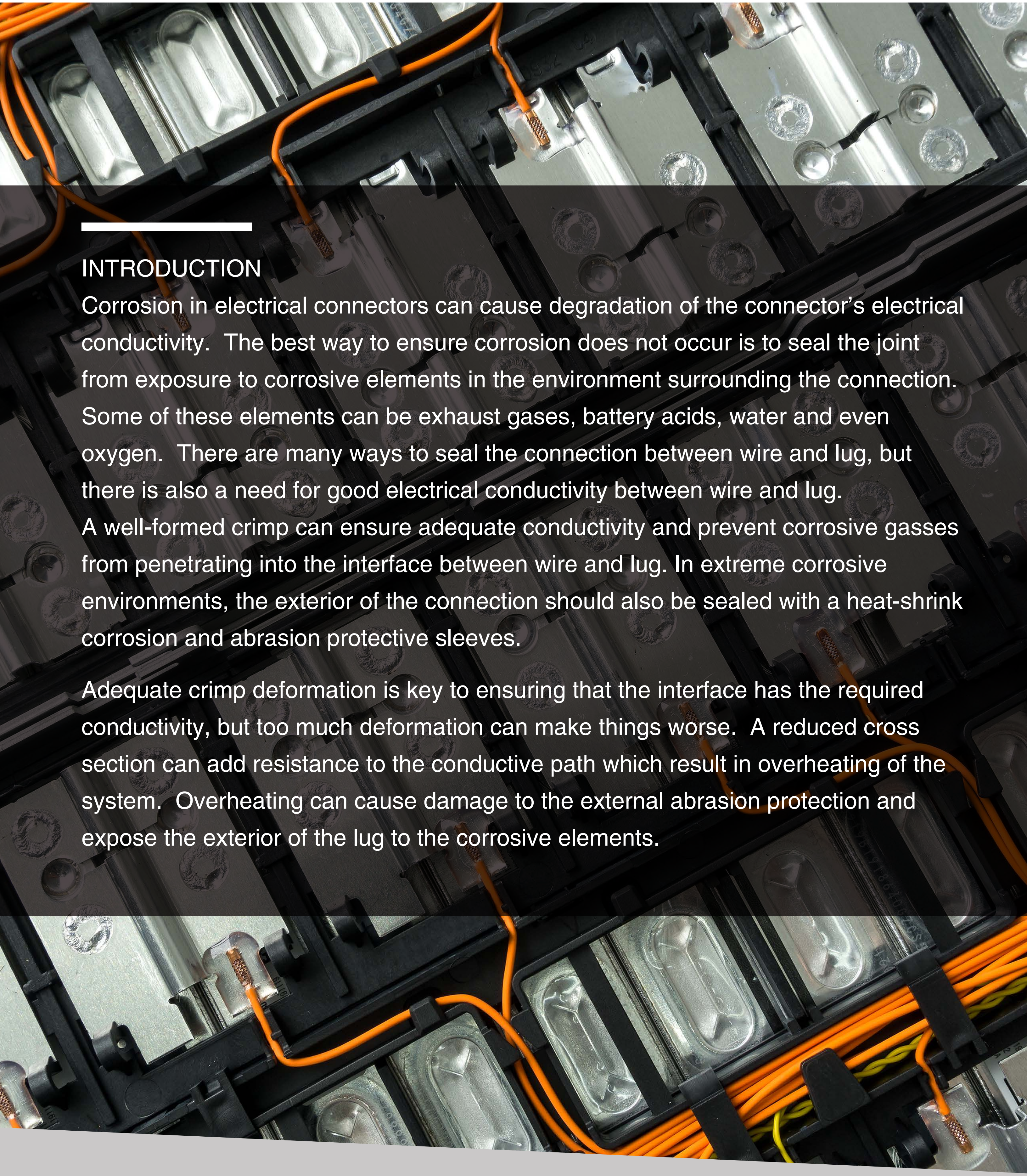
WHITE PAPER

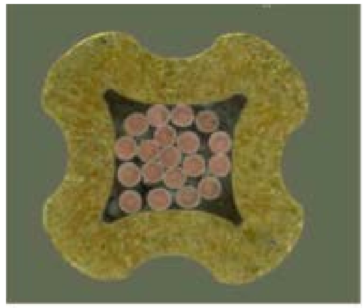
Panduit Gas-Tight Crimp Technical Publication

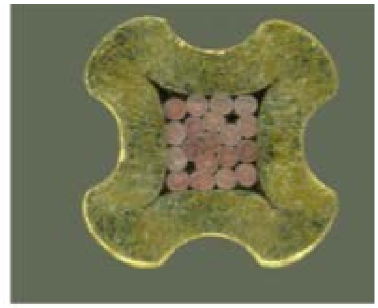


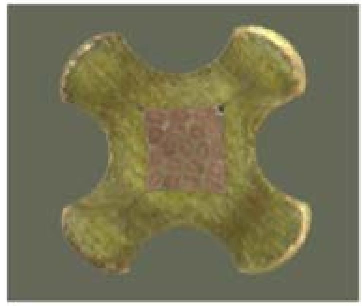
INTRODUCTION

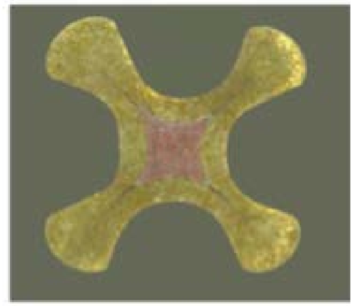
Corrosion in electrical connectors can cause degradation of the connector's electrical conductivity. The best way to ensure corrosion does not occur is to seal the joint from exposure to corrosive elements in the environment surrounding the connection. Some of these elements can be exhaust gases, battery acids, water and even oxygen. There are many ways to seal the connection between wire and lug, but there is also a need for good electrical conductivity between wire and lug.
A well-formed crimp can ensure adequate conductivity and prevent corrosive gasses from penetrating into the interface between wire and lug. In extreme corrosive environments, the exterior of the connection should also be sealed with a heat-shrink corrosion and abrasion protective sleeves.

Adequate crimp deformation is key to ensuring that the interface has the required conductivity, but too much deformation can make things worse. A reduced cross section can add resistance to the conductive path which result in overheating of the system. Overheating can cause damage to the external abrasion protection and expose the exterior of the lug to the corrosive elements.


Unacceptable: undercrimp


Limit of acceptability: void 10%


Acceptable: preferred


Not acceptable: overcrimp

To determine if the compression is appropriate for the conductor size and type, extensive testing has been performed. UL 486A and 486B tests have been performed to ensure that the finished wire/ lug/crimp die combination has the required tensile strength and the necessary electrical conductivity for the application. However, this test does not provide verification that the crimp is gas tight. For this, you must cross section the crimped area, mount the section in epoxy, polish, etch, and microscopically inspect the cross section for voids. This is a destructive procedure, therefor we have performed the process and presented the results in this report.

Two crimp configurations were evaluated for gas-tight connection in this report. The first configuration was a hex crimp in which we used a Panduit CT-3001/ST family crimper and KC22 series crimp dies with class K stranded wire and Panduit A-series lugs. For the hex crimp we performed the evaluation on four wire gauges: 8, 4, 2/0, and 4/0 AWG. The second configuration was a 4-indent crimp style using a Pico 500 series crimper with the appropriate crimp dies and locators. The same wire class and lug series was used in the Pico samples, but all 9 wire gauges were tested.

KC22 HEX CRIMP TESTING METHODS

Table 1 lists the specifics for the hex crimps using the Panduit CT-3001/ST family crimper.

Conductor Information				Crimp Information		
				Core Dimensions (mm)		
Cable Size (AWG)	Cable Type	Cross Section (mm2)	Pull-out Force (N)	Height	Width	Die Number
8	Class K	9.1	1000	5.1	6.0	KC22-8
4	Class K	122.7	1779	6.9	8.3	KC22-4
2/0	Class K	348.0	3336	12.3	13.6	KC22-2/0
4/0	Class K	525.4	3892	14.9	16.8	KC22-4/0

Crimp Height and Width: Each sample's measurements are tabulated. Crimp height, width, and Hex flat lengths are recorded. Hex flat lengths are useful when comparing to corresponding dimensions for Hex die. **Figure 3** is example of typical micrograph. Here we take measurements for crimp height, width, and flats. A digital microscope is used for all samples.

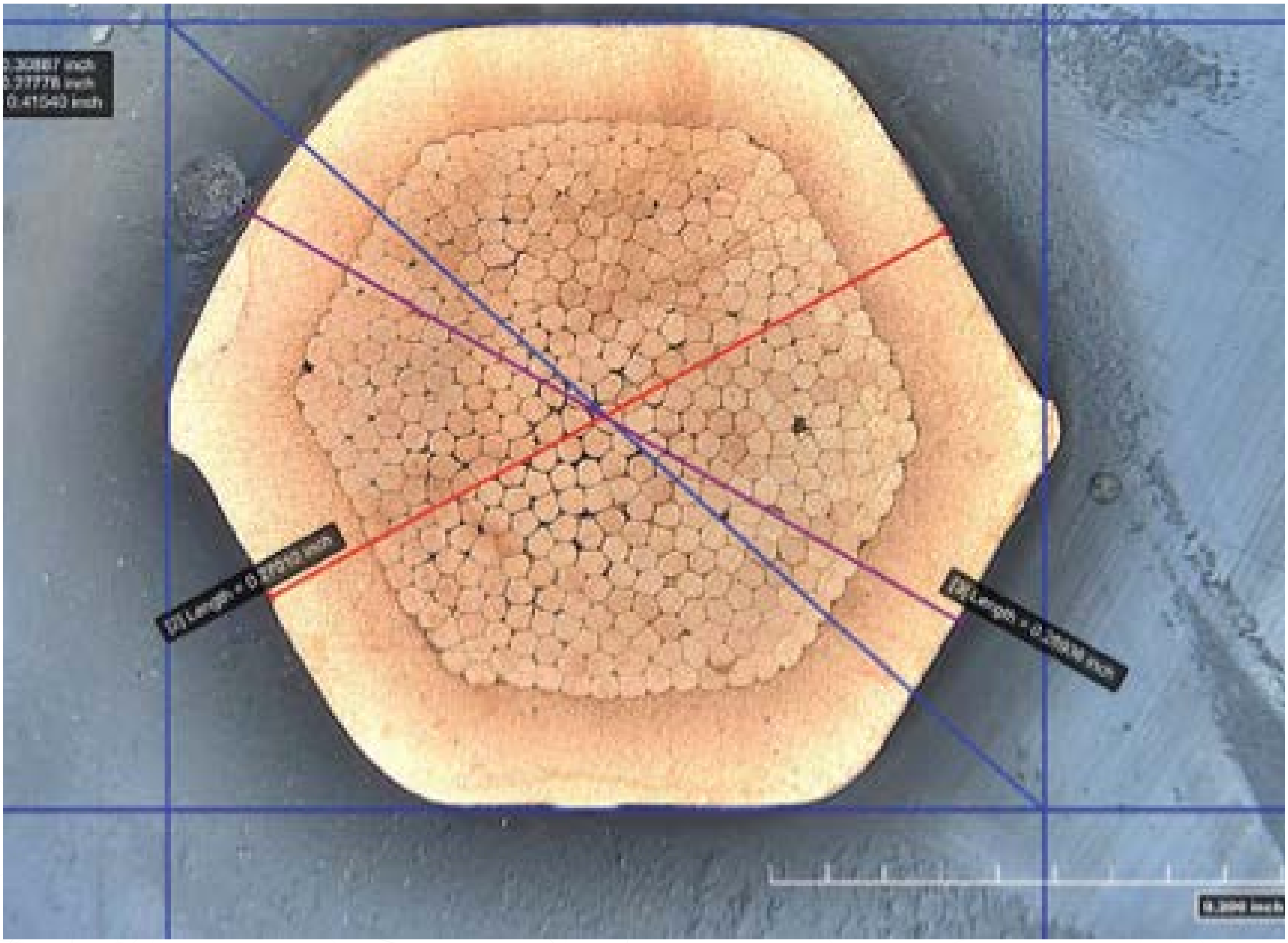


Figure 3: Crimp height, width, and Hex Flat measurements

Area and compression %:

Area and overall compression are measured using a microscope.
Figure 4 is a typical example of how measurement is made. Blue area surrounds conductor strands. Measured area is then compared to original ID of lug and calculation made to determine overall compaction percentage.

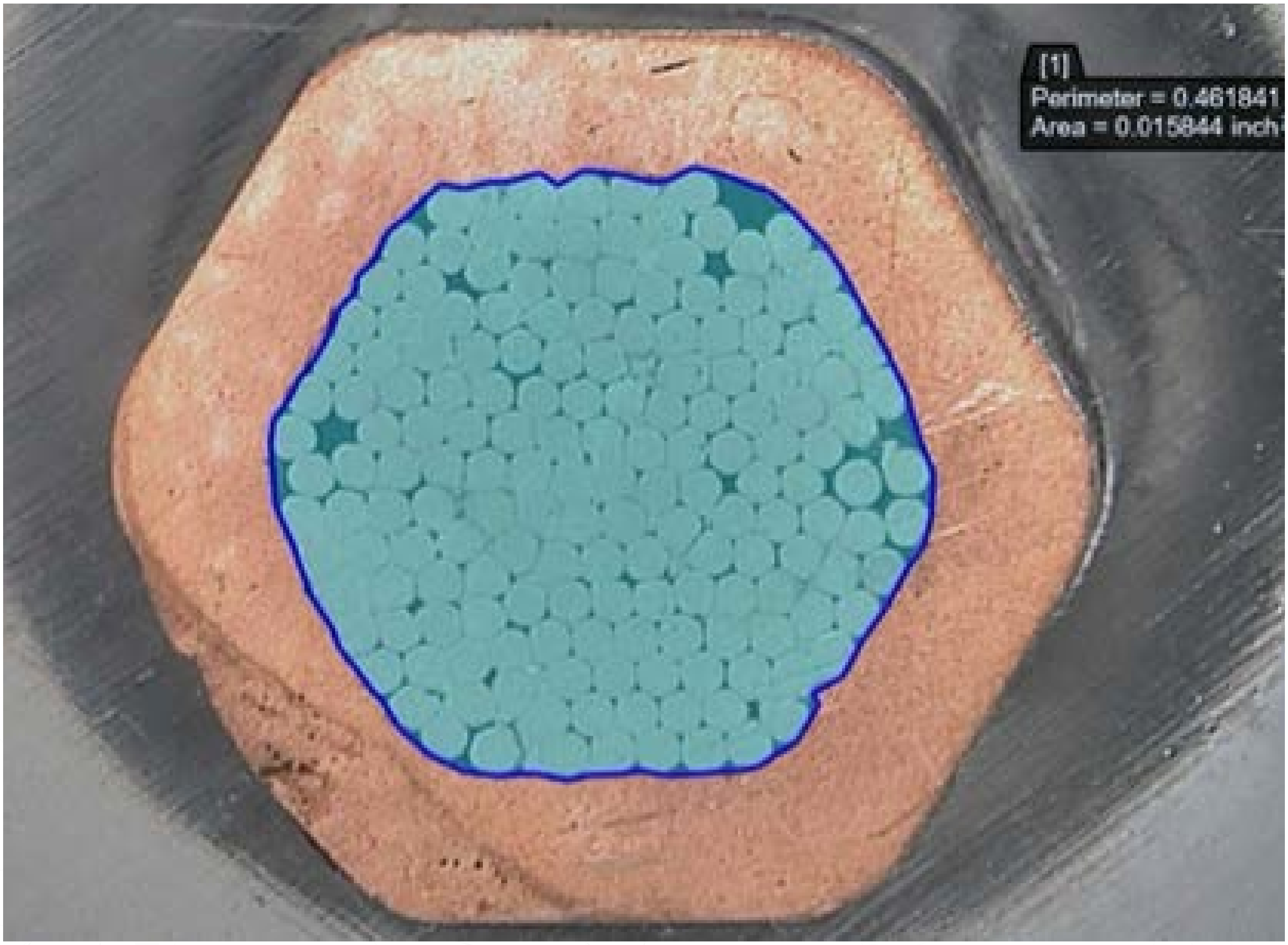


Figure 4: Area calculation

Void Calculations:

For samples that contain voids, area calculations are performed in same manner as calculated in Step 2; area(s) are drawn for all voids and total area is calculated. This area is then compared to overall conductor area to calculate void percentage.

Note: Coarse grain principles used when counting voids; some ‘voids’ may be result of actual explicit microstructure characteristic, and some maybe result of damage and/or side effects from sectioning saw, polishing, and acid etching. Gross calculation is useful when overall void area is less than 10% of total compaction area. There are no official standards for void percentage, but industry consensus typically suggests the figure of less than 10%.

Once overall void area is calculated, these regions are examined at higher magnifications, and with optical filters, as necessary. Samples that contain a high number of strands, polishing and etching artifacts can produce false positives. In these cases, higher magnification can probe suspected areas, especially in those segments where strand deformation is low, as shown in Figure 5. Polarizing filters can be useful in this regard, as the resulting image has enhanced contrast; some contaminants such as grease, oil, & dust will appear white, while metallic objects and depressions are in dark contrast, **Figure 6**.

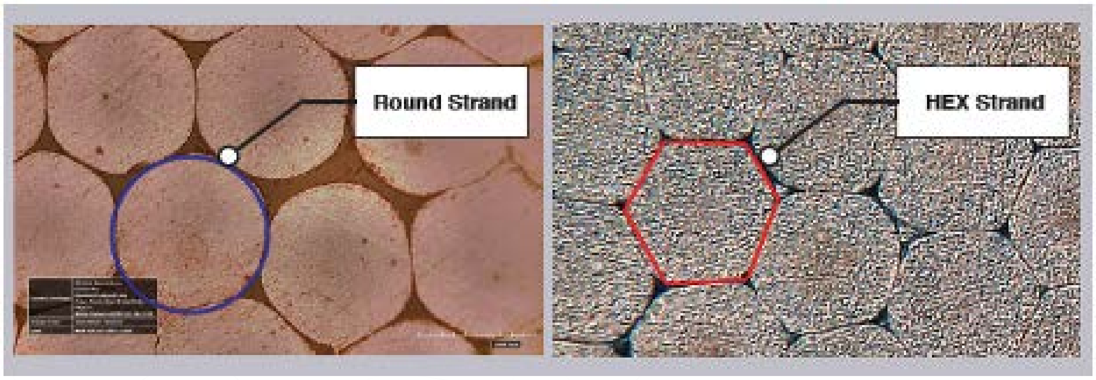


Figure 5: Round & Hex Strand Deformation

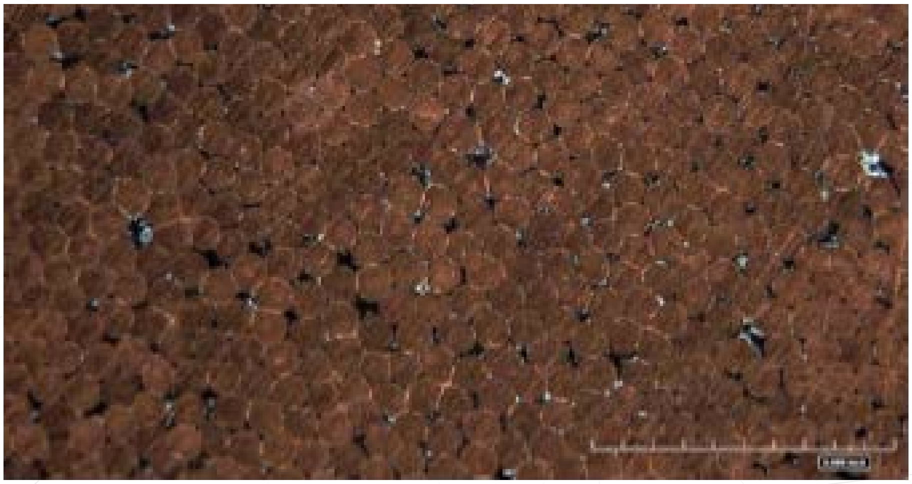


Figure 6: Polarizing filter. White regions are contaminants.

HEX CRIMP TEST RESULTS

Table 2 provides test data from the hex crimped portion of this test. Additional test data can be provided upon request.

AWG	OD in	ID in	Wall in	ID Area in²	Sample Area in²	Sample %	Hex Dimensions Height	Hex Dimensions Width	% Voids
8	0.27	0.18	0.045	0.025	0.0137	46.16	0.1929	0.2075	4.23
4	0.375	0.281	0.047	0.062	0.0313	49.53	0.2591	0.2957	<1
2/0	0.64	0.51	0.065	0.204	0.0928	54.56	0.3724	0.4807	<1
4/0	0.813	0.56	0.127	0.246	0.151	38.62	0.5843	0.6425	2.65

PICO CRIMPER TESTING METHODS

The second part of the report discusses using Pico 4-indent style crimpers with the appropriate crimp dies and locators. Table 3 lists the specifics for the 4-indent crimps using the Pico 400 and 500 series crimpers.

Conductor Information				Crimp Dimen-sions		400-BEC		500-DEC	
Cable Size (AWG)	Cable Type	Cross Section (mm2)	Pullout Force (N)	Core Height	Core Width	Die	Locator	Die	Locator
8	Class K	9.1	1001	3.7	3.8	414DA-8NIT-B.140	19352	514DA-8NIT-B.140	10894
6	Class K	11.6	1334	4.49	4.3	414DA-6NIT-B.150	19351	514DA-6NIT-B.150	10893
4	Class K	15.8	1779	4.6	4.69	414DA-4NIT-B.170	19353	514DA-4NIT-B.170	10969
2	Class K	16.8	2447	5.3	5.1	414DA-2NIT-B.190	19354	514DA-2NIT-B.190	5510-8
1	Class K	25.16	2891	6.7	6.6	414DA-1/0NIT-B.240	19350	514DA-1/0NIT-B.240	5510-11
1/0	Class K	30.96	3114	6.8	6.6	414DA-1/0NIT-B.240	19349	514DA-1/0NIT-B.240	10216
2/0	Class K	51.61	3336	7.6	7.55	414DA-2/0NIT-B.280	19348	514DA-2/0NIT-B.280	5521
3/0	Class K	74.18	3670	9.14	9.06	Not Possible		514DA-3/0NIT-B.325	5520-1
4/0	Class K	88.69	3892	9.6	9.56	Not Possible		514DA-4/0NIT-B.350	10892

Crimp Height, Width: Each sample's measurements are tabulated, including Crimp height, width, and compaction area. **Figure 7** shows that these measurements should be roughly equal and indicate the wire barrel has been evenly deformed. For the case when a Pico 400 o 500 die is used, the crimp width or height is roughly proportional to the nominal crimp depth of the die. There is some elastic recovery, up to 0.020" for crimps above 1 AWG.

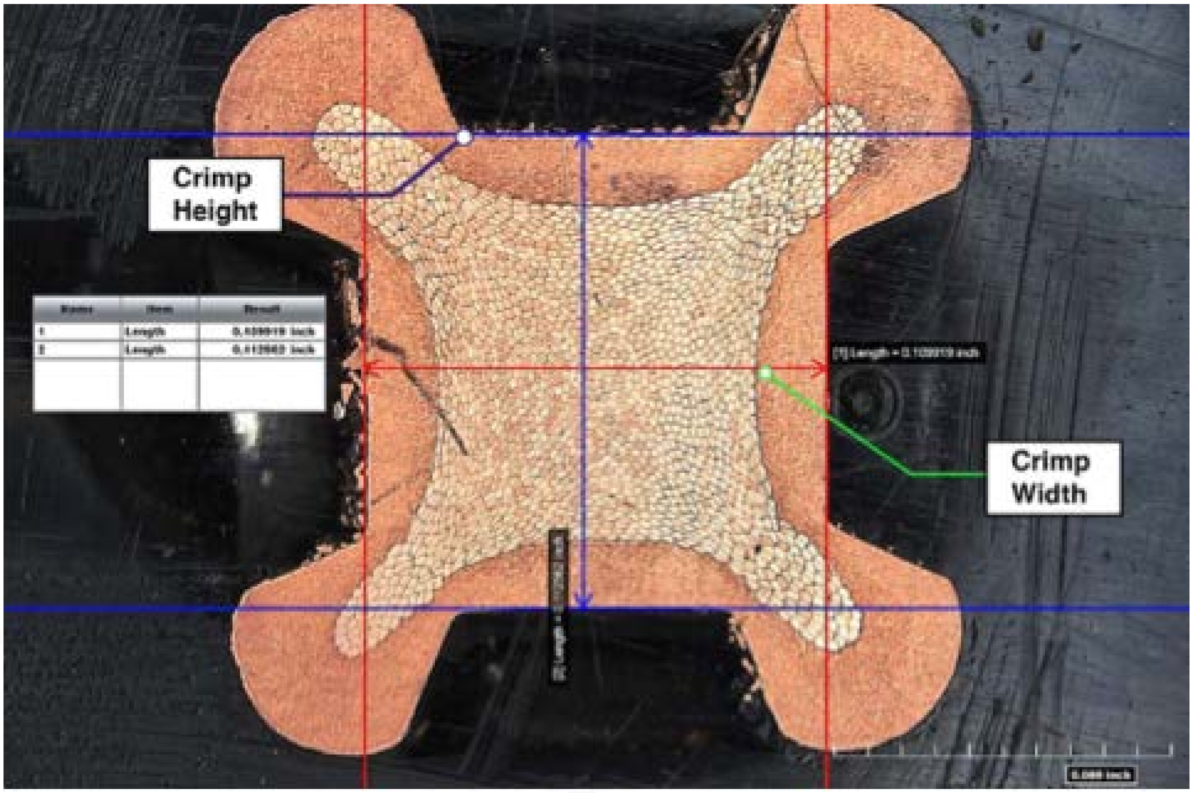


Figure 7: Crimp height Measurement

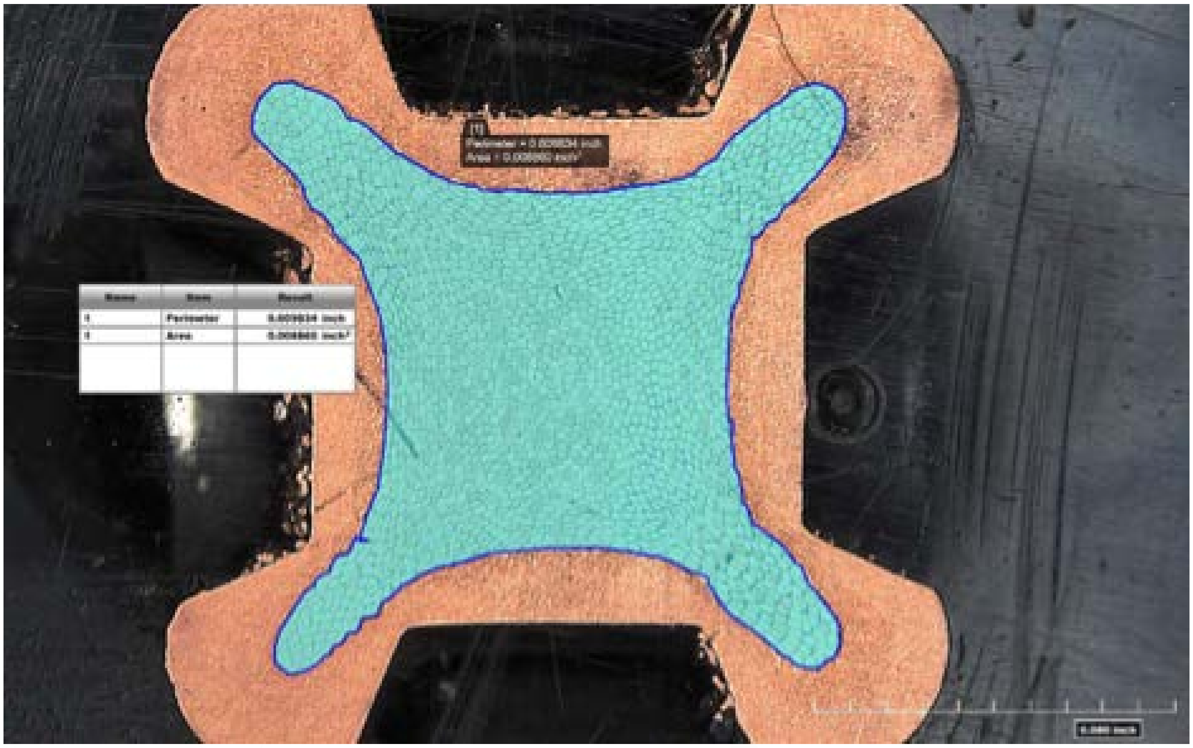


Figure 8: Crimp height Measurement

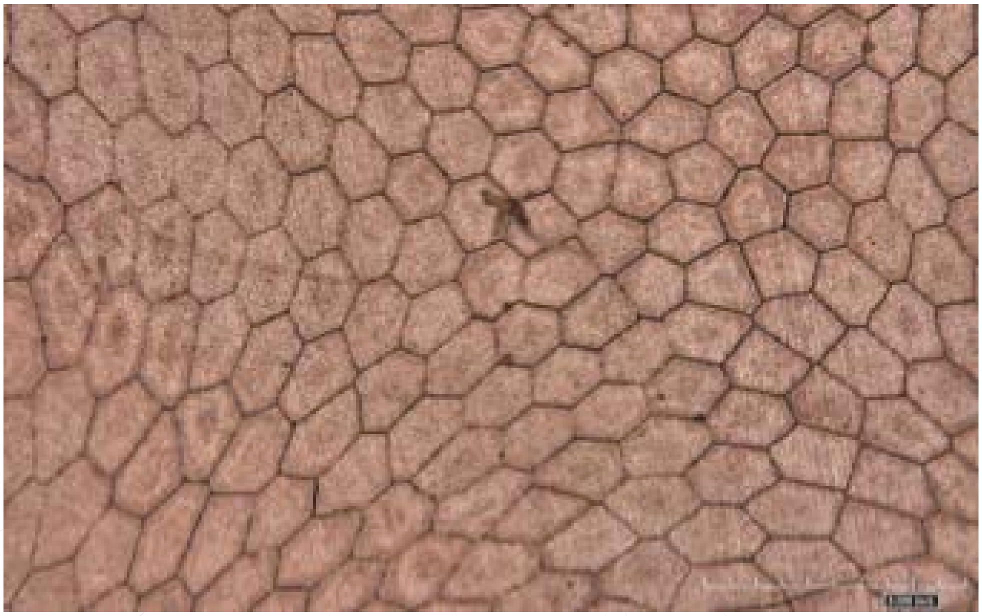


Figure 9: Crimp height Measurement

Area and compression %: Area and overall compression measured using an electronic microscope. **Figure 8** depicts a typical area measurement - blue area surrounds conductor (strands).

Compaction Analysis: An ideal crimp will produce uniform compression across the entire strand area and is also characterized by wire strand deformation towards hexagonal form, as shown in **Figure 9**. In practice, uniform compression is rarely achieved and depends on the style of crimp (4 indent, hex, circular, etc). Crimp style will correspond to application requirements - material & plating, whether barrel is annealed and wire properties (number of strands, tinned, etc).

PICO CRIMPER TEST RESULTS

Table 4 provides test data from the hex crimped portion of this test. Additional test data can be provided upon request.

AWG	OD in	ID in	Wall in	ID Area in^2	Sample Compression		Crimp Dimensions		% Voids
					Area in^2	%	Height	Width	
8	0.25	0.18	0.035	0.025	0.009	64.63	0.1334	0.1395	0
6	0.31	0.23	0.04	0.042	0.018	56.68	0.172	0.177	<.1
4	0.35	0.27	0.04	0.057	0.0243	57.56	0.178	0.189	0
2	0.42	0.31	0.055	0.075	0.026	65.57	0.199	0.207	<.1
1	0.47	0.36	0.055	0.102	0.038	62.67	0.26	0.264	<.1
1/0	0.5	0.39	0.055	0.119	0.0473	60.4	0.261	0.266	0
2/0	0.58	0.45	0.065	0.159	0.084	47.18	0.307	0.312	0
3/0	0.62	0.51	0.055	0.204	0.12	41.26	0.375	0.364	1.51
4/0	0.69	0.56	0.065	0.246	0.135	45.19	0.417	0.421	<.1

CONCLUSION

In general, both crimp styles did provide a crimp compaction which had less than 10% void measurements. This would be considered gas-tight by any current standards. However, the Pico crimps exhibited void measurements below 2%, with some below 0.1%. These types of results would clearly prohibit gasses from penetrating within the crimped area which would ensure that no internal corrosion could be possible. This internal corrosion resistance along with external corrosion/abrasion resistance will extend the reliability of your electrical connections in the most hostile environments.

A-series lugs are available in 9 wire gauges: 8, 6, 4, 2,1, 1/0, 2/0, 3/0 and 4/0 AWG. Tongue configurations include single-hole #10, 1/4", 5/16" 3/8", and 1/2" straight, 45°bent, and 90° bent.

Since 1955, Panduit's culture of curiosity and passion for problem solving have enabled more meaningful connections between companies' business goals and their marketplace success. Panduit creates leading-edge physical, electrical, and network infrastructure solutions for enterprise-wide environments, from the data center to the telecom room, from the desktop to the plant floor. Headquartered in Tinley Park, IL, USA and operating in 112 global locations, Panduit's proven reputation for quality and technology leadership, coupled with a robust partner ecosystem, help support, sustain, and empower business growth in a connected world.

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