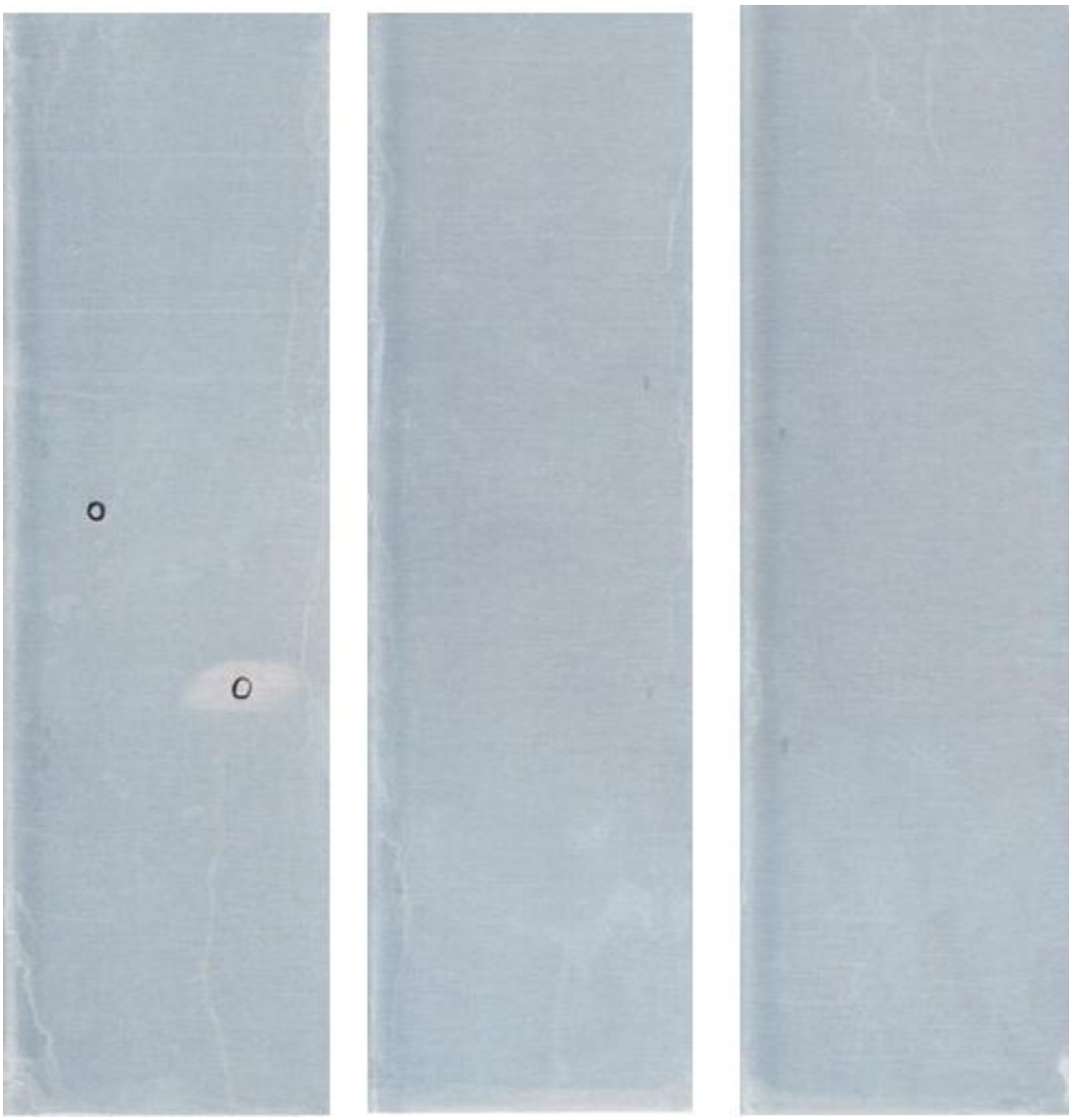
6061-T6

Pretreatment	**Panel #**	**Substrate**	**@168**	**@336**	**@504**	**@672**	**Total**
Alodine 1200S	Al 60 - 004	6061-T6	1	3	0	0	4
Alodine 1200S	Al 60 - 005	6061-T6	2	3	0	0	5
Alodine 1200S	Al 60 - 006	6061-T6	1	0	0	0	1



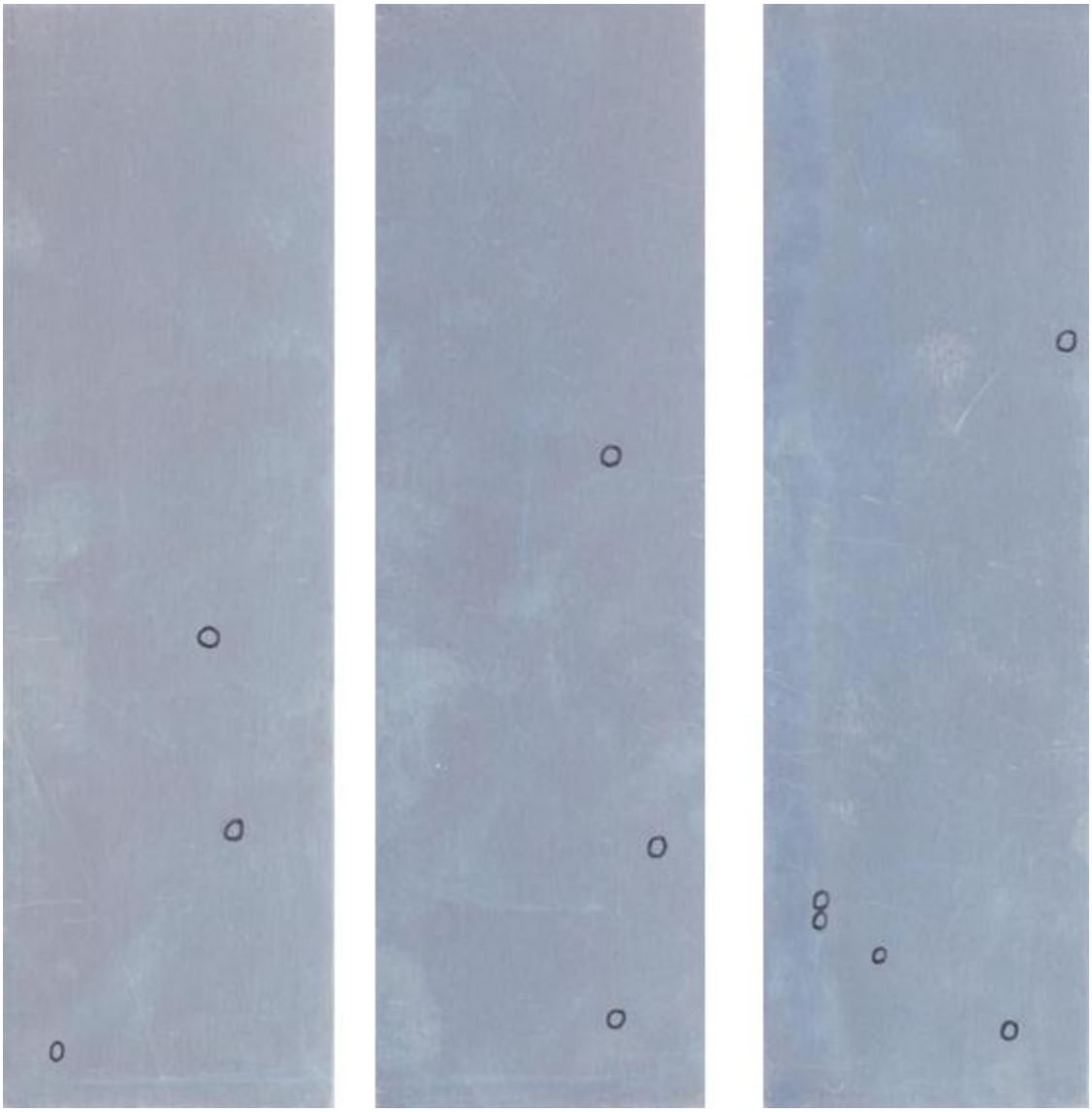
Metalast TCP-HF
5052-H32

Pretreatment	Panel #	Substrate	@168	@336	@504	@672	Total
Metalast TCP HF	M 50 - 004	5052-H32	0	0	1	1	2
Metalast TCP HF	M 50 - 005	5052-H32	0	0	0	0	0
Metalast TCP HF	M 50 - 006	5052-H32	0	0	0	0	0



6061-T6

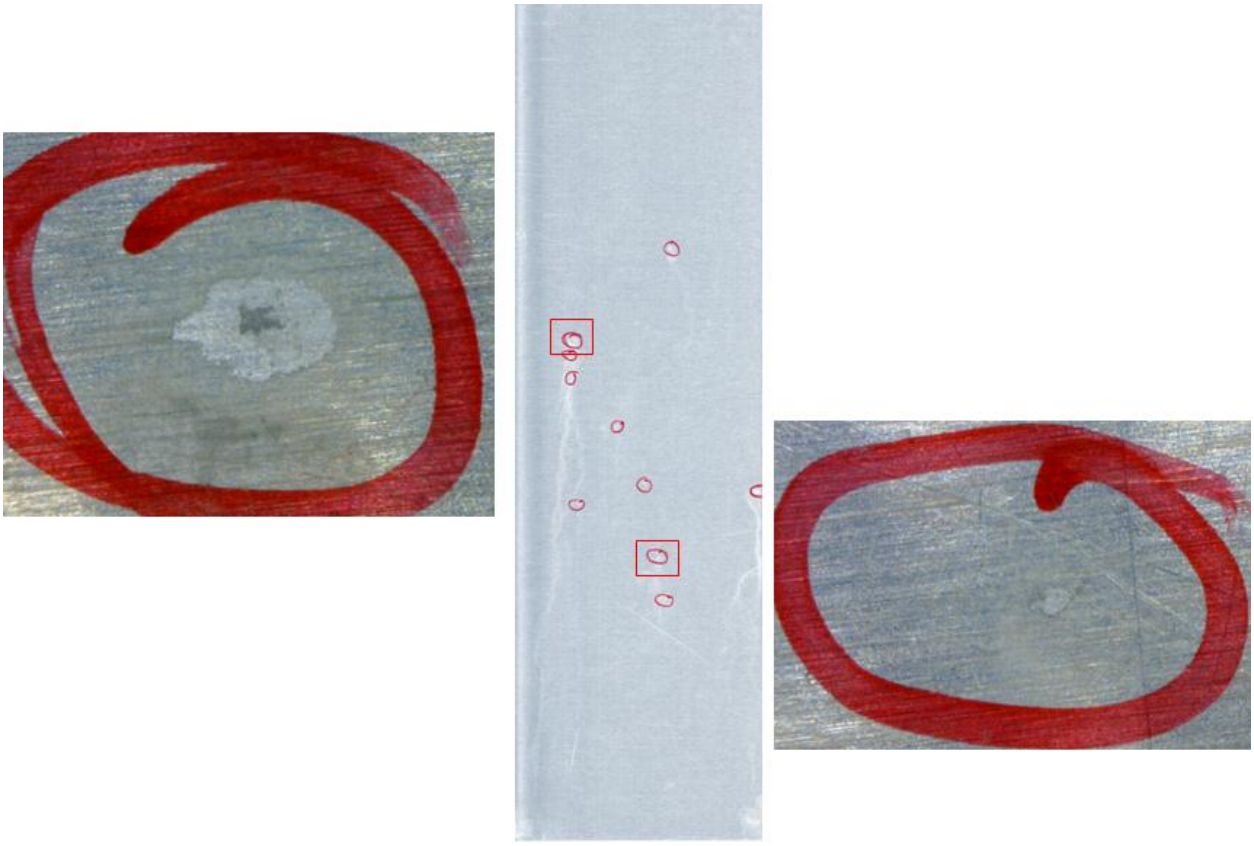
Pretreatment	Panel #	Substrate	@168	@336	@504	@672	Total
Metalast TCP HF	M 60 - 004	6061-T6	1	1	0	1	3
Metalast TCP HF	M 60 - 005	6061-T6	2	0	0	1	3
Metalast TCP HF	M 60 - 006	6061-T6	2	0	3	0	5



SurTec 650C

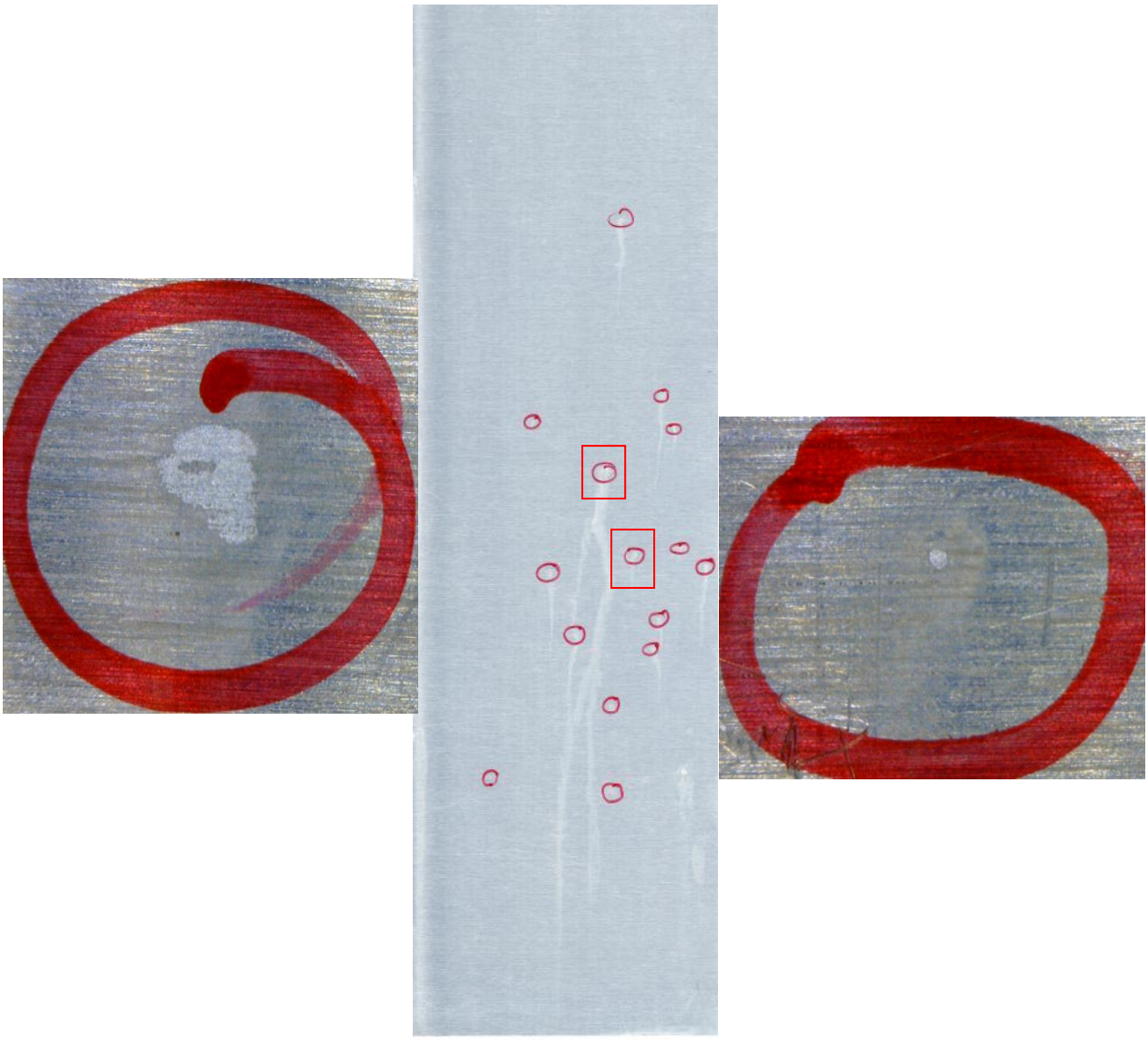
5052-H32 (S 50 – 004)

Pretreatment	Panel #	Substrate	@168	@336	Total
SurTec 650C	S 50 - 004	5052-H32	0	9	9
SurTec 650C	S 50 - 005	5052-H32	0	15	15
SurTec 650C	S 50 - 006	5052-H32	0	10	10



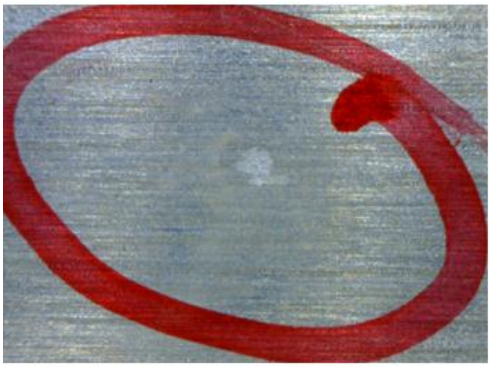
5052-H32 (S 50 – 005)

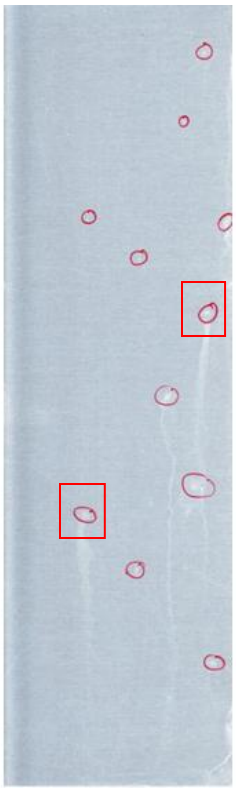
Pretreatment	Panel #	Substrate	@168	@336	Total
SurTec 650C	S 50 - 004	5052-H32	0	9	9
SurTec 650C	S 50 - 005	5052-H32	0	15	15
SurTec 650C	S 50 - 006	5052-H32	0	10	10



5052-H32 (S 50 – 006)

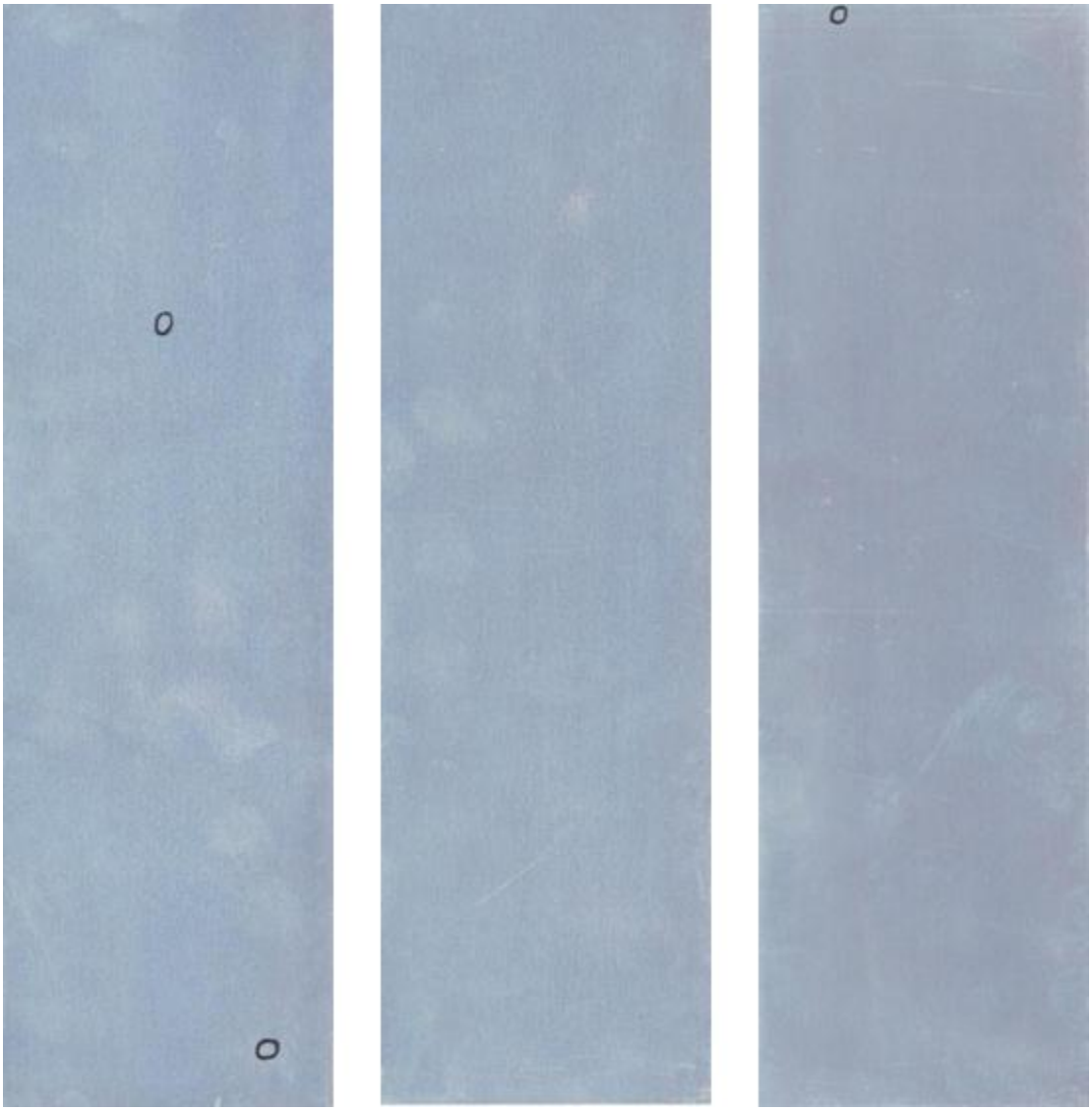
Pretreatment	Panel #	Substrate	@168	@336	Total
SurTec 650C	S 50 - 004	5052-H32	0	9	9
SurTec 650C	S 50 - 005	5052-H32	0	15	15
SurTec 650C	S 50 - 006	5052-H32	0	10	10





6061-T6

Pretreatment	Panel #	Substrate	@168	@336	@504	@672	Total
SurTec 650C	S 60 - 004	6061-T6	0	0	0	2	2
SurTec 650C	S 60 - 005	6061-T6	0	0	0	0	0
SurTec 650C	S 60 - 006	6061-T6	0	0	0	1	1



LIST OF ACRONYMS

DFARS	Defense Federal Acquisition Regulation Supplement
DoD	Department of Defense
EDL	Engineering Development Laboratory
EGSE	Electrical Ground Support Equipment
GSDO	Ground Support Development and Operations
GSE	Ground Support Equipment
JTP	Joint Test Protocol
KSC	Kennedy Space Center
NASA	National Aeronautics and Space Administration
NAVAIR	Naval Air Systems Command
OSHA	Occupational Safety and Health Administration
SEM	Scanning Electron Microscope
TEERM	Technology Evaluation for Environmental Risk Mitigation Principal Center