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REMINC

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Date:

May 26, 2020

Purchase Order:

9181

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PURPOSE

The purpose of this test report is to present the test results obtained during the performance of a test program. This report includes a brief description of the samples presented for test, a list of the documents presented as test instructions, and a summary of the testing performed and the results obtained. Applicable requirements and conclusions are based on the criteria provided by our client, or as specified in the reference document(s). All results relate only to the items tested, as listed within this report.

WORK REQUESTED / REFERENCE DOCUMENT(S)

Comparison testing per emails dated 06/21/19, 06/28/19, 07/03/19, and 08/05/19.

Reference Documents:

- SAE/USCAR-26 (August 2003)
- SAE/USCAR-2
- ASTM B117 (2018)
- Additional correspondence received in emails dated 07/26/19, 09/25/19, 02/03/20, and 02/28/20

SAMPLE DESCRIPTION

A total of three (3) types of Grounding Screws and Threaded Weld Nuts were presented by REMINC for testing with sample numbers as follows:

Sample Type	Sample Number
TAPTITE® PRO™ Thread Rolling Screws and Untapped Weld Nuts	1 to 20
POWERLOK® II™ Thread-Locking Screws and Threaded Weld Nuts	21 to 40
Machine Screws and Threaded Weld Nuts	41 to 58

Note: A total of fifty-eight (58) samples were tested instead of sixty (60) due to damaged terminals of two (2) machine screw samples per REMINC approval email dated 02/28/20.

TEST SEQUENCE

Test Name	Section	Sample Number	Test Date(s)
Test Preparation	4.2.2	1 to 58	02/27/20
	4.2.3		
	4.2.4		
Voltage Drop (Pretest)	4.8		03/02/20
Thermal Shock	4.4		03/04/20 to 03/13/20
Random Vibration	4.5		03/18/20 to 03/19/20
Temperature/Humidity	4.6		04/21/20 to 05/01/20
Salt Fog	4.7		05/04/20 to 05/15/20
Voltage Drop (Post Test)	4.8		05/18/20 to 05/19/20

TESTING PERFORMED

TEST PREPARATION

Procedure

4.2.2 Test Coupon Preparation:

Test coupon dimensions were 40 mm x 75 mm, made of steel and equipped with a weld nut to tighten the grounding screws into. The torque used to tighten the screws was 20 N·m per REMINC email dated 02/03/20.

Both the coupons and nuts were E-coated.

Coupons used for TAPTITE® PRO™ had untapped weld nuts.

Coupons used for POWERLOK® II™ and machine screws had threaded weld nuts.

4.2.3 Terminal Preparation:

A total of two (2) stacked terminals were used on each sample, one (1) terminal was for the power line and the other terminal was for a voltage sense wire.

4.2.4 Ground Wire Attachment to Test Coupon:

A total of two (2) ground wires were soldered to each coupon, 12 mm from the grounding screw.

Requirements

If multiple parts are attached to the same coupon, they may share both ground wires. One ground wire may be daisy chained from coupon to coupon, but a separate voltage sense wire shall be used for each attachment/coupon.

The area of attachment to the coupons may be coated.

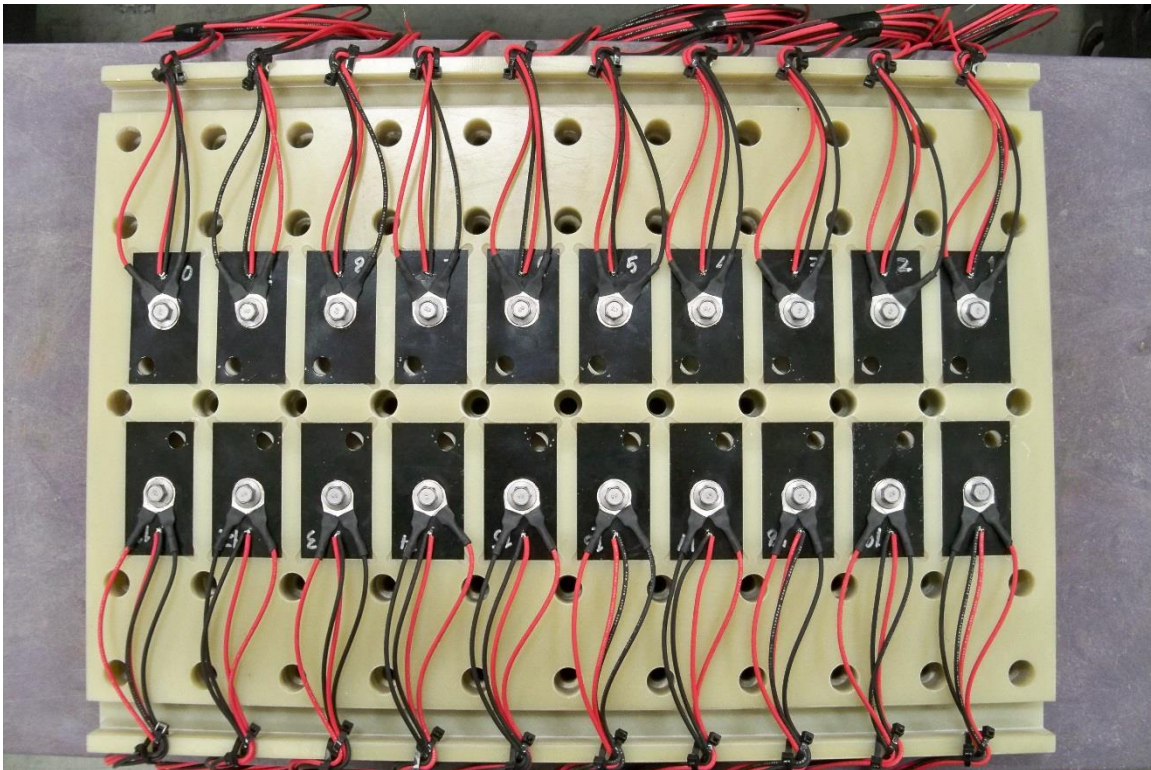
Sample groups shall conform to the statistical requirements of paragraph 4.2.1.

Results

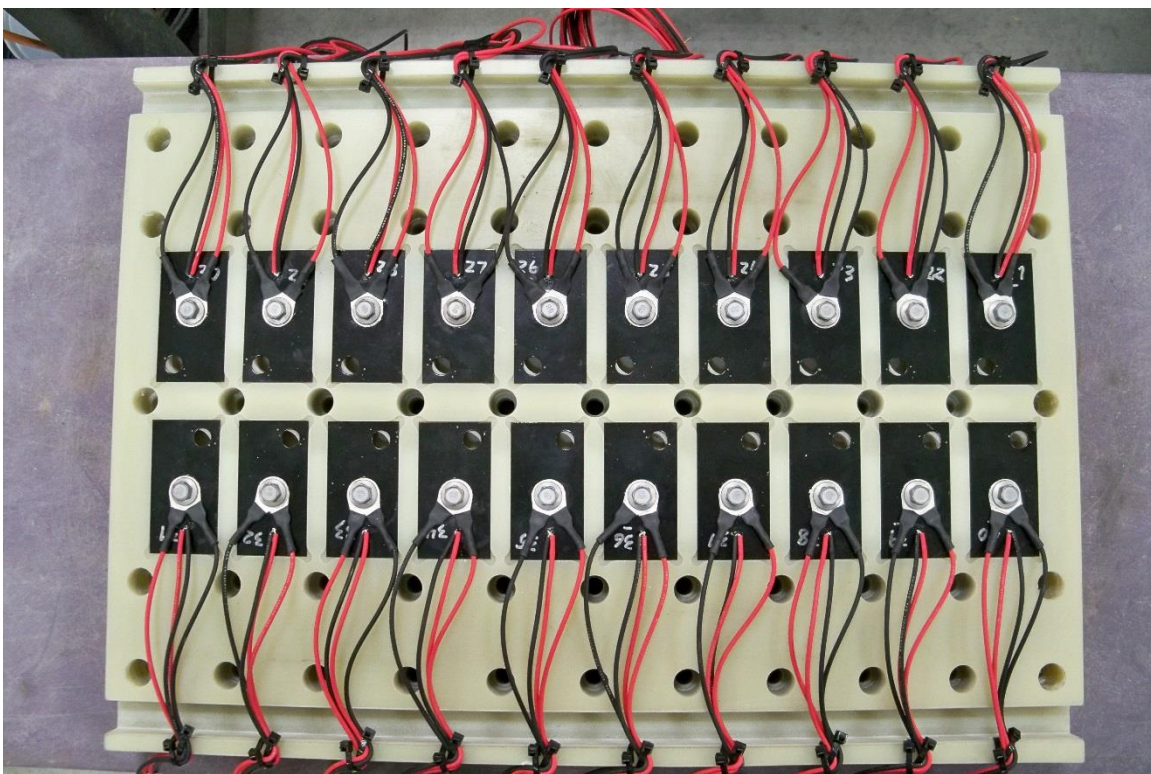
No visible damage was noted to sample numbers 1 to 58.

Conclusion

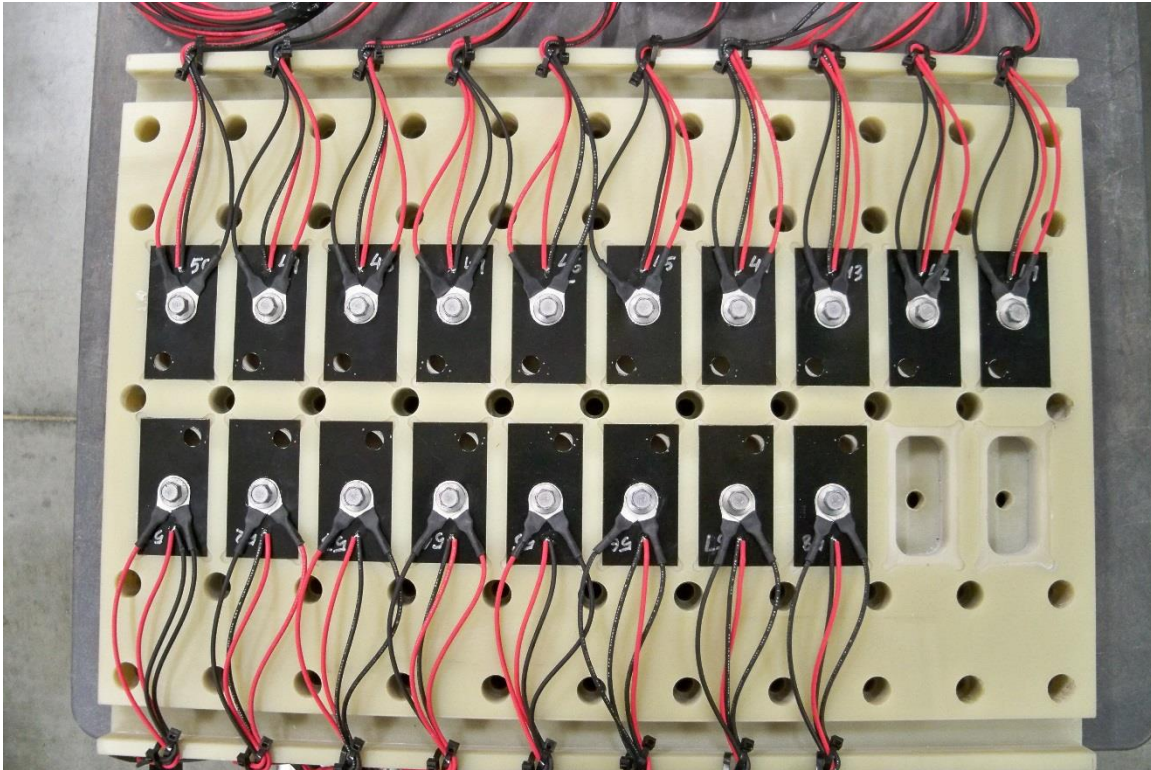
The test samples met the requirements specified.



TAPTITE® PRO™ Samples Mounted to Test Fixture (Pretest)



POWERLOK® II™ Samples Mounted to Test Fixture (Pretest)



Machine Screw Samples Mounted to Test Fixture (Pretest)

RESISTANCE MEASUREMENT (VOLTAGE DROP) (PRETEST AND POST TEST)

Procedure

Each sample was tested individually.

Connected the measurement power supply to the sample.

Using a mV meter, applied a 1 A current through the power wires then measured and recorded the voltage drop across the sense wires.

Completed the Visual Examination procedure per SAE/USCAR-2.

Requirements

The maximum voltage drop recorded in paragraph 4.8 shall not exceed 1 mV per amp.

The change in voltage drop (6) from beginning to end of all conditioning procedures shall not exceed 0.5 mV per amp.

Results

Sample Number (TAPTITE® PRO™)	mV Drop at 1A (Pre-Test)	mV Drop at 1A (Post Test)	Change (mV)
1	0.24	0.26	0.02
2	0.20	0.22	0.02
3	0.28	0.30	0.02
4	0.27	0.29	0.02
5	0.21	0.21	0.00
6	0.22	0.24	0.02
7	0.23	0.26	0.03
8	0.22	0.23	0.01
9	0.20	0.21	0.01
10	0.24	0.27	0.03
11	0.22	0.25	0.03
12	0.26	0.30	0.04
13	0.27	0.30	0.03
14	0.23	0.25	0.02
15	0.30	0.31	0.01
16	0.25	0.27	0.02
17	0.21	0.25	0.04
18	0.21	0.25	0.04
19	0.21	0.26	0.05
20	0.26	0.28	0.02

Results (Continued)

Sample Number (POWERLOK [®] II [™])	mV Drop at 1A (Pre-Test)	mV Drop at 1A (Post Test)	Change (mV)
21	0.22	0.24	0.02
22	0.28	0.26	-0.02
23	0.22	0.24	0.02
24	0.21	0.24	0.03
25	0.24	0.30	0.06
26	0.22	0.30	0.08
27	0.24	0.28	0.04
28	0.21	0.23	0.02
29	0.23	0.27	0.04
30	0.22	0.26	0.04
31	0.24	0.29	0.05
32	0.22	0.26	0.04
33	0.24	0.27	0.04
34	0.19	0.22	0.03
35	0.21	0.25	0.04
36	0.28	0.33	0.05
37	0.23	0.26	0.03
38	0.22	0.25	0.03
39	0.25	0.24	-0.01
40	0.24	0.26	0.03

Results (Continued)

Sample Number (Machine Screw)	mV Drop at 1A (Pre-Test)	mV Drop at 1A (Post Test)	Change (mV)
41	0.25	0.41	0.16
42	0.29	0.35	0.06
43	0.22	0.22	0.00
44	0.21	0.26	0.05
45	0.35	0.34	-0.01
46	0.34	0.32	-0.02
47	0.50	0.41	-0.09
48	0.27	0.37	0.10
49	0.49	0.81	0.32
50	0.48	0.43	-0.05
51	0.28	0.30	0.02
52	0.74	0.62	-0.12
53	0.33	1.14	0.81
54	0.73	0.52	-0.21
55	0.46	0.52	0.06
56	0.56	0.39	-0.17
57	0.29	0.27	-0.02
58	0.58	0.55	-0.03

No visible damage was noted to sample numbers 1 to 58.

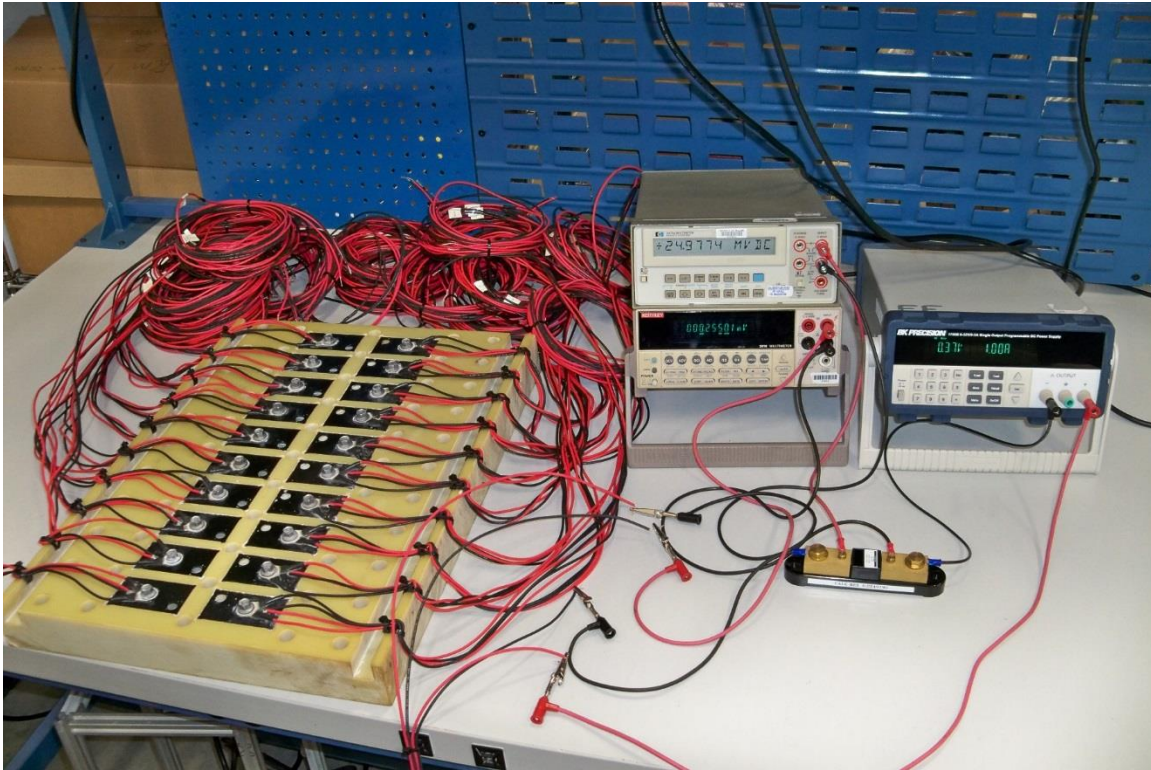
The maximum voltage drop did not exceed 1 mV per amp, with exception of sample number 53.

The change in voltage drop from beginning to end of all conditioning procedures did not exceed 0.5 mV per amp, with exception of sample number 53.

Conclusion

Sample numbers 1 to 52, and 54 to 58 met the requirements specified.

Sample number 53 did not meet the requirements specified.



Resistance Measurement (Voltage Drop) Test Setup

THERMAL SHOCK

Procedure

The samples were placed in an environmental chamber and subjected to Thermal Shock testing, per the following test parameters. The samples were unpowered during testing.

Grounding Screws	
Temperature	Duration
-40°C	2 hours
+125°C	2 hours
Transition time of 10 seconds between temperature extremes.	
Repeat for a total of 50 cycles.	

Note: Sample numbers 1 to 40 were tested together in one chamber and 41 to 58 were tested in a separate chamber.

Requirements

No specific criteria. Exposure only.

Results

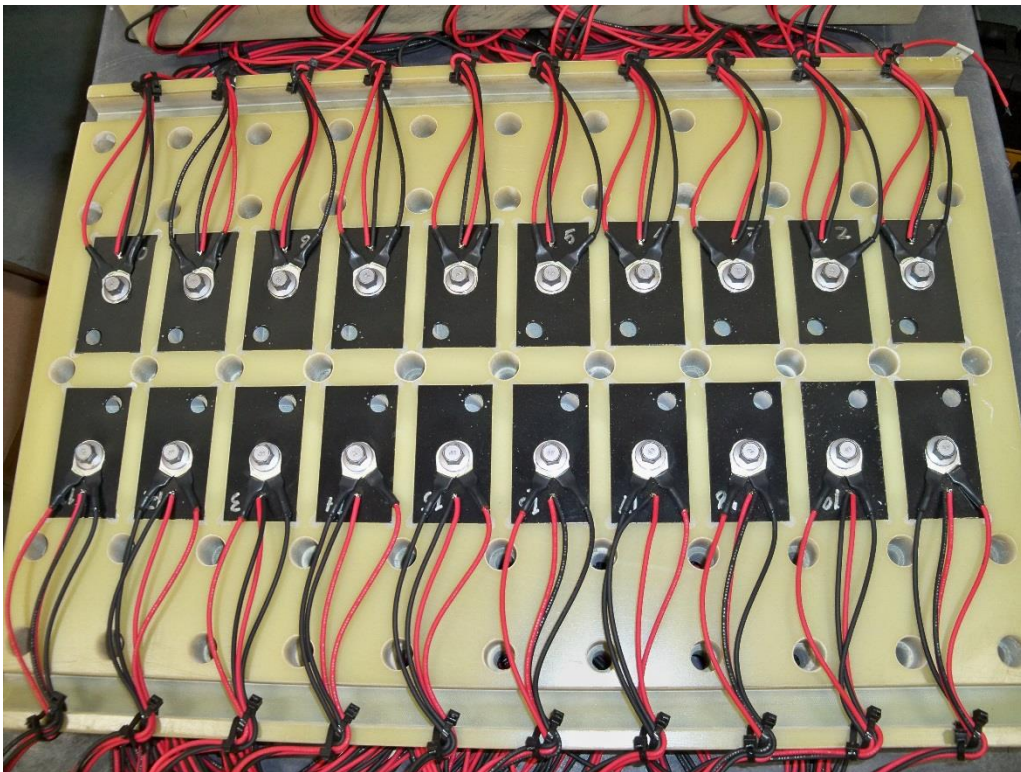
No visible damage was noted to sample numbers 1 to 58.

Conclusion

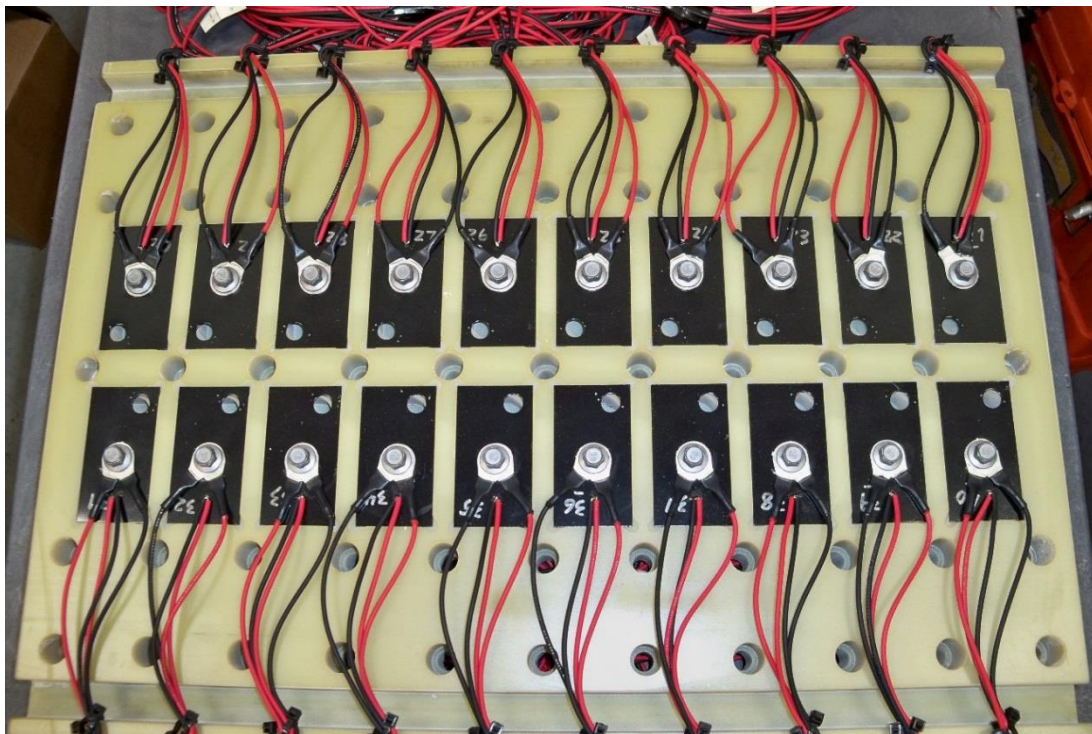
To be determined by REMINC.



Thermal Shock, TAPTITE® PRO™ Samples 1 to 20 and POWERLOK® II™ Samples 21 to 40, Setup



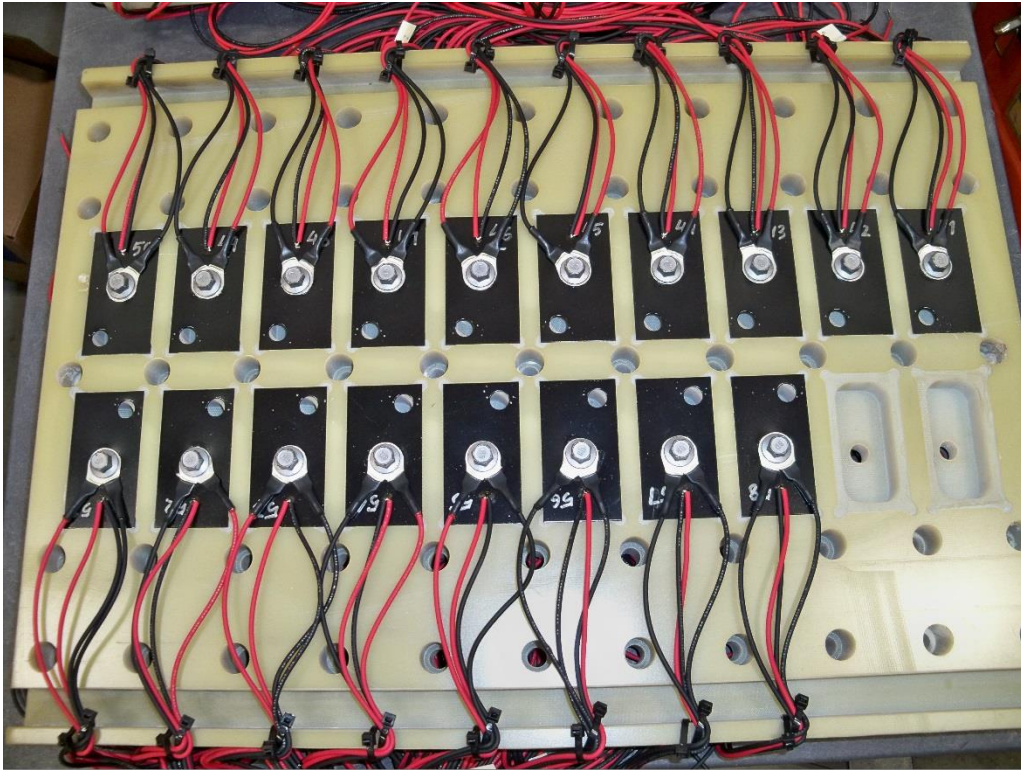
Thermal Shock, TAPTITE® PRO™ Samples 1 to 20, Post Test



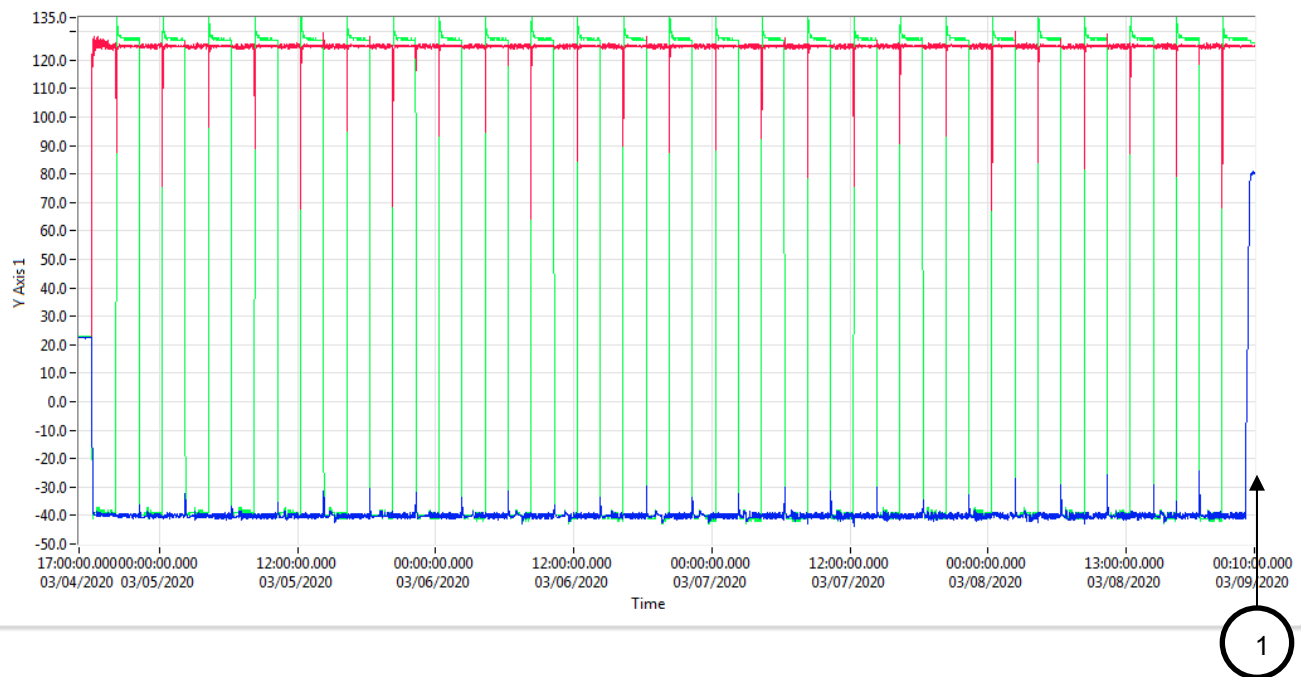
Thermal Shock, POWERLOK® II™ Samples 21 to 40, Post Test



Thermal Shock, Machine Screw Samples 41 to 58, Setup



Thermal Shock, Machine Screw Samples 41 to 58, Post Test

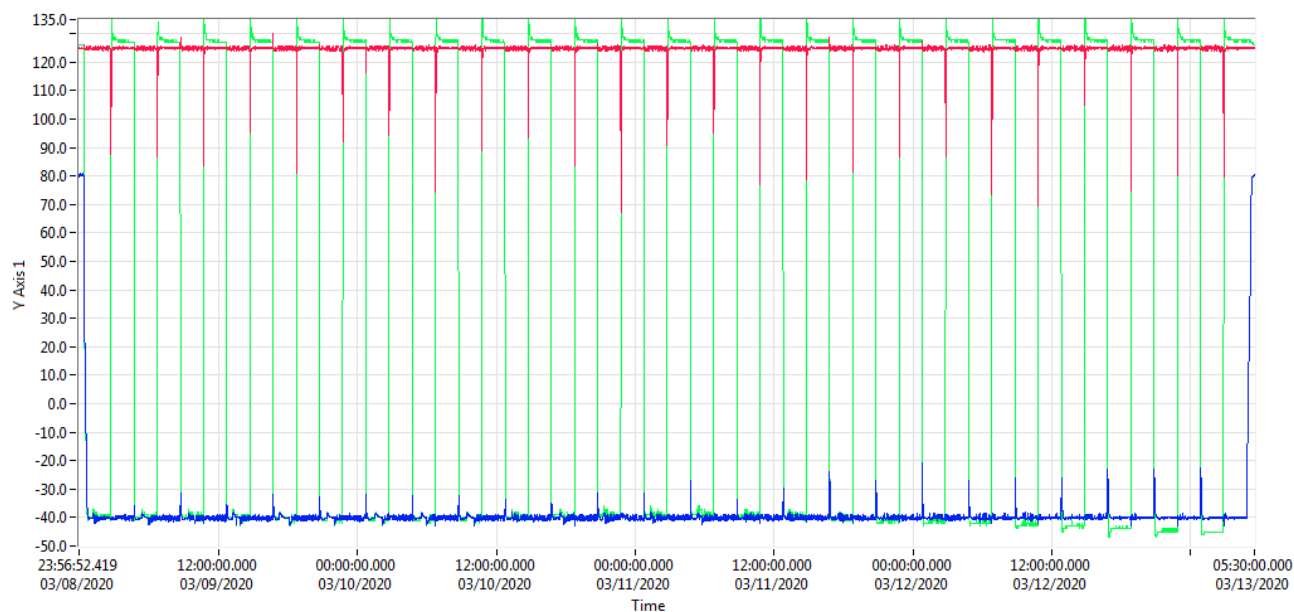


Raw File: 03042020

- ☒ EC236 Cold Box PV °C 1 ■
- ☒ EC236 Hot Box PV °C 1 ■
- ☒ EC236 Basket PV °C 1 ■

Thermal Shock, Samples 1 to 40

Note 1: Chamber scheduled defrost.

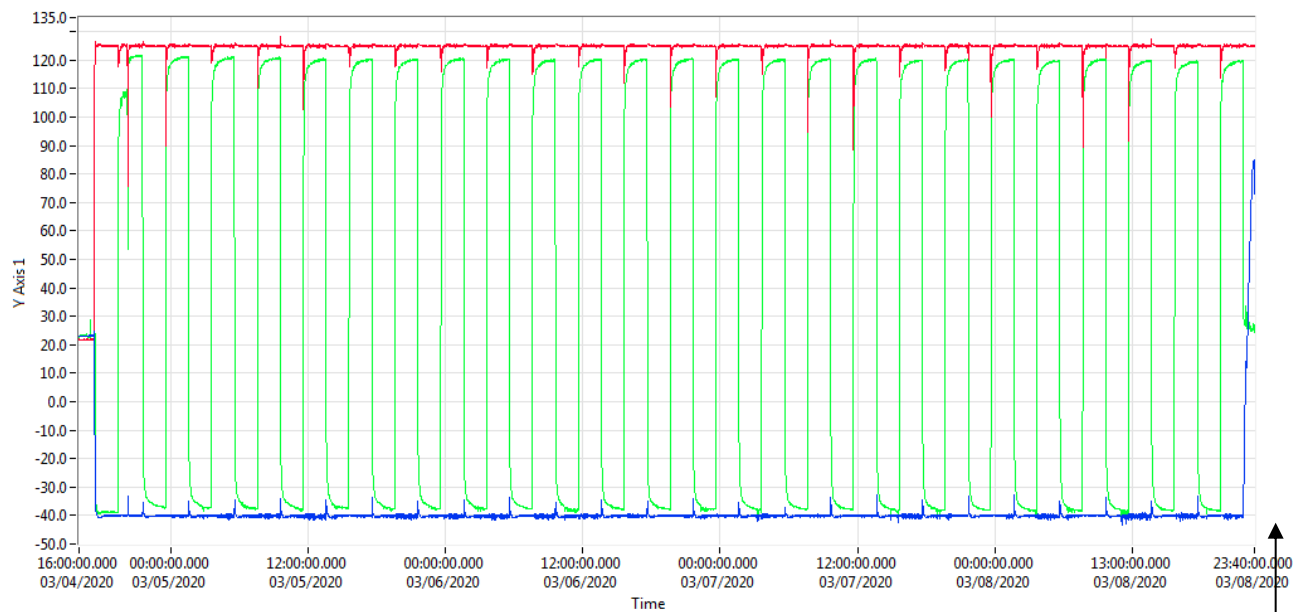


Raw File: 03042020

- ☒ EC236 Cold Box PV °C
- ☒ EC236 Hot Box PV °C
- ☒ EC236 Basket PV °C

1 ■
1 ■
1 ■

Thermal Shock, Samples 1 to 40 (Continued)

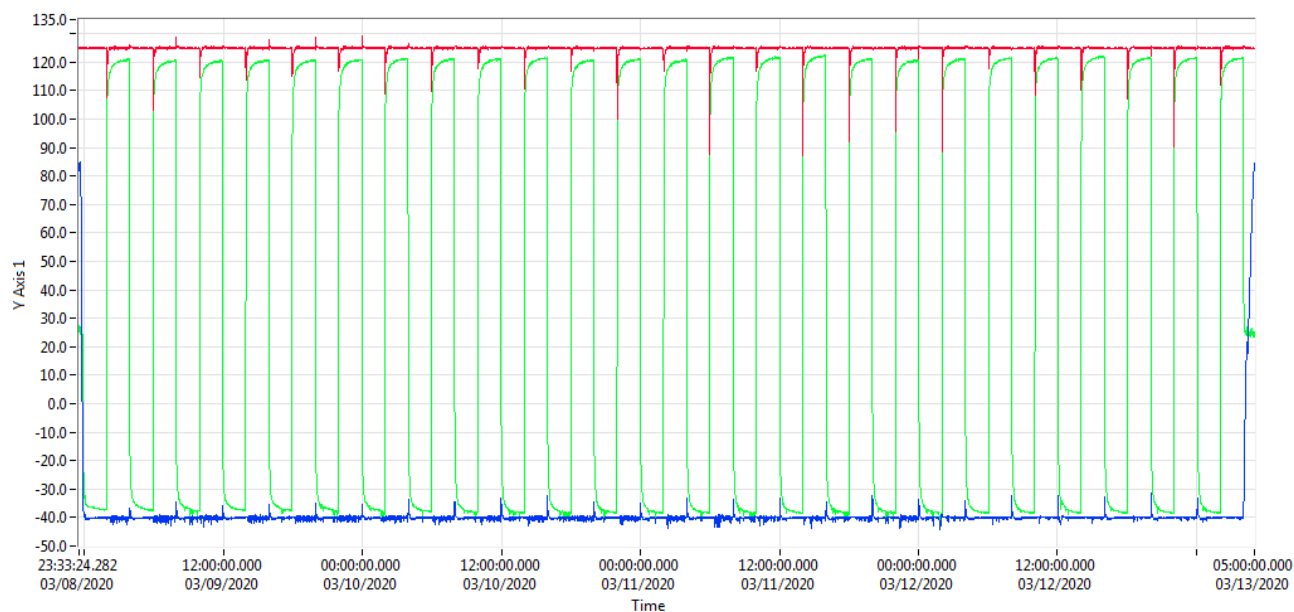


Raw File: 03042020

- ☒ EC157 Cold Box PV °C 1 ■
- ☒ EC157 Hot Box PV °C 1 ■
- ☒ EC157 Basket PV °C 1 ■

Thermal Shock, Samples 41 to 58

Note 1: Chamber scheduled defrost.



Raw File: 03042020

- ☒ EC157 Cold Box PV °C
- ☒ EC157 Hot Box PV °C
- ☒ EC157 Basket PV °C

1 ■

1 ■

1 ■

Thermal Shock, Samples 41 to 58 (Continued)

RANDOM VIBRATION

Procedure

The samples were attached to the vibration test fixture in their normal mounting position by using their intended mounting means. The fixture was secured to the vibration exciter.

The samples were subjected to a random vibration at all frequencies from 5 Hz to 1000 Hz. The samples were subjected to this vibration for 8 hours in each of three (3) mutually perpendicular axes for a total accumulated vibration time of 24 hours.

The Random Vibration Test levels applied to the samples were in accordance with the following schedule:

Frequency (Hz)	PSD ((m/s ²) ² /Hz)	PSD (g ² /Hz)
5.0	0.192	0.00200
12.5	23.8	0.00248
77.5	0.307	0.00320
145.0	0.192	0.00200
200.0	1.13	0.01180
230.0	0.031	0.00032
1000.0	0.002	0.00002
Acceleration Grms = 1.81 (17.74 m/s ²)		

Requirements

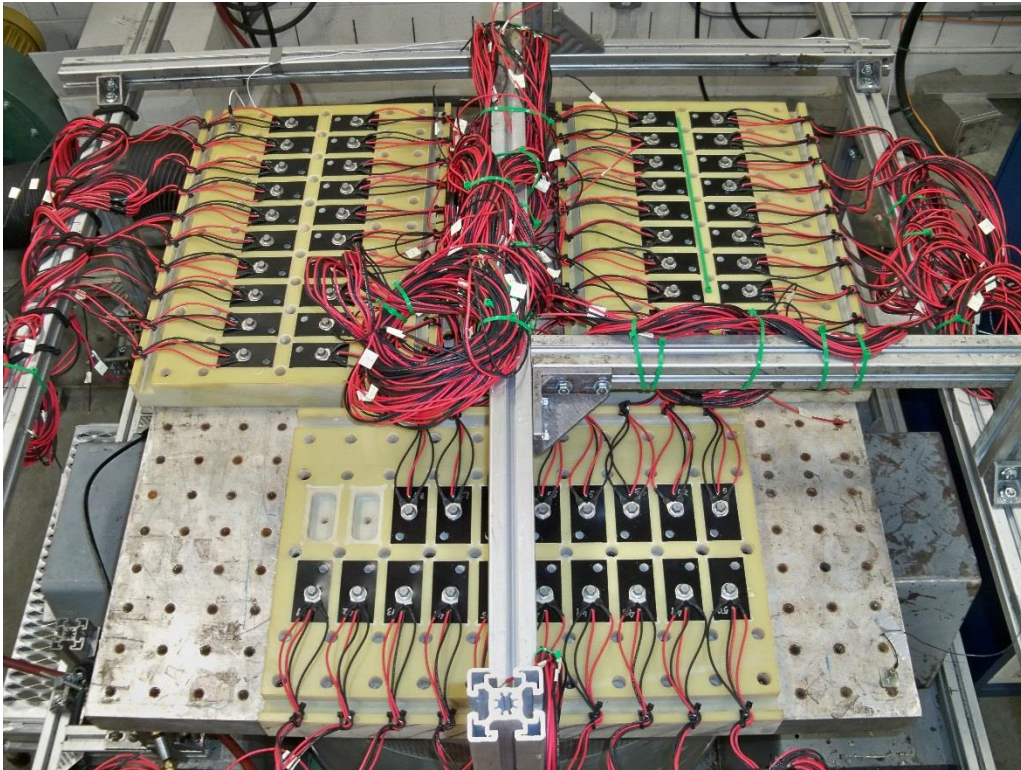
No specific criteria.

Results

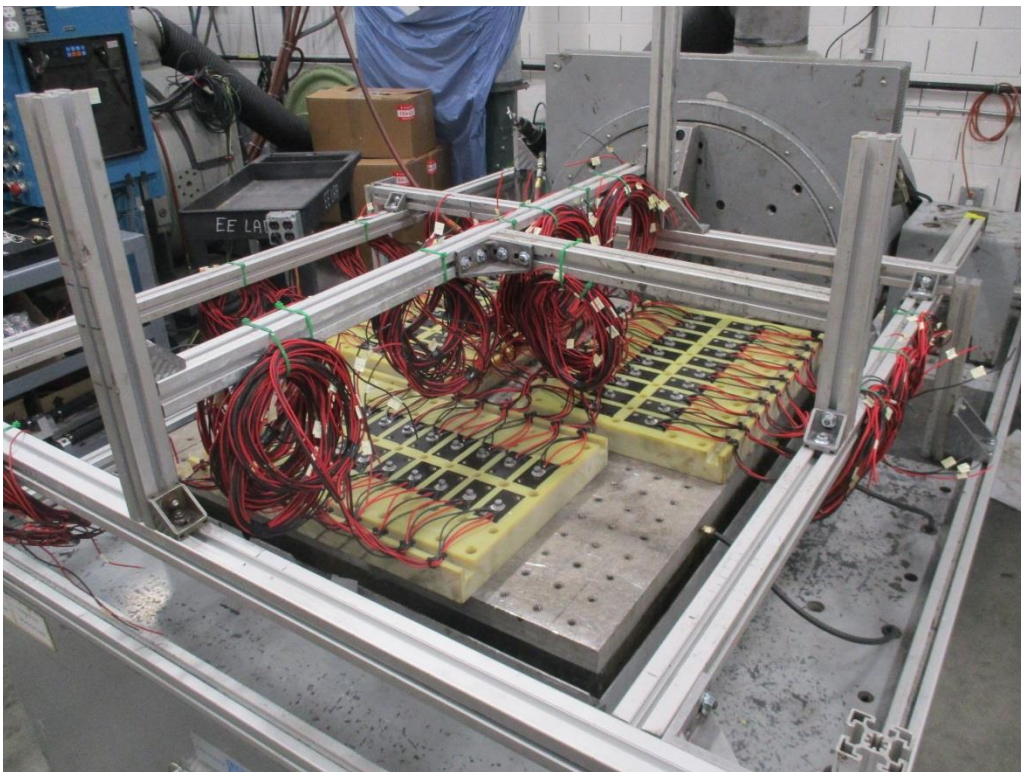
No visible damage was noted to sample numbers 1 to 58.

Conclusion

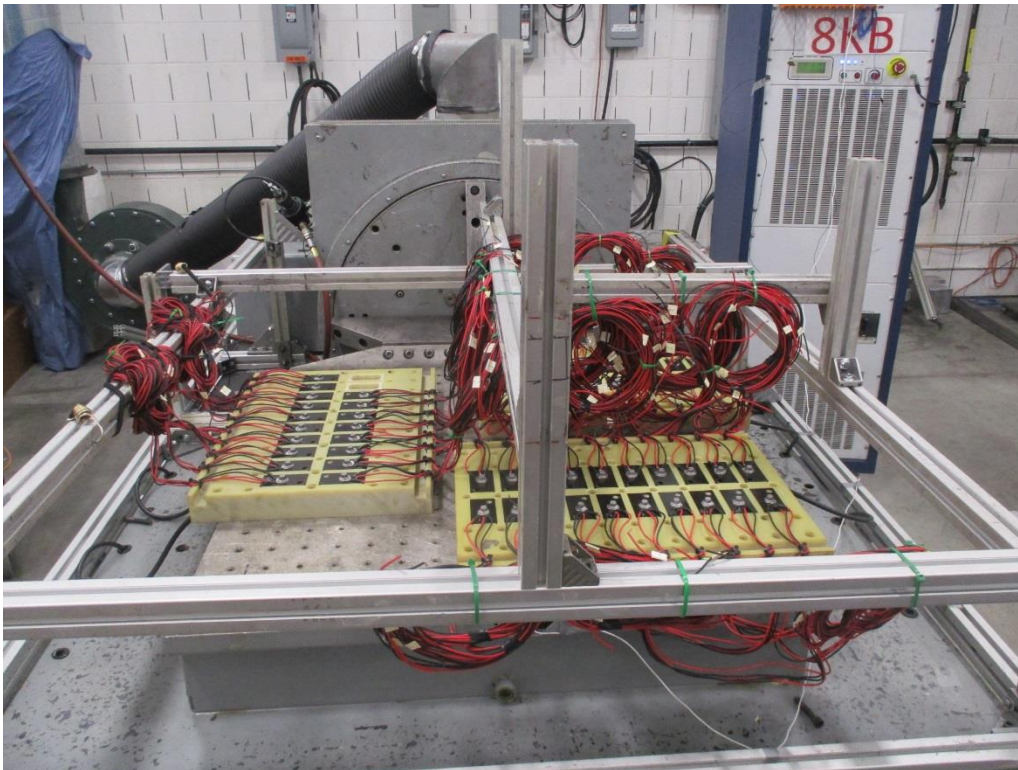
To be determined by REMINC.



Random Vibration, Vertical Axis, Samples 1 to 58

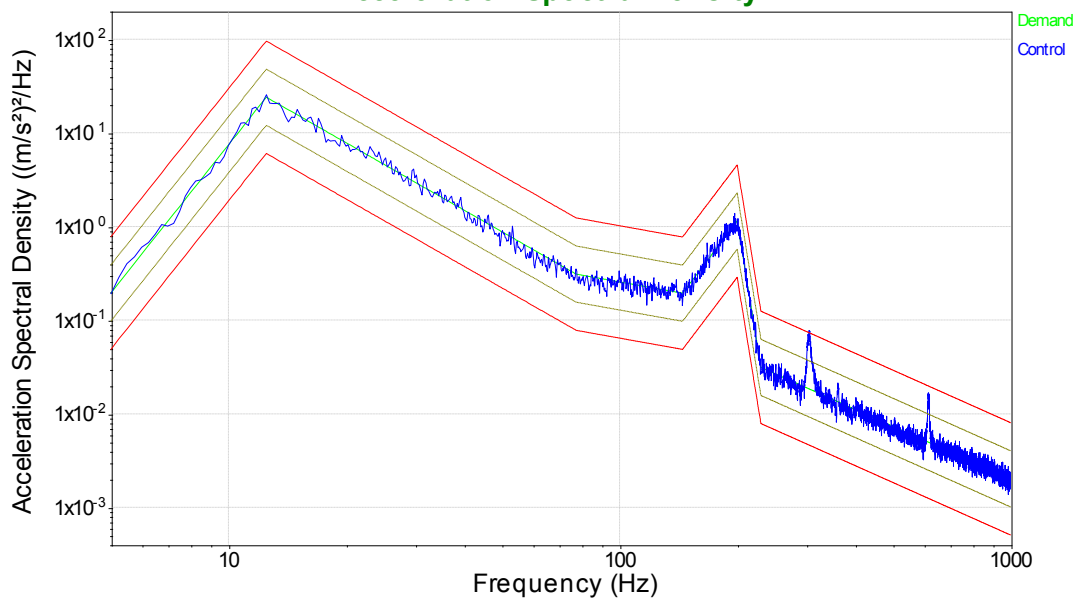


Random Vibration, First Horizontal Axis, Samples 1 to 58



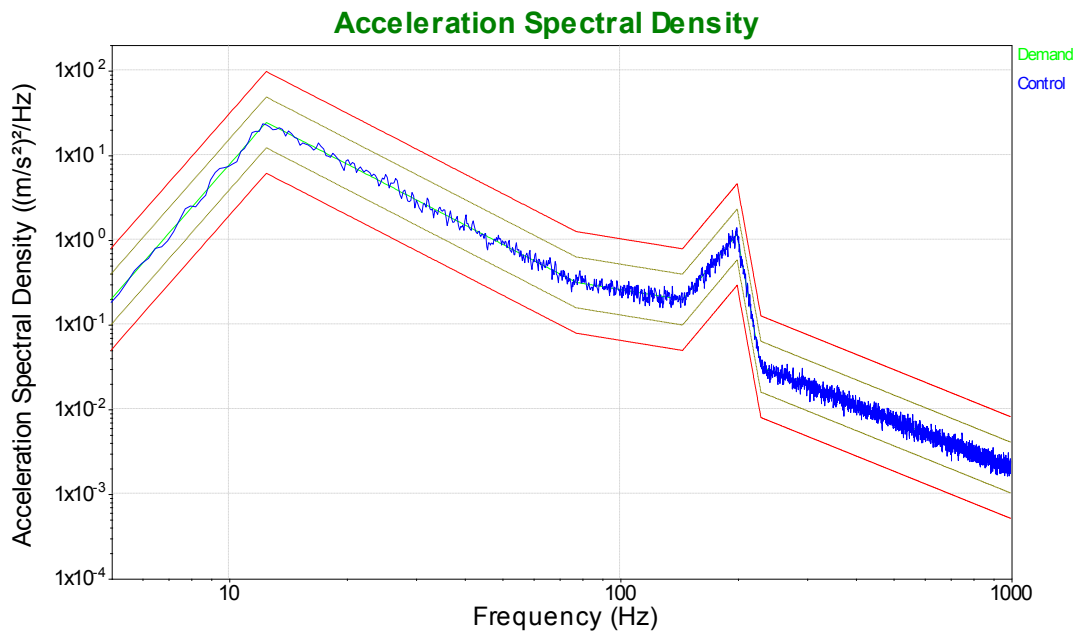
Random Vibration, Second Horizontal Axis, Samples 1 to 58

Acceleration Spectral Density



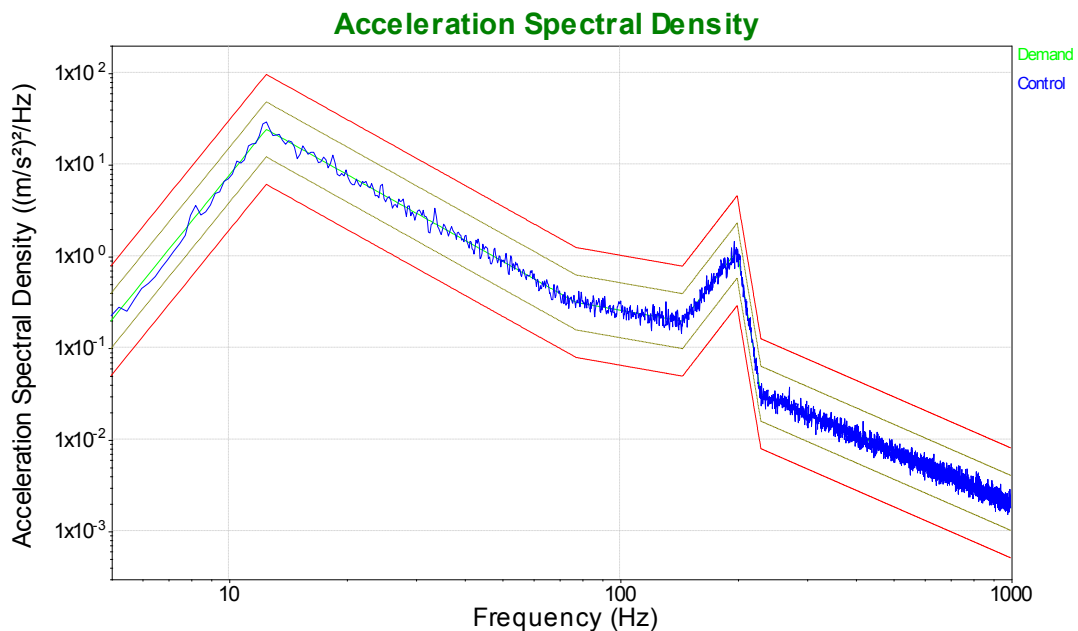
Mar 19, 2020 00:33:32	Level 1) 100 %	Output: 0.2246 Volts RMS	17.74 m/s² RMS Random Vibration
Demand: 17.51 m/s² RMS	Level Time: 8:00:00		Vertical Axis SN 1-58
Control: 17.39 m/s² RMS	Total Time: 8:00:17	End of Test	REMNC EWA106759P

Random Vibration, Vertical Axis, Samples 1 to 58



Mar 19, 2020 10:54:47 Level 1) 100 % Output: 0.1882 Volts RMS 17.74 m/s² RMS Random Vibration
Demand: 17.51 m/s² RMS Level Time: 8:00:00 1st Horizontal Axis SN 1-58
Control: 17.57 m/s² RMS Total Time: 8:00:20 End of Test REMNC EWA106759P

Random Vibration, First Horizontal Axis, Samples 1 to 58



Mar 19, 2020 19:17:55 Level 1) 100 % Output: 0.1847 Volts RMS 17.74 m/s² RMS Random Vibration
Demand: 17.51 m/s² RMS Level Time: 8:00:00 2nd Horizontal Axis SN 1-58
Control: 17.54 m/s² RMS Total Time: 8:00:20 End of Test REMNC EWA106759P

Random Vibration, Second Horizontal Axis, Samples 1 to 58

TEMPERATURE/HUMIDITY

Procedure

The samples were placed into an environmental chamber and positioned ensuring there was no substantial obstruction to the air flow across and around the samples. The samples were not touching each other. The samples were exposed to the following temperature humidity profile for a total of 200 hours. The samples were powered at 1 A continuously during testing.

Step	Mode	Duration	Temperature (°C)	Humidity (% RH)
1	Soak	30 minutes	-40	Uncontrolled
2	Ramp	30 minutes	+85	85
3	Soak	4 hours	+85	85
4	Ramp	30 minutes	+125	Uncontrolled
5	Soak	1 hour 30 minutes	+125	Uncontrolled
6	Ramp	1 hour	-40	Uncontrolled

Repeated steps 1 to 6 above for a total of 25 cycles.

Requirements

No specific criteria.

Results

No visible damage was noted to sample numbers 1 to 58.

Conclusion

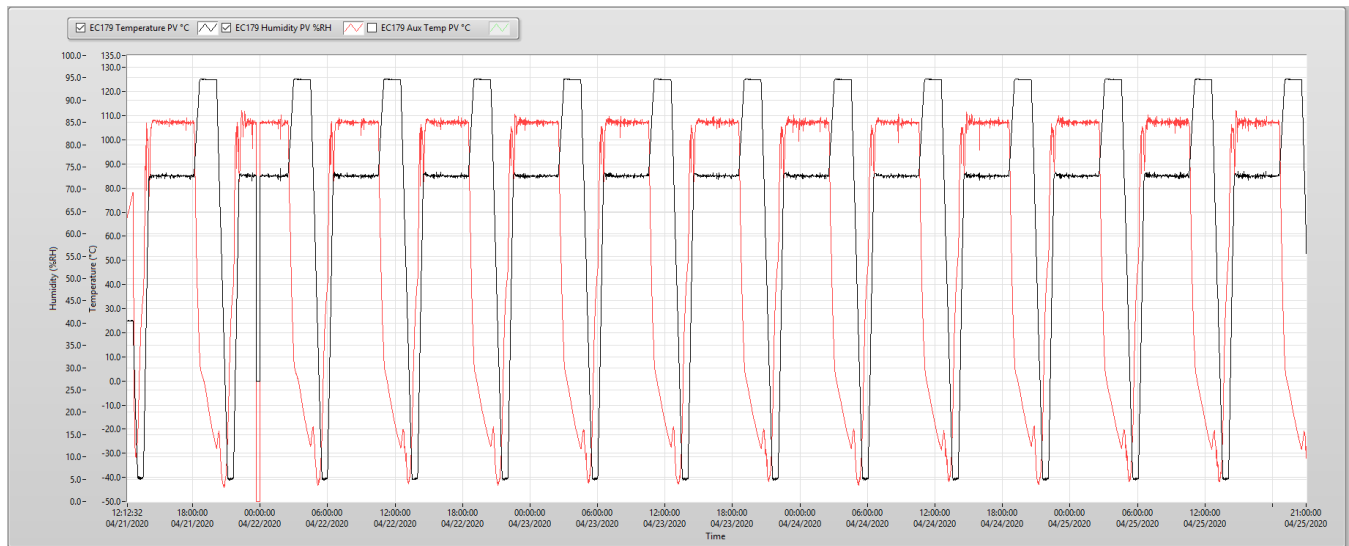
To be determined by REMINC.



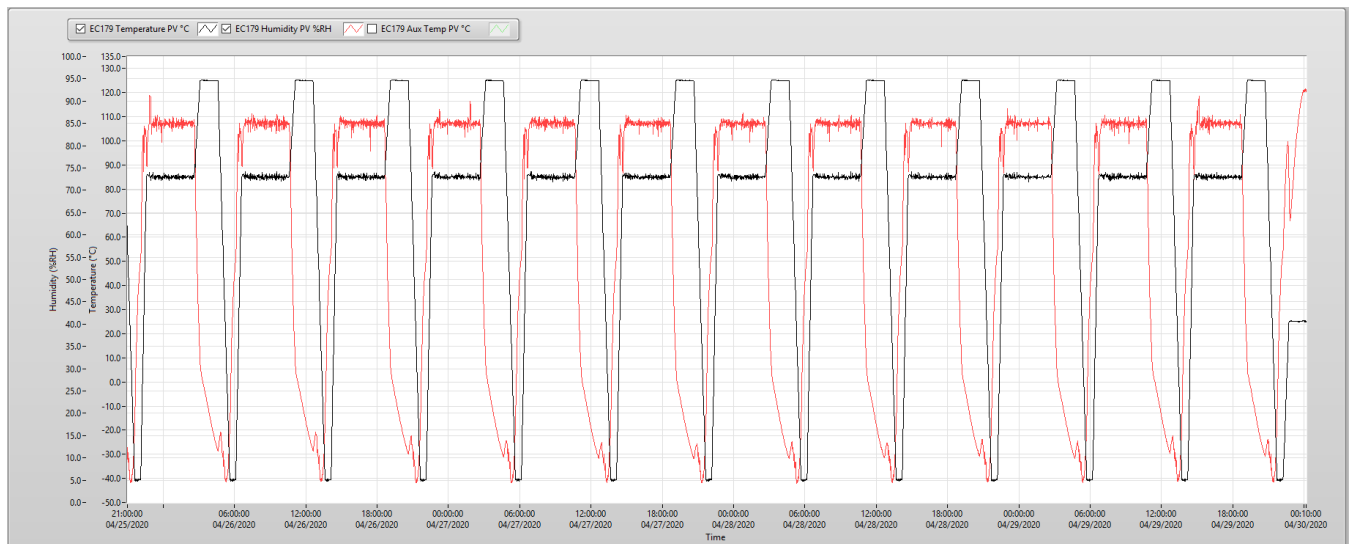
Temperature/Humidity, Samples 1 to 58, Test Setup



Temperature/Humidity, Samples 1 to 58, Post Test



Temperature/Humidity, Samples 1 to 58



Temperature/Humidity, Samples 1 to 58 (Continued)

SALT FOG

Procedure

The salt solution was in accordance with ASTM B117 (18) Section 8. The pH value of the solution was in the range (6.5 to 7.2), at a temperature of $+40^{\circ}\text{C} \pm 2^{\circ}\text{C}$.

All surfaces of the sample were clean and free from oils, greases or other protective materials not part of the design. The samples were mounted in a salt fog chamber. The samples did not contact each other or with other metal parts. The samples were powered at 1 A continuously during test.

The temperature was adjusted to $+40^{\circ}\text{C} \pm 2^{\circ}\text{C}$. The salt mist conditions were maintained in all parts of the exposure zone, such that a clean collecting receptacle with a horizontal collecting area of 80 cm^2 , placed at any point in the exposure zone, collecting between 1.0 ml and 2.0 ml of solution per hour averaged over a minimum period of 16 hours. A minimum of two (2) receptacles were used. The receptacles were placed such that they were not shielded by the samples and so that no condensate from any source was collected.

The samples were exposed to the salt fog atmosphere for 96 hours.

At the completion of the test, the samples were removed from the chamber and allowed to cool to room temperature for approximately 1 to 2 hours. The samples were rinsed with DI water, no warmer than $+38^{\circ}\text{C}$, then allowed to dry at room temperature for 24 hours. The samples were visually inspected. Any anomalies were noted.

The solution collected during the test, was measured to verify that the concentration of the solutions equaled $5 \pm 1\%$ and the pH was within the range of 6.5 to 7.2.

Requirements

Per USCAR-26:

Samples shall not exhibit heavy corrosion that could result in mechanical or electrical failure.

Results

Average Temperature: +40°C
Average pH: 6.8
Average Specific Gravity: 1.032 at +24.0°C
Average Collection Rate: 1.5 ml/hr

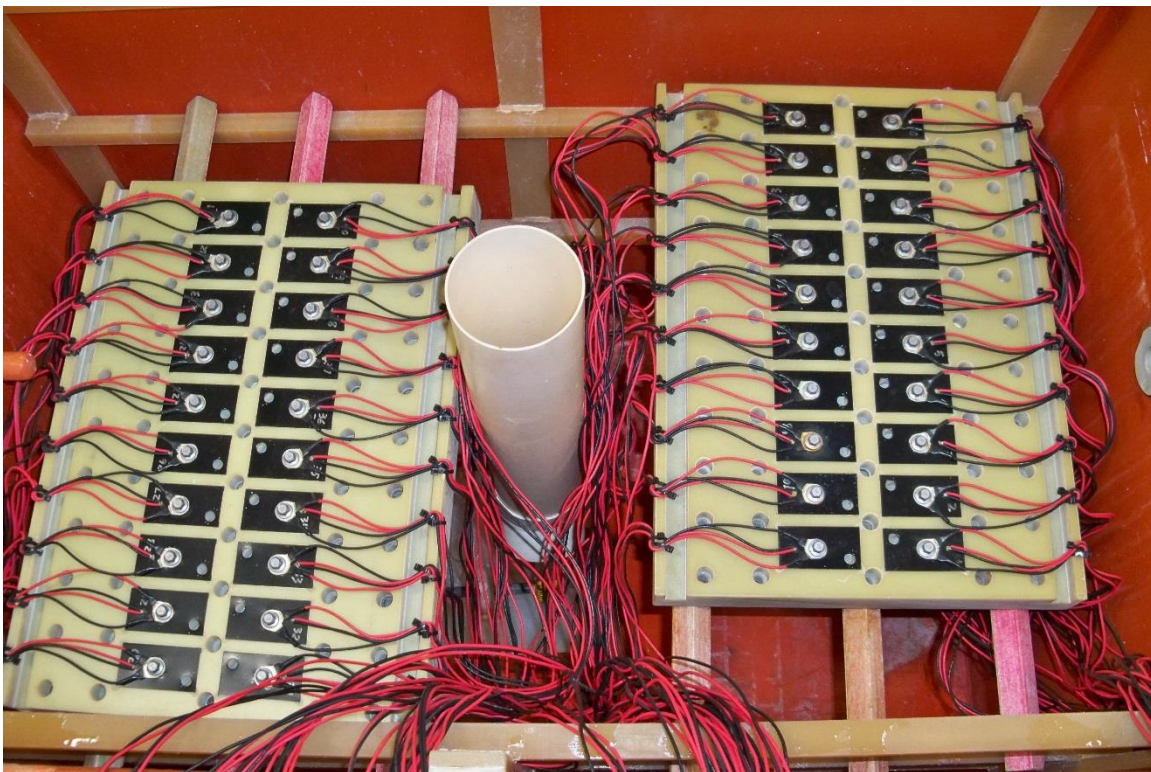
No heavy corrosion was noted on sample numbers 1 to 58. No corrosion that could result in mechanical or electrical failure.

Conclusion

The test samples met the requirements specified.



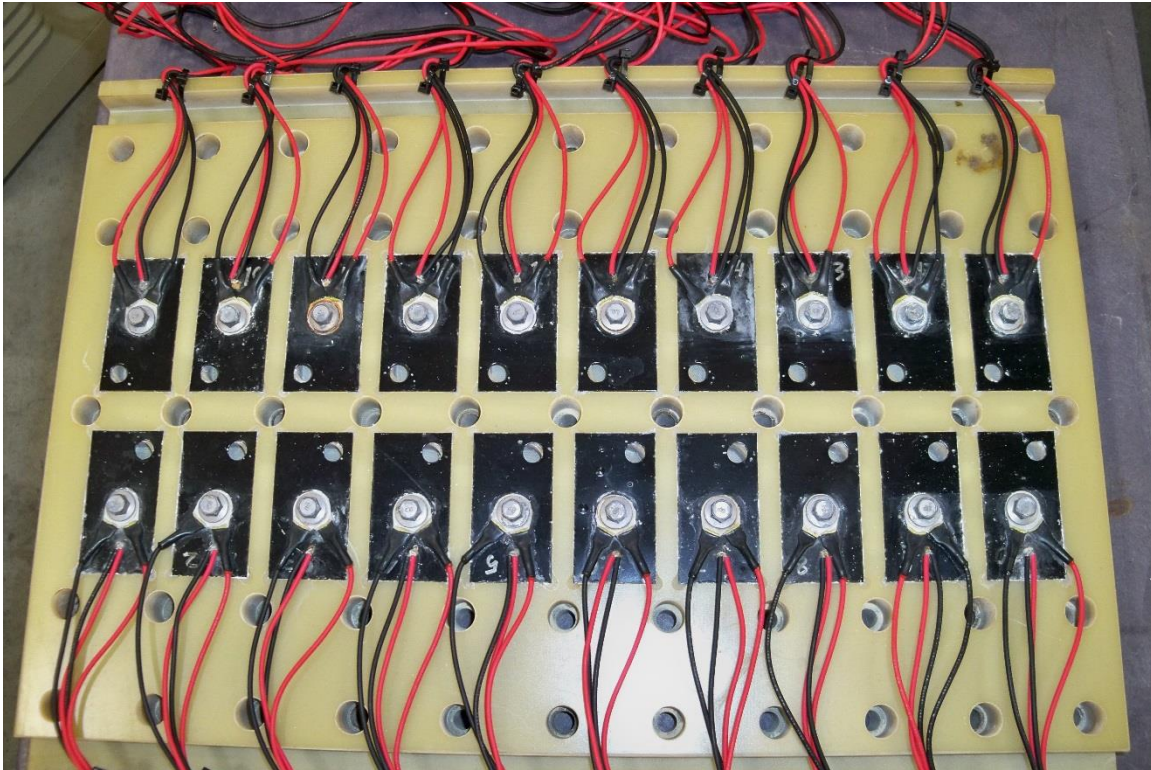
Salt Fog, Test Setup



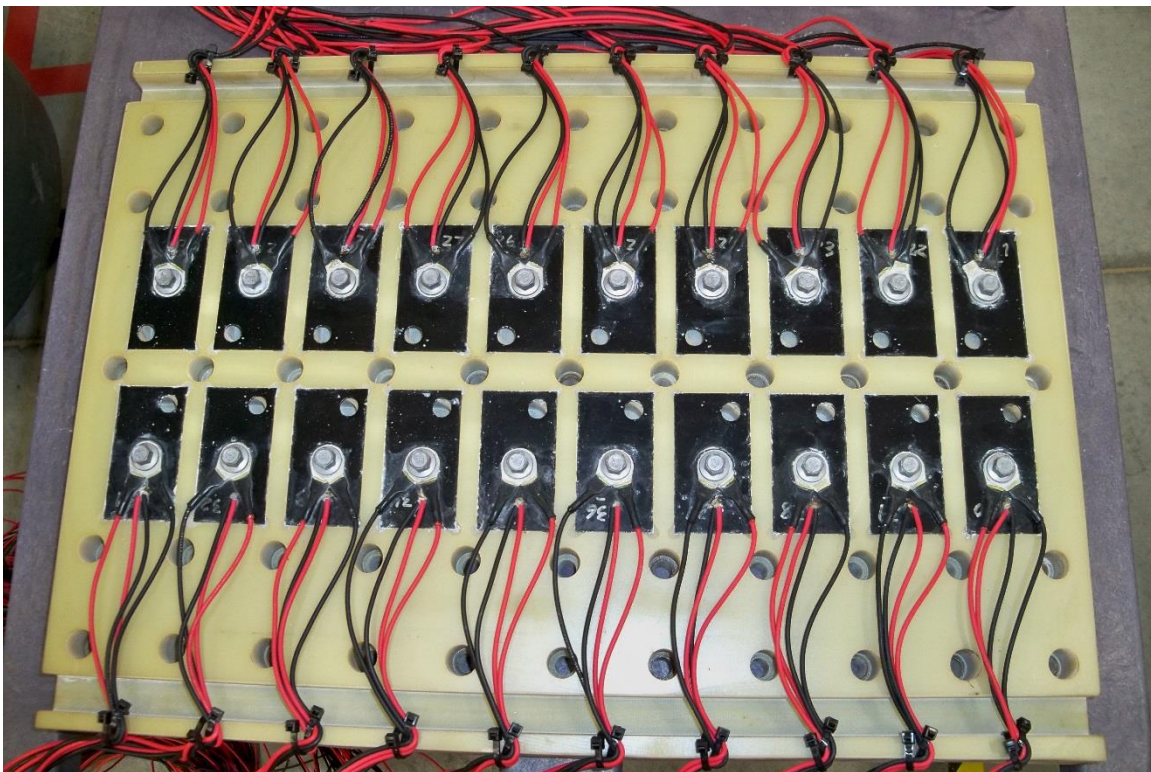
Salt Fog, Samples 1 to 40 in Salt Fog Chamber



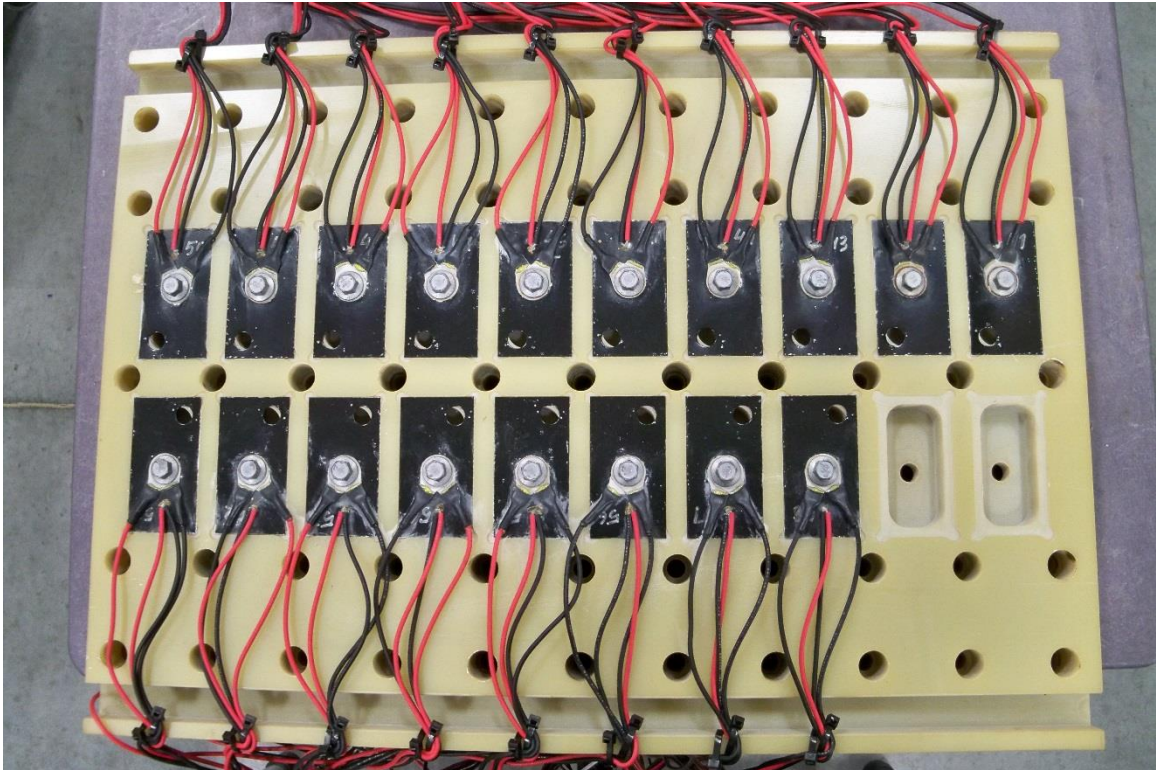
Salt Fog, Samples 41 to 58 in Salt Fog Chamber



Salt Fog, Samples 1 to 20, Post Test



Salt Fog, Samples 21 to 40, Post Test



Salt Fog, Samples 41 to 58, Post Test

TEST EQUIPMENT

All test instruments were calibrated and are traceable to the International System of Units (SI) through a National Measurement Institute such as the National Institute of Standards and Technology (NIST) or through consensus standards. The Element Warren calibration system meets the requirements of ISO 17025:2005.

ID	Description	Manufacturer	Model	Calibration Due
15438	Vibration Controller	Vibration Research	9500	09/04/20
13301	Electro Dynamic Shaker	Unholtz-Dickie	8KB	NCR
12506	Accelerometer	PCB Piezotronics	353B16/ACS-23	08/28/20
16219	Accelerometer	PCB Piezotronics	353B18/ACS-23	07/31/20
14236	Torque Wrench	CDI	3002LDIN (300 in-lbf)	06/27/20
15108	Digital Caliper	Mitutoyo	CD-S6 inch CT	06/05/20
16757	Power Supply	BK Precision	1786B	NCR
09202	Digital Multimeter	Keithley Instruments	2010	06/10/20
15294	Digital Multimeter	Hewlett Packard	3478A	01/17/21
16903	Current Shunt	Crompton	FN-2-50	07/01/21
EC157	Environmental Chamber	Thermotron	ATS-900-H-25-25	05/21/20
EC236	Environmental Chamber	Thermotron	ATS-900-V-25-25-LN	08/12/20
EC179	Environmental Chamber	ESPEC	EMX6-10JA	09/13/20
18088	LXI Data Acquisition/Switch Unit	Keysight Technologies	34972A	10/27/20
17040	LXI Data Acquisition/Switch Unit	Keysight Technologies	34972A	10/26/20
13973	40 Channel Multiplexer Board	Hewlett Packard	34908A	02/10/21
14153	40 Channel Multiplexer Board	Agilent Technologies	34908A	02/10/21
18085	20 Channel Multiplexer Board	Keysight Technologies	34901A	02/11/21
15614	20 Channel Multiplexer Board	Agilent Technologies	34901A	02/11/21
16192	20 Channel Multiplexer Card	Keysight Technologies	34901A	02/11/21
17711	Power Supply	Keysight Technologies	N8734A	NCR
15018	Current Shunt	Ram Meter	200 AMP / 50 mV	08/28/21
EC122	Salt Spray Chamber	Singleton	22	06/04/20
09479	Balance	Friden Alcatel	8620	06/17/20
16981	Hydrometer	HB Instruments / VWR	34620-164	02/04/23

NCR – No Calibration Required

TEST EQUIPMENT (CONTINUED)

ID	Description	Manufacturer	Model	Calibration Due
18267	pH Meter	Extech Instruments	PH100	CBU
18559	pH Buffer (4.005)	Traceable Products	4280	12/27/21
18560	pH Buffer (7.000)	Traceable Products	4281	12/11/21
18564	pH Buffer (10.012)	Traceable Products	4282	11/21/21
08173	Digital Thermometer	Fluke	51	05/28/20
16994	Thermocouple Wire (Type K)	Pyromation	K24-2-516	ICO
16624	Graduated Cylinder	Fisher Scientific	(0 to 100) mL	ICO

ICO – Initial Calibration Only, CBU – Calibrate Before Use

REVISION HISTORY

Rev. #	Description/Changes	Date
0	Initial Release	05/26/20