2D AMPLIVAR* Pigtail Splice Qualification

1. INTRODUCTION

1.1 Purpose

Qualification testing was performed on the TE Connectivity (TE) 2D AMPLIVAR Pigtail Splice in accordance with Product Specification 108-143147, Rev. A and the test request.

1.2 Scope

This report covers the electrical, environmental, and mechanical performance of the TE 2D AMPLIVAR Pigtail Splice. Testing was performed at the Harrisburg Electrical Components Test Laboratory (HECTL) between 16-April-2020 and 28-July-2020. Documentation is on file and maintained at HECTL under EA20200105T.

1.3 Conclusion

All Test Sets met the requirements listed in Product Specification 108-143147 Rev. A.

1.4 Product Description

The 2D Amplivar 9-Serration Open Barrel Pigtail Splice Terminal is designed to splice unstripped copper or aluminum magnet wires together or along with stranded lead wire within a combined total range of 1500-7000 CMA.

1.5 Test Specimens

The test specimens were representative of normal production lots, and the following part numbers in Table 1 were used for testing:

Table 1 – Test Specimens

Test Set	QTY	Part Number	Description
1	10	2238236-1 Rev 4	2D Amplivar Pigtail Splice: Crimped to (2) #29 AWG cu + (1) #26 AWG cu mag CMA 658 @ .052 CH x .130 CW
2	10	2238236-1 Rev 4	2D Amplivar Pigtail Splice: Crimped to (2) #29 AWG cu + (1) #26 AWG lead wire CMA 616 @ .052 CH x .130 CW
3	10	2238236-1 Rev 4	2D Amplivar Pigtail Splice: Crimped to (2) #27 AWG al + (1) #26 AWG cu mag CMA 838 @ .052 CH x .130 CW
4	10	2238236-1 Rev 4	2D Amplivar Pigtail Splice: Crimped to (2) #19 AWG cu + (1) #16 AWG cu mag CMA 5889 @ .083 CH x .130 CW
5	10	2238236-1 Rev 4	2D Amplivar Pigtail Splice: Crimped to (2) #19 AWG cu + (1) #16 AWG lead wire CMA 5580 @ .083 CH x .130 CW
6	10	2238236-1 Rev 4	2D Amplivar Pigtail Splice: Crimped to (2) #17 AWG al + (1) #16 AWG lead wire CMA 7246 @ .083 CH x .130 CW
7	10	2238236-1 Rev 4	2D Amplivar Pigtail Splice: Crimped to (2) #29 AWG cu + (1) #26 AWG cu mag CMA 658 @ .052 CH x .130 CW
8	10	2238236-1 Rev 4	2D Amplivar Pigtail Splice: Crimped to (2) #29 AWG cu + (1) #26 AWG lead wire CMA 616 @ .052 CH x .130 CW
9	10	2238236-1 Rev 4	2D Amplivar Pigtail Splice: Crimped to (2) #27 AWG al + (1) #26 AWG cu mag CMA 838 @ .052 CH x .130 CW

Table 1 – Test Specimens (Continued)

Test Set	QTY	Part Number	Description
10	10	2238236-1 Rev 4	2D Amplivar Pigtail Splice: Crimped to (2) #19 AWG cu + (1) #16 AWG cu mag CMA 5889 @ .083 CH x .130 CW
11	10	2238236-1 Rev 4	2D Amplivar Pigtail Splice: Crimped to (2) #19 AWG cu + (1) #16 AWG lead wire CMA 5580 @ .083 CH x .130 CW
12	10	2238236-1 Rev 4	2D Amplivar Pigtail Splice: Crimped to (2) #17 AWG al + (1) #16 AWG lead wire CMA 7246 @ .083 CH x .130 CW
13	10	2238236-1 Rev 4	2D Amplivar Pigtail Splice: Crimped to (2) #29 AWG cu + (1) #26 AWG cu mag CMA 658 @ .052 CH x .130 CW
14	10	2238236-1 Rev 4	2D Amplivar Pigtail Splice: Crimped to (2) #29 AWG cu + (1) #26 AWG lead wire CMA 616 @ .052 CH x .130 CW
15	10	2238236-1 Rev 4	2D Amplivar Pigtail Splice: Crimped to (2) #27 AWG al + (1) #26 AWG cu mag CMA 838 @ .052 CH x .130 CW
16	10	2238236-1 Rev 4	2D Amplivar Pigtail Splice: Crimped to (2) #19 AWG cu + (1) #16 AWG cu mag CMA 5889 @ .083 CH x .130 CW
17	10	2238236-1 Rev 4	2D Amplivar Pigtail Splice: Crimped to (2) #19 AWG cu + (1) #16 AWG lead wire CMA 5580 @ .083 CH x .130 CW
18	10	2238236-1 Rev 4	2D Amplivar Pigtail Splice: Crimped to (2) #17 AWG al + (1) #16 AWG lead wire CMA 7246 @ .083 CH x .130 CW

1.6 Qualification Test Sequence

The test specimens referred to in paragraph 1.5 were tested according to the test sequences listed in Table 2.

Table 2 - Test Sequence

Test or Examination	Test Set		
	1 to 6	7 to 12	13 to 18
	Test Sequence (a)		
Examination of Product	1, 11	1, 5	1, 3
Low Level Contact Resistance	2, 6, 9	2, 4	
Temperature Rise vs Current	3, 10		
Temperature Life	4		
Thermal Shock	5		
Humidity Exposure	7		
Random Vibration	8		
Current Cycling		3	
Termination Tensile Strength			2

Note: (a) Numbers indicate sequence in which tests were performed.

1.7 Environmental Conditions

Unless otherwise stated, the following environmental conditions prevailed during testing:

Temperature: 15°C to 35°C
Relative Humidity 20% to 80%

2. SUMMARY OF TESTING

2.1 Initial Examination of Product – All Test Sets

A C of C was issued stating that all specimens in this test package were produced, inspected, and accepted as conforming to product drawing requirements, and were manufactured using the same core manufacturing processes and technologies as production parts. Where specified, specimens were visually examined and no evidence of physical damage detrimental to product performance was observed.

2.2 Low Level Contact Resistance – Test Sets 1 to 12

Resistance measurements of all specimens met the maximum requirements listed in the Product Specification. See Table 3 and Table 4 for a summary of the test results.

Table 3 – Low Level Contact Resistance Summary Results in milli-Ohms – Test Sets 1 to 6

	Initial	After Thermal Shock	Final	Initial	After Thermal Shock	Final
Test Set	**Test Set 1**					
Wire Type	**#29 AWG (cu mag wire) – 18.0 mΩ Max**			**#26 AWG (cu mag wire) – 9.1 mΩ Max**		
Minimum	10.586	10.804	10.888	5.537	5.599	5.689
Maximum	12.374	12.578	12.860	6.032	6.228	6.334
Average	11.419	11.688	11.786	5.733	5.829	5.944
Count	20	20	20	10	10	10
Test Set	**Test Set 2**					
Wire Type	**#29 AWG (cu mag wire) – 18.0 mΩ Max**			**#26 AWG (stranded wire) – 9.1 mΩ Max**		
Minimum	9.754	10.966	10.994	4.748	4.920	4.887
Maximum	12.944	13.036	13.194	6.097	6.500	6.147
Average	11.333	11.820	12.058	5.352	5.382	5.402
Count	20	20	20	10	10	10
Test Set	**Test Set 3**					
Wire Type	**#27 AWG (al mag wire) – 20.0 mΩ Max**			**#26 AWG (cu mag wire) – 9.1 mΩ Max**		
Minimum	8.786	8.980	9.272	5.006	5.667	5.714
Maximum	11.686	10.518	11.568	6.190	6.321	6.671
Average	9.791	9.833	9.998	5.768	5.944	6.063
Count	20	20	18 (a)	10	10	10
Test Set	**Test Set 4**					
Wire Type	**#19 AWG (cu mag wire) – 2.2 mΩ Max**			**#16 AWG (cu mag wire) – 1.6 mΩ Max**		
Minimum	1.108	1.114	1.146	0.553	0.565	0.592
Maximum	1.256	1.392	1.462	0.626	0.642	0.687
Average	1.167	1.213	1.271	0.586	0.601	0.640
Count	20	20	20	10	10	10
Test Set	**Test Set 5**					
Wire Type	**#19 AWG (cu mag wire) – 2.2 mΩ Max**			**#16 AWG (stranded wire) – 1.6 mΩ Max**		
Minimum	0.976	1.128	1.164	0.566	0.569	0.569
Maximum	1.226	1.270	1.336	0.634	0.700	0.690
Average	1.148	1.198	1.252	0.594	0.607	0.615
Count	20	20	20	10	10	10
Test Set	**Test Set 6**					
Wire Type	**#17 AWG (al mag wire) – 3.6 mΩ Max**			**#16 AWG (stranded wire) – 1.6 mΩ Max**		
Minimum	0.990	1.038	1.024	0.571	0.597	0.598
Maximum	1.264	1.290	1.438	0.656	0.688	0.753
Average	1.108	1.140	1.189	0.599	0.629	0.641
Count	20	20	19 (b)	10	10	10

(a) Two positions were unable to be read due to a broken wire caused by improper crimping
(b) One position was unable to be read due to a broken wire caused by improper crimping

Table 4 – Low Level Contact Resistance Summary Results in milli-Ohms – Test Sets 7 to 12

	Initial	After 5,000 Thermal Cycles	Final	Initial	After 5,000 Thermal Cycles	Final
Test Set	**Test Set 7**					
Wire Type	**#29 AWG (cu mag wire) – 18.0 mΩ Max**			**#26 AWG (cu mag wire) – 9.1 mΩ Max**		
Minimum	10.782	10.872	10.964	5.019	5.429	5.400
Maximum	11.656	11.598	11.776	5.900	5.859	5.785
Average	11.310	11.335	11.371	5.611	5.689	5.639
Count	20	20	20	10	10	10
Test Set	**Test Set 8**					
Wire Type	**#29 AWG (cu mag wire) – 18.0 mΩ Max**			**#26 AWG (stranded wire) – 9.1 mΩ Max**		
Minimum	10.864	10.918	9.526	4.771	4.783	5.423
Maximum	12.032	12.156	12.07	5.853	5.301	5.953
Average	11.382	11.514	10.722	5.115	5.027	5.725
Count	20	20	20	10	10	10
Test Set	**Test Set 9**					
Wire Type	**#27 AWG (al mag wire) – 20.0 mΩ Max**			**#26 AWG (cu mag wire) – 9.1 mΩ Max**		
Minimum	7.728	9.052	9.286	4.271	5.611	5.641
Maximum	12.828	11.010	11.418	6.076	6.072	6.041
Average	9.561	9.656	9.752	5.673	5.831	5.832
Count	20	20	20	10	10	10
Test Set	**Test Set 10**					
Wire Type	**#19 AWG (cu mag wire) – 2.2 mΩ Max**			**#16 AWG (cu mag wire) – 1.6 mΩ Max**		
Minimum	0.956	1.118	1.132	0.566	0.576	0.568
Maximum	1.254	1.290	1.288	0.608	0.616	0.618
Average	1.165	1.191	1.198	0.590	0.596	0.587
Count	20	20	20	10	10	10
Test Set	**Test Set 11**					
Wire Type	**#19 AWG (cu mag wire) – 2.2 mΩ Max**			**#16 AWG (stranded wire) – 1.6 mΩ Max**		
Minimum	1.122	1.110	1.104	0.553	0.566	0.565
Maximum	1.238	1.246	1.224	0.629	0.606	0.601
Average	1.179	1.180	1.171	0.580	0.588	0.585
Count	20	20	20	10	10	10
Test Set	**Test Set 12**					
Wire Type	**#17 AWG (al mag wire) – 3.6 mΩ Max**			**#16 AWG (stranded wire) – 1.6 mΩ Max**		
Minimum	1.008	1.008	1.004	0.565	0.577	0.565
Maximum	1.190	1.336	1.222	0.632	0.641	0.645
Average	1.082	1.109	1.094	0.599	0.604	0.605
Count	20	20	20	10	10	10

2.3 Temperature Rise vs Current – Test Sets 1 to 6

Temperature rise measurements all met the 30°C maximum temperature rise requirement listed in the Product Specification. See Table 5 for detailed test results.

Table 5 – Temperature Rise vs Current Summary Results in °C – Test Sets 1 to 6

Test Set	Test Set 1		Test Set 2		Test Set 3		Test Set 4		Test Set 5		Test Set 6	
Run	**Initial**	**Final**	**Initial**	**Final**	**Initial**	**Final**	**Initial**	**Final**	**Initial**	**Final**	**Initial**	**Final**
Minimum	11.80	12.20	10.59	10.61	11.60	12.18	14.70	13.44	14.54	12.39	13.50	12.65
Maximum	16.63	25.13	12.79	13.35	15.39	17.72	17.95	18.61	16.65	19.21	16.99	23.32
Average	14.14	14.41	11.81	12.00	13.58	14.13	17.11	16.66	15.69	16.61	15.22	16.78
Count	10	10	10	10	10	10	10	10	10	10	10	10

2.4 Temperature Life – Test Sets 1 to 6

No apparent physical damage detrimental to product performance was visible due to exposure to temperature life.

2.5 Thermal Shock – Test Sets 1 to 6

No apparent physical damage detrimental to product performance was visible due to exposure to Thermal Shock.

2.6 Humidity Exposure – Test Sets 1 to 6

No apparent physical damage detrimental to product performance was visible due to Humidity Exposure.

2.7 Random Vibration – Test Sets 1 to 6

No apparent physical damage detrimental to product performance was visible and no discontinuities of one microsecond or greater occurred during Random Vibration.

2.8 Current Cycling – Test Sets 7 to 12

No apparent physical damage detrimental to product performance was visible due to Current Cycling.

2.9 Termination Tensile Strength – Test Sets 13 to 18

All specimens met the minimum tensile strength requirements listed in the Product Specification. The failure mode for all specimens was either the conductor breaking outside the crimp area or the conductor breaking in the crimp area. See Table 6 and Table 7 for a summary of the test results.

Table 6 – Termination Tensile Strength Summary Results in lbs. – Test Sets 13, 14, & 15

Test Set	Test Set 13		Test Set 14		Test Set 15	
Wire Type	#29 AWG (cu mag wire)	#26 AWG (cu mag wire)	#29 AWG (cu mag wire)	#26 AWG (stranded wire)	#27 AWG (al mag wire)	#26 AWG (cu mag wire)
Requirement	2.1lbs Min	4.2lbs Min	2.1lbs Min	4.2lbs Min	1.2lbs Min	4.2lbs Min
Minimum	2.61	6.96	3.68	5.54	1.31	7.03
Maximum	3.96	7.99	3.95	8.78	3.10	8.03
Mean	3.43	7.69	3.87	7.37	2.64	7.70
Count	20	10	20	10	20	10

Table 7 – Termination Tensile Strength Summary Results in lbs. – Test Sets 16, 17, & 18

Test Set	Test Set 16		Test Set 17		Test Set 18	
Wire Type	#19 AWG (cu mag wire)	#16 AWG (cu mag wire)	#19 AWG (cu mag wire)	#16 AWG (stranded wire)	#17 AWG (al mag wire)	#16 AWG (stranded wire)
Requirement	23.1lbs Min	46.2lbs Min	23.1lbs Min	46.2lbs Min	11.9lbs Min	46.2lbs Min
Minimum	34.13	57.77	34.71	48.18	17.38	53.49
Maximum	34.98	75.49	35.02	56.24	22.46	66.50
Mean	34.75	66.75	34.90	51.35	20.83	62.04
Count	20	10	20	10	20	10

2.10 Final Examination of Product – All Test Sets

Specimens were visually examined with the unaided eye for signs of physical damage detrimental to product performance. Some specimens were found to have damaged magnet wire or individual lead wire strands at the entrance to the crimp interface. It was determined that the damage was caused to these particular specimens by improper wire placement during the sample preparation crimping process and subsequent readings not able to be acquired. All other test specimens were determined to be crimped properly. Testing was performed in accordance with EIA-364-18B.

3. TEST METHODS

3.1. Initial Examination of Product

Specimens were visually examined for physical damage that could be detrimental to product performance in accordance with Test Procedure EIA 364-18B and the test request.

3.2 Low Level Contact Resistance

Specimens were subjected to low level contact resistance in accordance with Test Procedure EIA 364-23C and the test request. See Figure 1 and Figure 2 for representative images of the test setup.

Resistance measurements were made using a four-terminal measuring technique. A 20-millivolt maximum open circuit voltage and 100-milliamp maximum current were used. Equalizer wires were soldered 1.5 inches from the terminal measurement point. Mini-grabbers were applied to the lead-in wires for the source current. Voltage was sensed using a hand-probe on the terminal measurement point and a micro-grabber attached to the equalizer wire.

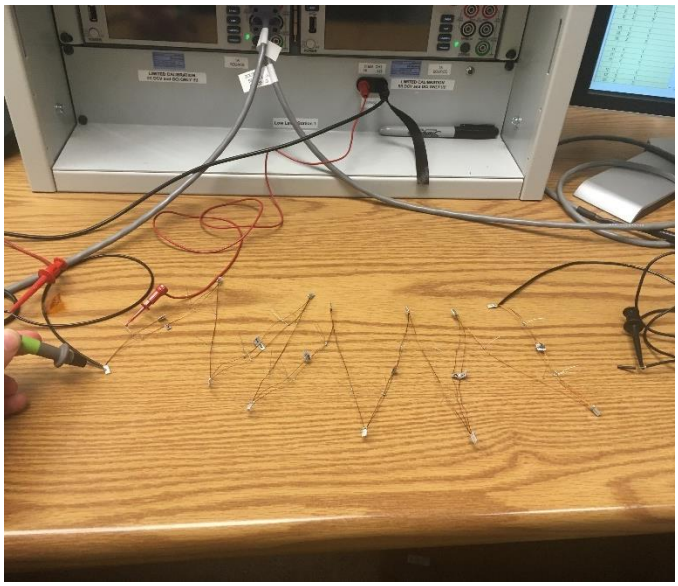

Figure 1 – Low Level Contact Resistance Test Setup

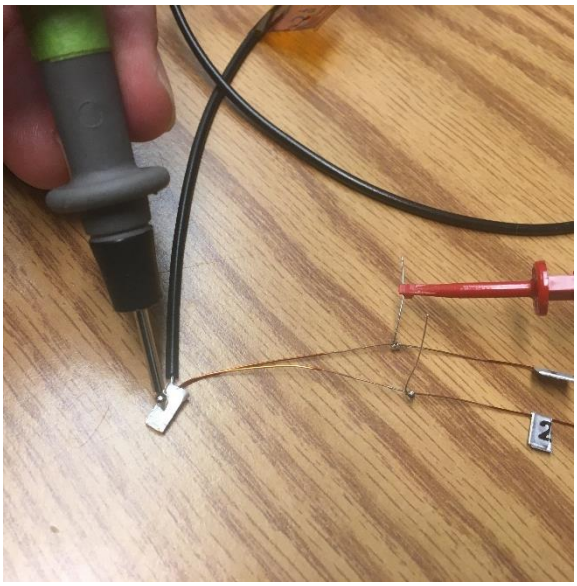

Figure 2 – Low Level Contact Resistance Test Setup – Close Up

3.3 Temperature Rise vs Current

Specimens were subjected to temperature rise in accordance with Test Procedure EIA 364-70C, Method I and the test request. See Figure 3 for a representative image of the test setup.

Each specimen was prepared using a beaded 36-inch length of 30 AWG, type T thermocouple attached to the flat side of the terminal.

A specimen chain was connected to a power supply and placed in free air suspension. The specimens were then connected to a data acquisition station to monitor temperature. A thermocouple for ambient temperature was placed in the center of the temperature rise enclosure. A 3.5 Amp current was applied to the specimens from Test Sets 1, 2, & 3, while a 14 Amp current was applied to specimens 4, 5, & 6. When each temperature reached stability, 3 consecutive readings taken at 5-minute intervals not differing by more than 1°C, the temperature measurements were recorded. This procedure was repeated for each specimen chain applying the appropriate current.

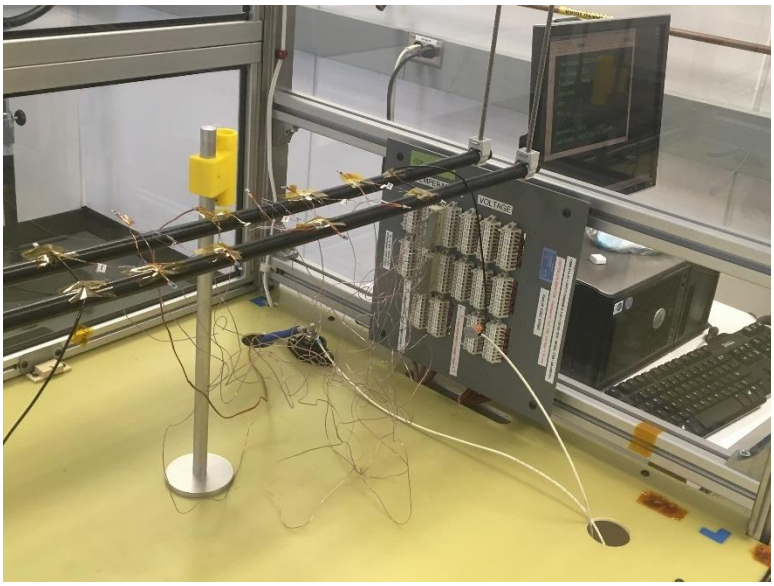

Figure 3 – Temperature Rise Test Setup

3.4 Temperature Life

Specimens were subjected to temperature life in accordance with Test Procedure EIA 364-17C and the test request. Specimens were subjected to 150 °C for 96 hours.

3.5 Thermal Shock

Specimens were subjected to thermal shock in accordance with Test Procedure EIA 364-32G and the test request. Specimens were subjected to 50 cycles between -65 °C and +150 °C with 30 minute dwell times at each temperature extreme.

3.6 Humidity Exposure

Specimens were subjected to humidity exposure in accordance with Test Procedure EIA 364-31F and the test request. Specimens were subjected to 96 hours at 90-95% RH and 40 °C.

3.7 Random Vibration

Specimens were subjected to random vibration in accordance with Test Procedure EIA 364-28F, Test Condition VII, Test Condition Letter D and the test request. See Figures 4 to 6 for representative images of the test setup.

The parameters of this test condition are specified by a random vibration spectrum with excitation frequency bounds of 20 and 500 Hertz (Hz). The spectrum remains flat at 0.02 G^2/Hz from 20 Hz to the upper bound frequency of 500 Hz. The root-mean square amplitude of the excitation was 3.1 GRMS. The test specimens were subjected to this test for 3 hours in each of the three mutually perpendicular axes, for a total test time of 9 hours per test specimen. The test specimens were monitored for discontinuities of 1 microsecond or greater using an energizing current of 100 milliamperes.

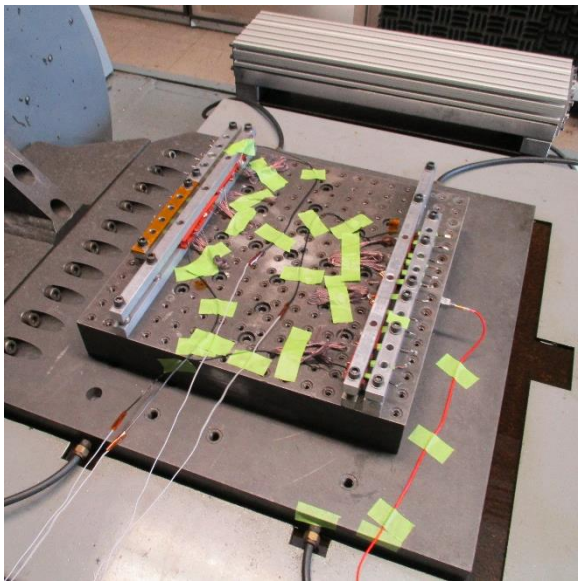

Figure 4 – Random Vibration Test Setup

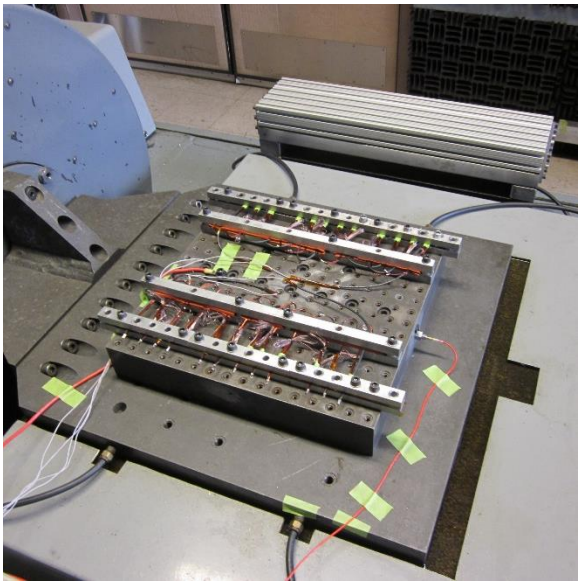

Figure 5 – Random Vibration Test Setup

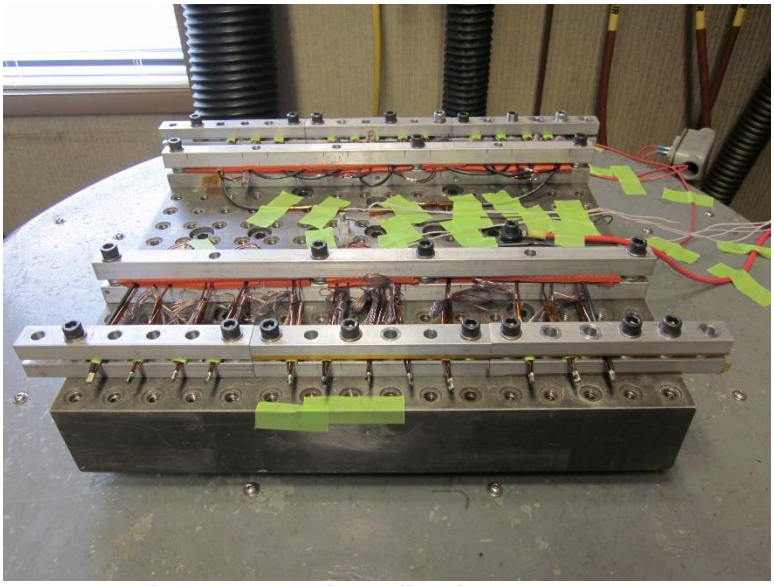

Figure 6 – Random Vibration Test Setup

3.8 Current Cycling

Specimens were subjected to current cycling in accordance with the EIA 364-55B. See Figure 7 for a representative image of the test setup.

A specimen chain was connected to a power supply and placed on risers 2” from the surface in air-flow free room. The specimens were then connected to a data acquisition station to monitor temperature. A thermocouple for ambient temperature was placed in the center of the specimen chain.

Specimens were then subjected to 10,000 cycles of 3 minutes on with the specified current applied and 3 minutes off. A 7.5 Amp current was specified for specimens from Test Sets 1, 2, & 3 during the on cycle, while a 28 Amp current was specified for specimens 4, 5, & 6. Low level contact resistance readings were taken every 5,000 cycles.

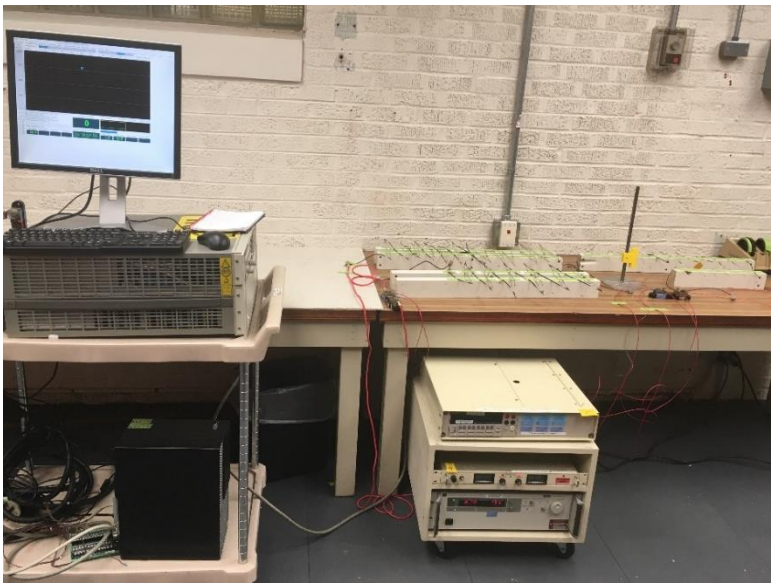

Figure 7 – Current Cycling Test Setup

3.9 Termination Tensile Strength

Specimens were subjected to a termination tensile strength test with a tensile / compression machine in accordance with Test Procedure EIA 364-08C and the test request. See Figure 8 and Figure 9 for representative images of the test setup.

The specimen was held in a vice with “L” shaped jaws attached a an XYR alignment table secured to the base of the tensile / compression machine. The wire was held in a wire clamping fixture attached to the load cell and crosshead of the tensile / compression machine. The crosshead was raised at a rate of 25 mm/min until separation of the wire from the splice occurred. The peak tensile force, the force graph, and the separation mode were recorded. The smaller gauge of magnet wires in each splice were pulled first.

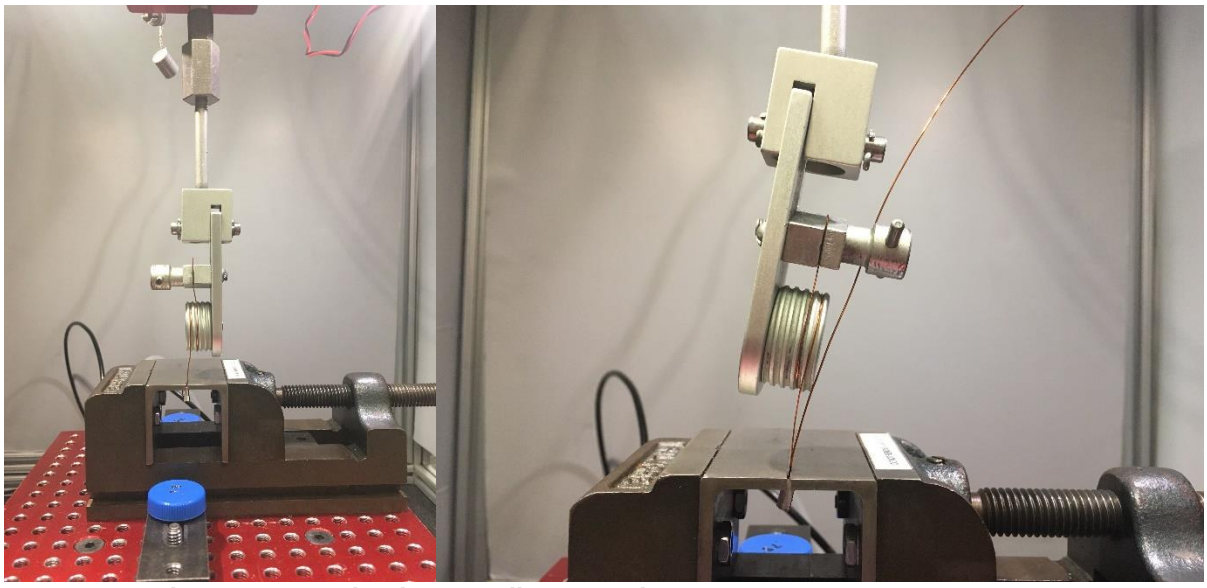

Figure 8 – Termination Tensile Strength Test Setup – Test Sets 13 to 15

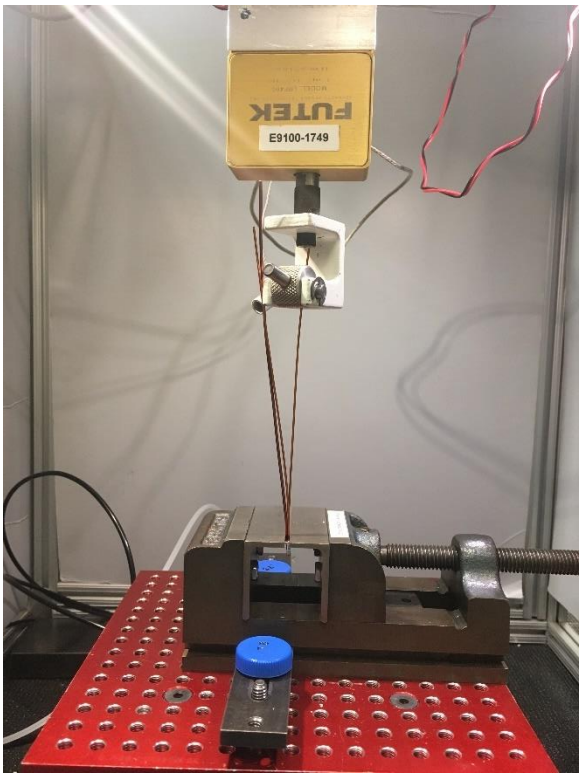

Figure 9 – Termination Tensile Strength Test Setup – Test Sets 16 to 18

3.10 Final Examination

Specimens were visually examined for physical damage that could be detrimental to product performance in accordance with Test Procedure EIA 364-18B and the test request.