ELECTROMAGNETIC INTERFERENCE (EMI) SOLUTIONS FOR HYBRID ELECTRIC VEHICLES

Comparison of Connector Performance for Automotive EMI Bundle Shielding Cables

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INTRODUCTION

Hybrid and Electric Vehicles have been growing at a higher rate than the total automotive industry for the last decade. Manufacturers continue to innovate with increased motor performance, stronger batteries and new features to meet the changing market demands. As more electronic components and electric power vehicles are introduced, one area of concern is electromagnetic interference or EMI. EMI is defined as a disturbance generated by an external source that affects an electrical circuit by electromagnetic induction, electrostatic coupling or conduction. This whitepaper will focus on a common disturbance point where EMI is generated: The Connector.

Through a series of tests simulating ground vehicle performance over 100,000 miles, we will evaluate attaching common wire braid sheathing to three simulated connector fixtures with four different stainless steel connector bands. Each connector band was tested using test standard EIA-364-83 -- Shell-to-shell resistance test procedure for electrical connectors – Pre and Post Test resistance values were recorded.

Vibration Testing

Random vibration testing was performed on a total of 12 test samples in accordance with MIL-STD-810G. For this testing, each sample was exposed to the vibration profile for 100,000 miles in each of the three mutually perpendicular axes.

Thermal Shock / Thermal Cycling Testing

Thermal Cycling testing was performed on a total of twelve test samples in accordance with MIL-STD-810G. The Temperature range was cycled between 71C to -51C.

Axial Pull Test to Destruction of Braid (Band Strength)

This test determined the amount of force required to render the protective braid unfit. The maximum force was recorded rendering the strength of the band in this test fixture application. The two groups of twelve samples were tested after the Vibration and Thermal Cycling testing were completed.

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THE ULTIMATE FASTENING SYSTEMS

METHODOLOGY

Compare the performance characteristics of four different band connectors evaluating the effects of random vibration and thermal shock on shell-to-shell conductivity, and axial pull strength of the different bands when attached to an aluminum fixture.

The wire braid sheathing will be attached to the connector analogs utilizing one of four different metal bands. One complete test group will have 12 variations. There are two test groups. One will be subjected to the random vibration and then axial pull tested and the other will be subjected to the thermal shock and then axial pull tested. Post vibration or thermal test an axial pull maximum pound-force will be recorded.

BAND-IT Bands Used in Test

Mini Tie-Lok Tie
0.177" width
304 Stainless Steel

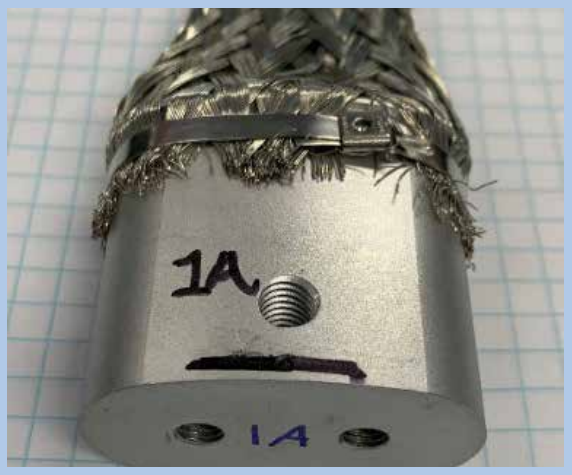
1/4" Tie-Lok Tie
0.25" width
304 Stainless Steel

1/4" Preformed Universal Clamp
0.25" width
201 Stainless Steel

1/4" Preformed Junior Clamp
0.25" width
304 Stainless Steel

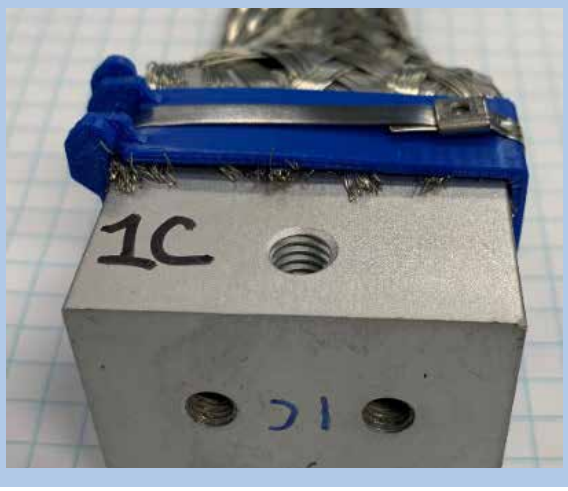
Simulated Fixtures

Large Oval



Small Oval

Rectangular



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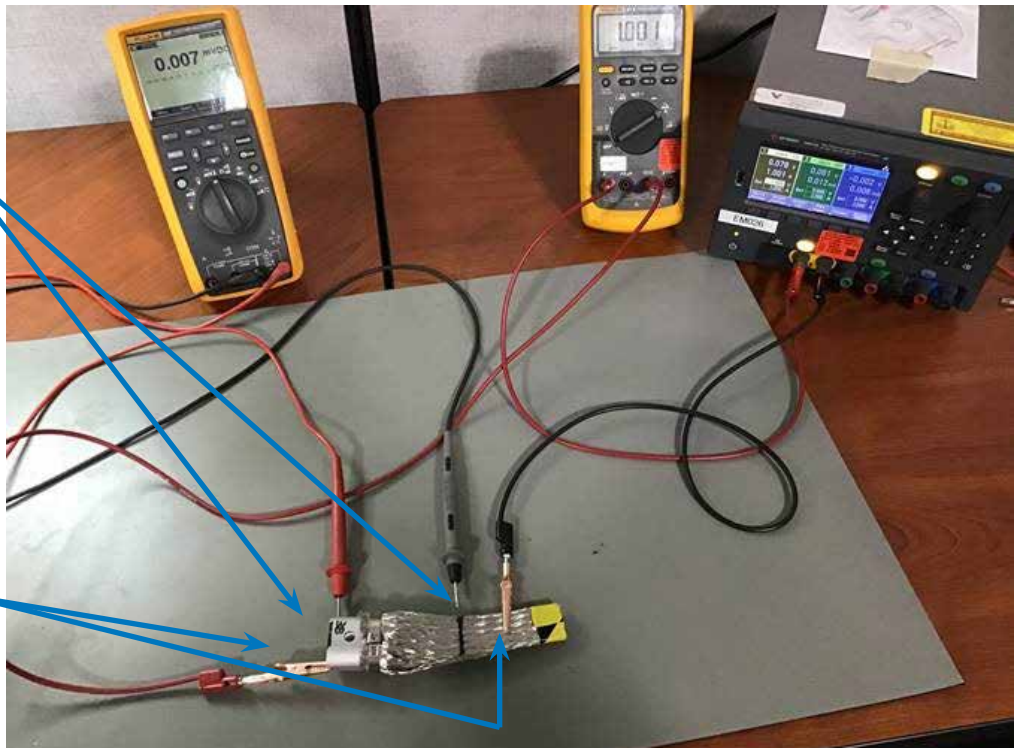
Cable Shield / Cable Braid Sheathing
The sheathing used to test the Shell-to-Shell Conductivity and Axial pull follows AS84049C, Connector accessories, Electrical General Specification.
See Figure A.

Shell to Shell Resistance Procedure
Shell conductivity was measured in accordance with EIA 364-83. The applied potential shall be 1.5 Volts maximum. A resistance shall be inserted in the circuit to limit the current to 1.0 amperes +/- 0.1 amperes. Measurements shall be made from a point on the overall cable shield located 1.0 inch +/- 0.25 inch to the rear of the connector accessory, to the point on the fixture shape / back shell flange as specified in EIA 364-83.

Each band was tested on the three fixture shapes / back shell prior to performing the test and after the test was complete providing a table of Pre and Post test results. All readings were measured in milliohms mΩ.

Figure A



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Random Vibration Testing

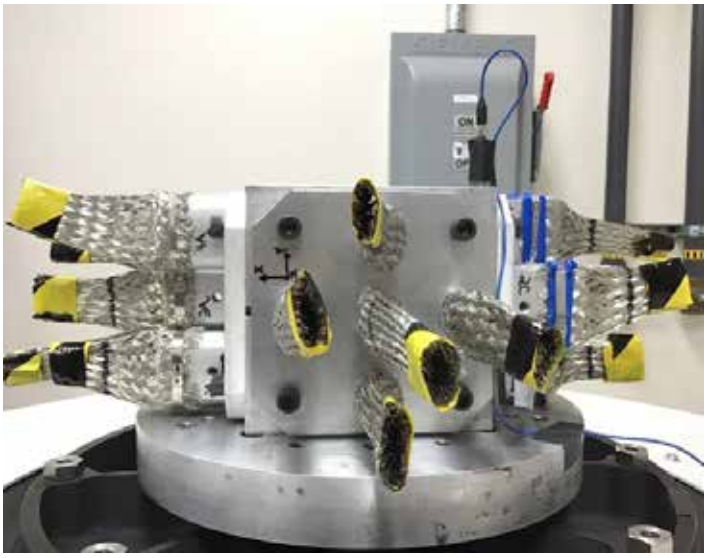
Random vibration testing was performed on a total of 12 test samples in accordance with MIL-STD-810G. For this testing, each sample was exposed to the vibration profile for 100k miles in each of the three mutually perpendicular axes.

The table below highlights the three access planes the vibration test was conducted.

Table 514.8C-VII. Category – 4 – Composite wheeled vehicle vibration exposure. (Break points for curves of Figure 514.8C-6.)

Vertical		Transverse		Longitudinal	
Frequency, Hz	ASD, g^2/Hz	Frequency, Hz	ASD, g^2/Hz	Frequency, Hz	ASD, g^2/Hz
5	0.12765	5	0.04070	5	0.01848
6	0.12926	6	0.04415	6	0.02373
7	0.30000	7	0.11000	7	0.05000
8	0.30000	8	0.11000	8	0.05000
9	0.10000	9	0.04250	9	0.02016
12	0.10000	12	0.04250	12	0.02016
14	0.15000	14	0.07400	14	0.05000
16	0.15000	16	0.07400	16	0.05000
19	0.04000	19	0.02000	19	0.01030
90	0.00600	100	0.00074	23	0.01030
125	0.00400	189	0.00130	25	0.00833
190	0.00400	350	0.00400	66	0.00114
211	0.00600	425	0.00400	84	0.00107
440	0.00600	482	0.00210	90	0.00167
500	0.00204	500	0.00142	165	0.00151
				221	0.00333
				455	0.00296
				500	0.00204
rms = 2.24 g		rms = 1.45 g		rms = 1.32 g	

Vibration Test Setup



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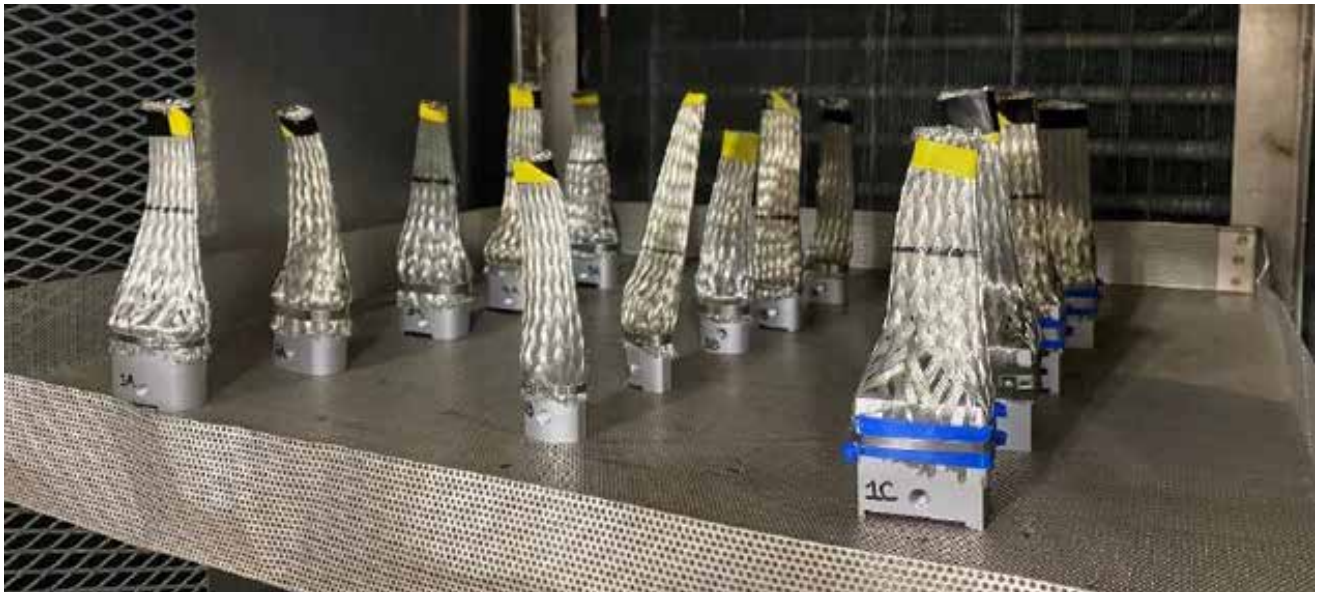
Thermal Cycling / Thermal Shock Testing

Thermal Cycling testing was performed on a total of twelve test samples in accordance with MIL-STD-810G. The Temperature range was cycled between 71C to -51C.

For this testing, each sample was exposed to 3 cycles with a transfer time of less than 1 minute, with 1-hour soak at each temperature extreme.



Temperature Chamber

Axial Pull Test to Destruction of Braid (Band Strength)

Test fixtures were mounted on fixture in an appropriate tensile testers for braid retention testing to destruction. The connector was mounted to the base of the tensile tester and the braid clamped on the opposing actuated side of the tester. The braid was pulled at 1 inch / minute until a significant failure with the braid or the band becomes apparent with the load and position data recorded.

Axial Pull Test

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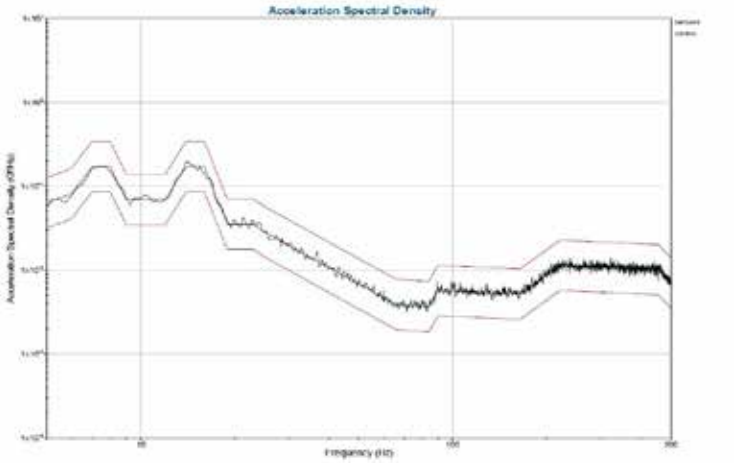
KEY FINDINGS

The testing results are reported in four separate sections: Vibration, Thermal Shock / Cycling and Post Axial Pull Testing for the Vibration and Thermal Cycling Tests. Each fixture (Large Oval, Small Oval, and Rectangular) has data outlined per EIA-364-83 and highlighted by the band installed to the fixture.

VIBRATION TESTING

The EIA-364-83 test results highlighted each fixture assembly performed well pre and post test with similar resistance values indicating the band held the sheathing tightly under the vibrating conditions.



Large Oval Fixture Performance

BAND-IT Band	Band Width	Band Material	Pre-Test (in m Ohm's)	Post-Test (in m Ohm's)
Mini Tie-Lok Tie	0.177" width	304 Stainless Steel	0.052 mΩ	0.057 mΩ
1/4" Tie-Lok Tie	0.25" width	304 Stainless Steel	0.034 mΩ	0.039 mΩ
1/4" Universal Clamp	0.25" width	201 Stainless Steel	0.038 mΩ	0.049 mΩ
1/4" Preformed Jr Clamp	0.25" width	201 Stainless Steel	0.032 mΩ	0.032 mΩ

Small Oval Fixture Performance

BAND-IT Band	Band Width	Band Material	Pre-Test (in m Ohm's)	Post-Test (in m Ohm's)
Mini Tie-Lok Tie	0.177" width	304 Stainless Steel	0.025 mΩ	0.039 mΩ
1/4" Tie-Lok Tie	0.25" width	304 Stainless Steel	0.023 mΩ	0.042 mΩ
1/4" Universal Clamp	0.25" width	201 Stainless Steel	0.027 mΩ	0.030 mΩ
1/4" Preformed Jr Clamp	0.25" width	201 Stainless Steel	0.022 mΩ	0.025 mΩ

Rectangle Fixture Performance

BAND-IT Band	Band Width	Band Material	Pre-Test (in m Ohm's)	Post-Test (in m Ohm's)
Mini Tie-Lok Tie	0.177" width	304 Stainless Steel	0.041 mΩ	0.051 mΩ
1/4" Tie-Lok Tie	0.25" width	304 Stainless Steel	0.022 mΩ	0.048 mΩ
1/4" Universal Clamp	0.25" width	201 Stainless Steel	0.032 mΩ	0.063 mΩ
1/4" Preformed Jr Clamp	0.25" width	201 Stainless Steel	0.036 mΩ	0.027 mΩ

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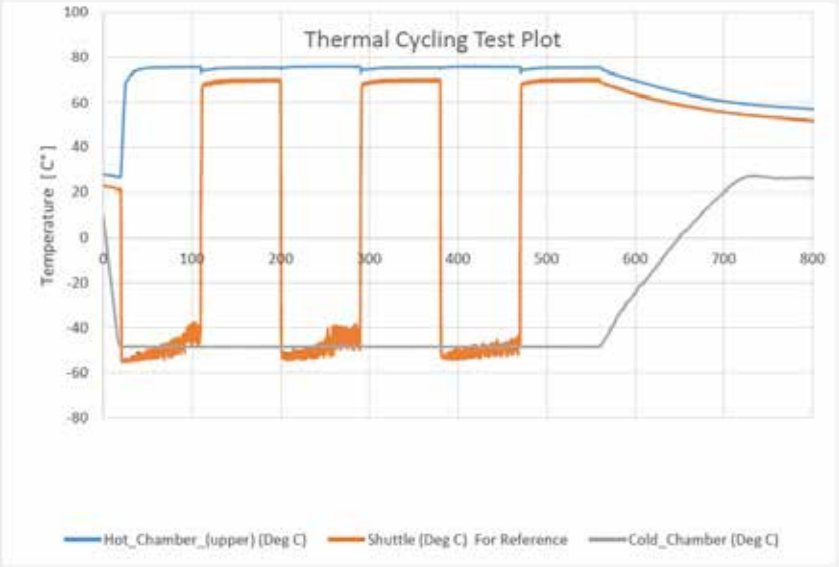
THERMAL CYCLING / THERMAL SHOCK TESTING

Exposing the fixture assemblies to thermal cycling increased the overall electrical performance indicating a 'seating' or tightening of the band connection.



Thermal Cycling Graphical Results

Large Oval Fixture Performance

BAND-IT Band	Band Width	Band Material	Pre-Test (in m Ohm's)	Pre-Test (in m Ohm's)
Mini Tie-Lok Tie	0.177" width	304 Stainless Steel	0.105 mΩ	0.057 mΩ
1/4" Tie-Lok Tie	0.25" width	304 Stainless Steel	0.124 mΩ	0.066 mΩ
1/4" Universal Clamp	0.25" width	201 Stainless Steel	0.159 mΩ	0.064 mΩ
1/4" Preformed Jr Clamp	0.25" width	201 Stainless Steel	0.111 mΩ	0.048 mΩ

Small Oval Fixture Performance

BAND-IT Band	Band Width	Band Material	Pre-Test (in m Ohm's)	Pre-Test (in m Ohm's)
Mini Tie-Lok Tie	0.177" width	304 Stainless Steel	0.068 mΩ	0.049 mΩ
1/4" Tie-Lok Tie	0.25" width	304 Stainless Steel	0.089 mΩ	0.037 mΩ
1/4" Universal Clamp	0.25" width	201 Stainless Steel	0.094 mΩ	0.036 mΩ
1/4" Preformed Jr Clamp	0.25" width	201 Stainless Steel	0.077 mΩ	0.043 mΩ

Rectangle Fixture Performance

BAND-IT Band	Band Width	Band Material	Pre-Test (in m Ohm's)	Pre-Test (in m Ohm's)
Mini Tie-Lok Tie	0.177" width	304 Stainless Steel	0.108 mΩ	0.068 mΩ
1/4" Tie-Lok Tie	0.25" width	304 Stainless Steel	0.117 mΩ	0.061 mΩ
1/4" Universal Clamp	0.25" width	201 Stainless Steel	0.126 mΩ	0.081 mΩ
1/4" Preformed Jr Clamp	0.25" width	201 Stainless Steel	0.128 mΩ	0.085 mΩ

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AXIAL PULL TEST

Most band strength was higher post thermal cycling vs. post vibration and aligns with the EIA-364-83 test highlighting better electrical performance post thermal cycling.

AXIAL PULL PERFORMANCE (POST VIBRATION TESTING)

Large Oval Fixture Performance

BAND-IT Band	Band Width	Band Material	Post-Test Maximum lbf
Mini Tie-Lok Tie	0.177" width	304 Stainless Steel	421 lbf
1/4" Tie-Lok Tie	0.25" width	304 Stainless Steel	609 lbf
1/4" Universal Clamp	0.25" width	201 Stainless Steel	760 lbf
1/4" Preformed Jr Clamp	0.25" width	201 Stainless Steel	663 lbf

Small Oval Fixture Performance

BAND-IT Band	Band Width	Band Material	Post-Test Maximum lbf
Mini Tie-Lok Tie	0.177" width	304 Stainless Steel	580 lbf
1/4" Tie-Lok Tie	0.25" width	304 Stainless Steel	680 lbf
1/4" Universal Clamp	0.25" width	201 Stainless Steel	830 lbf
1/4" Preformed Jr Clamp	0.25" width	201 Stainless Steel	915 lbf

Rectangle Fixture Performance

BAND-IT Band	Band Width	Band Material	Post-Test Maximum lbf
Mini Tie-Lok Tie	0.177" width	304 Stainless Steel	244 lbf
1/4" Tie-Lok Tie	0.25" width	304 Stainless Steel	267 lbf
1/4" Universal Clamp	0.25" width	201 Stainless Steel	158 lbf
1/4" Preformed Jr Clamp	0.25" width	201 Stainless Steel	183 lbf

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AXIAL PULL PERFORMANCE (POST THERMAL TESTING)

Large Oval Fixture Performance

BAND-IT Band	Band Width	Band Material	Post-Test Maximum lbf
Mini Tie-Lok Tie	0.177" width	304 Stainless Steel	563 lbf
1/4" Tie-Lok Tie	0.25" width	304 Stainless Steel	804 lbf
1/4" Universal Clamp	0.25" width	201 Stainless Steel	632 lbf
1/4" Preformed Jr Clamp	0.25" width	201 Stainless Steel	1,007 lbf

Small Oval Fixture Performance

BAND-IT Band	Band Width	Band Material	Post-Test Maximum lbf
Mini Tie-Lok Tie	0.177" width	304 Stainless Steel	393 lbf
1/4" Tie-Lok Tie	0.25" width	304 Stainless Steel	636 lbf
1/4" Universal Clamp	0.25" width	201 Stainless Steel	863 lbf
1/4" Preformed Jr Clamp	0.25" width	201 Stainless Steel	1,149 lbf

Rectangle Fixture Performance

BAND-IT Band	Band Width	Band Material	Post-Test Maximum lbf
Mini Tie-Lok Tie	0.177" width	304 Stainless Steel	88 lbf
1/4" Tie-Lok Tie	0.25" width	304 Stainless Steel	225 lbf
1/4" Universal Clamp	0.25" width	201 Stainless Steel	195 lbf
1/4" Preformed Jr Clamp	0.25" width	201 Stainless Steel	249 lbf

FIXTURE SHAPE: THE FIXTURE SHAPE IS THE LARGEST DETERMINANT OF MAXIMUM STRENGTH WITH OVAL SHAPES PERFORMING MUCH BETTER THAN RECTANGULAR SHAPES.

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CONCLUSION

Currently Hybrid and Electric Vehicle Automakers desiring to use high performance and low weight EMI Expandable Bundle Shielding for their high voltage cables have a dilemma, the current connector shapes require custom manufactured bolt clamps to match the shape of their varying connector bodies, adding complexity, weight and cost, negating the financial savings and performance benefits of expandable shielding.

BAND-IT's metal band solution eliminates the "customized" bolt clamp by providing clamps that are a one-size-fits-all solution. BAND-IT provides reduced diameter clamps minimizing variation in the connectors, eliminating complexity and reducing the cost of expandable shielding.

Using BAND-IT's industry leading installation tools, assembly can be performed with an intuitive pneumatic tool, simply feed the band into the too, push the button and the clamps are tightened down to the proper size and shape. Clamps are installed to a preset tension, ensuring all clamps are properly tightened and the shielding is properly terminated for best performance. No nuts, no bolts, no screws and the lowest possible profile for a no interference application. A win-win: highest performance shielding with the lowest possible weight.

Key Takeaways

- Minimal SKU count can reduce complexity at automakers. When designing a connector and wire braiding assembly, A Mini Tie-Lok or ¼" Tie-Lok can be made to fit any number of fixture / connector shapes with a single SKU.
- Consistent performance under extreme conditions: The conductive back shell values under extreme vibration and thermal cycling conditions remained constant highlighting consistency amongst the various banding solutions.
- Strength of the band connector is dependent on the type of band and the shape of the fixture. BAND-IT offers a number of bands for these applications from Preformed bands to flat bands.
- Installation Tools guarantee a consistent installation minimizing the variation of assembly.

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