Attachment No. 4

TEST OF HIGH STRENGTH NICKEL PLATED WIRE

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ABSTRACT

The selection of wire material is critical to the performance of cable assemblies because wire materials and processing contribute to the mechanical and electrical performance of interconnect components and assemblies.

Testing was done to determine the extent of compliance with SAE AS39029 specification for the application of High Strength Nickel Plated Wire (HSNPW), crimped by using a standard Mil-Spec crimp tool. Also to investigate the extent of degradation of contact resistance of nickel plated contacts when compared with standard gold plated contacts.

INTRODUCTION

High Strength Nickel Plated Wire (Mil-W-22759) has been in production for a number of years yet it has limited use. Its electrical performance when compared with Silver Plated Copper Wire (Mil-W-16878) is clearly inferior; however it has favorable mechanical properties. It will be useful to know if High Strength Nickel Plated Wire could satisfy the requirements of AS39029. If it does, expanded applications for its use would arise. If a standard crimp tool could be used in conjunction with AS39029 requirements using High Strength Nickel Plated Wire, the use of HSNPW would be further facilitated.

A significant challenge of manufacturing AS39029 contacts is to provide uniform gold plating through the depth of the electrical crimp barrel. Plating solution ionic dilution in the crimp barrel area often causes “dark bore” which in turn raises concerns relative to contact resistance. The question arises, if gold plating were to be entirely removed (to bare nickel under-plates) how much would contact resistance be degraded. If, for example, the performance of a nickel plated part was compared to a gold plated part, the importance of “dark bore” on contact performance could be better understood.

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Testing was done to AS39029 Group I & Group III as noted below:

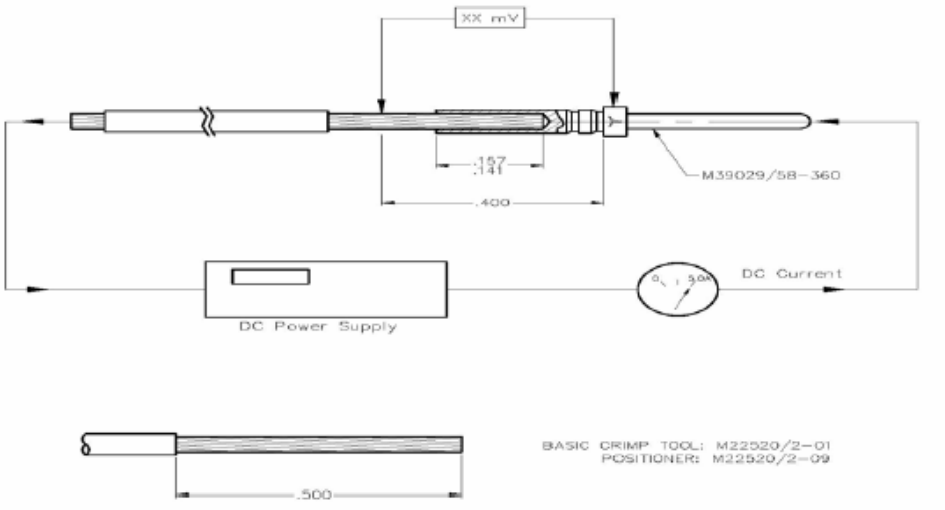
Group I

- Examination of products
- Preparation of samples
- Axial concentricity
- Contact resistance at 5 Amps current
  (method per Mil-DTL-22520)
- Crimp tensile strength

Group III

- Examination of products
- Preparation of samples
- Contact resistance at 5 Amps current
  (method per Mil-DTL-22520)
- Temperature life (200° C, no current)
- Contact resistance at high temperature
  (method per AS39029)
- Contact resistance at rated current
  (method per Mil-Std-1344)
- Contact resistance at 5 Amps current
  (method per Mil-Std-22520)
- Contact tensile strength

CONTACT RESISTANCE MEASUREMENT GROUP 1
PER MIL-DTL-22520



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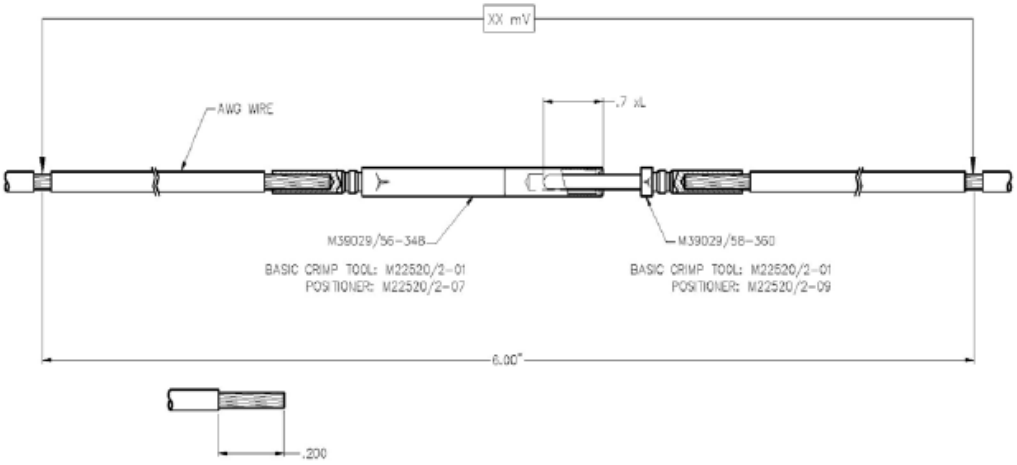

Contact Resistance Set-up

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Test Plan Matrix

Group I

	Tool (H)	Tool (L)
Gold Plated Pin Contact + 24AWG H.T. Wire	8	8
Gold Plated Pin Contact + 26AWG H.T. Wire	8	8
Nickel Plated Pin Contact + 24AWG H.T. Wire	8	8
Nickel Plated Pin Contact + 26AWG H.T. Wire	8	8
Gold Plated Pin Contact + 24AWG Silver Wire	8	8
Gold Plated Pin Contact + 26AWG Silver Wire	8	8

Group III

	Tool (H)	Tool (L)
Gold Plated Pin Contact + 24AWG H.T. Wire	8	8
Gold Plated Pin Contact + 26AWG H.T. Wire	8	8
Nickel Plated Pin Contact + 24AWG H.T. Wire	8	8
Nickel Plated Pin Contact + 26AWG H.T. Wire	8	8
Gold Plated Pin Contact + 24AWG Silver Wire	8	8
Gold Plated Pin Contact + 26AWG Silver Wire	8	8
Gold Plated Skt Contact + 24AWG H.T. Wire	8	8
Gold Plated Skt Contact + 26AWG H.T. Wire	8	8
Nickel Plated Skt Contact + 24AWG H.T. Wire	8	8
Nickel Plated Skt Contact + 26AWG H.T. Wire	8	8
Gold Plated Skt Contact + 24AWG Silver Wire	8	8
Gold Plated Skt Contact + 26AWG Silver Wire	8	8

Testing was done to determine the performance of High Strength Nickel Plated Wire after conditioning to the environments specified in AS39029. In addition, the performance of Nickel Plated contacts when used in conjunction with High Strength Nickel Plated Wire was investigated.

Testing Laboratory Facilities

Testing was conducted at Tri-Star Electronics International Qualification Laboratory located in El Segundo, California. Tri-Star's laboratory has been audited by DSCC and NAVAIR to the requirements of Mil-Std-790. All testing was done by qualified laboratory technicians using calibrated equipment under the supervision of a Laboratory Manager.

Axial Concentricity

Paragraph 3.5.2.2 of AS39029 specifies that the T.I.R. after crimping (Wire size 20 through 28) shall not exceed .011 inches.

Table 1 below indicates that the maximum T.I.R. is .0085 max. and .008 average for contacts crimped with 24 gauge wire when using crimp tool set to L (when set to L, tool makes deeper indents than when set to H). When crimp tool was set to H, T.I.R. max. reading is .0025 and average reading is .0021. With both tool settings all T.I.R. readings pass AS39029 requirement. There was no noticeable difference in T.I.R. between High Strength Nickel Plated Wire and Silver Plated Copper Wire.

Table 1 Axial Concentricity per SAE 39029

Part number	A dimension (Tool H)	TIR reading Spec limit		A dimension (Tool L)	TIR reading Spec limit
315-2222-103-L		.011 max.			.011 max.
Sample 1	0.0025	.011 max.	Sample 9	0.0085	.011 max.
Sample 2	0.0015	.011 max.	Sample 10	0.007	.011 max.
Sample 3	0.002	.011 max.	Sample 11	0.0085	.011 max.
Sample 4	0.0025	.011 max.	Sample 12	0.006	.011 max.
Sample 5	0.0015	.011 max.	Sample 13	0.0085	.011 max.
Sample 6	0.0025	.011 max.	Sample 14	0.0085	.011 max.
Sample 7	0.002	.011 max.	Sample 15	0.0085	.011 max.
Sample 8	0.002	.011 max.	Sample 16	0.0085	.011 max.
Average TIR	**0.0021**	**.011 max.**		**0.008**	**.011 max.**

(T.I.R. data was taken on more samples than shown. This data is representative of total sample size.)

Crimp Tensile Strength

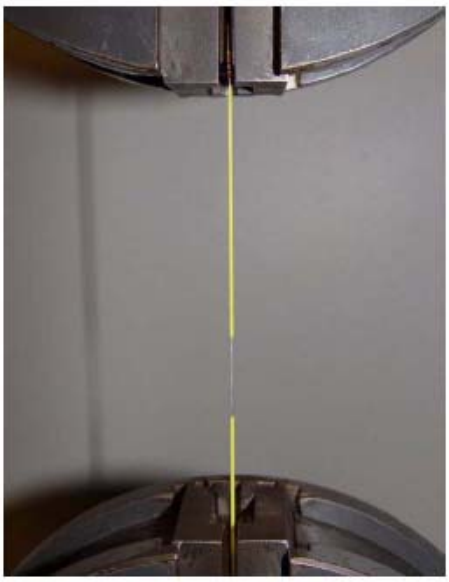
Tensile testing was performed to determine the performance of High Strength Nickel Plated Wire when used with standard AS39029 contacts in order to compare the performance with Silver Plated Copper Wire and to observe the effect of crimp tool settings.

Table X of AS39029 specifies tensile strength for AWG 24 Silver Plated Wire before conditioning to be 8 lbs – after conditioning 6 lbs. For Nickel Plated Copper Wire AS39029 specifies 6 lbs pre-conditioning and 4.5 lbs post-conditioning (for 24AWG).

Table 2 below shows the average pre-conditioning tensile strength for High Strength Nickel Plated Wire to be 14.5 lbs and post-conditioning to be 16.5 lbs. This performance far exceeds the requirements specified for Silver or Nickel Plated Copper Wire. The failure mode for the Silver Plated Copper Wire was broken wire in crimp barrel. The failure mode for High Strength Nickel Plated Wire was slippage from crimp barrel. The weak tensile link for High Strength Nickel Plated Wire crimped contacts is the contact crimp barrel.

Table # 2 Crimp Tensile strength per SAE 39029

			Tensile strength before and after temp life			
Average Readings			Nickel		Silver	
Tensile Strength		Crimp	Before	After	Before	After
Wire	24	High	17.0 lbs	17.0 lbs	15.0 lbs	11.0 lbs
	24	Low	18.0 lbs	21.0 lbs	14.0 lbs	9.3 lbs
	26	High	9.9 lbs	10.0 lbs	9.3 lbs	7.6 lbs
	26	Low	13.0 lbs	18.0 lbs	9.0 lbs	5.7 lbs



PIN

SOCKET

After 1000 hours at 200°C life testing, the crimp tensile strength of High Strength Nickel Plated Wire increased by 13.8%. The Silver Plated Copper Wire shows a decrease in tensile strength of 28.8% after high temperature life testing exposure.

The test samples crimped by using tool "L" setting have a higher crimp tensile strength for High Strength Nickel Plated Wire but a lower crimp tensile strength for Silver Plated Copper Wire. The maximum indentation in the case of High Strength Nickel Plated Wire increases the slippage force without significantly decreasing the cross section area of the wire. In the case of the softer Silver Plated Copper Wire, the maximum indentation decreases the cross sectional area of the wire causing a lower ultimate tensile strength for the wire.

Although AS39029 does not specify a crimp tensile strength requirement for High Strength Nickel Plated Wire, the High Strength Nickel Plated Wire exhibits a significant higher crimp tensile strength both before and after high temperature conditioning than the requirements specified for Nickel Plated Copper Wire.

Contact Resistance Per Mil-Std-1344 (EIA-364)

Contact resistance with High Strength Nickel Plated Wire and Silver Plated Copper Wire was measured after 1000 hours at 200°C for both 24 and 26 AWG. This was performed to the requirements of AS39029 which requires that voltage drop across the connection be measured at 3.0 and 2.0 Amps respectively. As stated earlier, AS39029 does not specify the connection resistance for High Strength Nickel Plated Wire. The specification limit shown in Table 3 is for Nickel Plated Copper Wire.

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Table 3 Contact Resistance per Mil-Std-1344

Gold Plated Contacts (Selectively) Average Readings		Average readings Contact Resistance after temperature Life Test.					Contact Resistance At high temperature		Contact Resistance At high temperature		Contact Resistance after Hi temp @ 25C		Contact Resistance after Hi temp @ 25C	
Per Mil-Std-1344	Wire	Crimp	Nickel Plated Wire		Silver Plated Wire		200C	Nickel	200C	Silver		Nickel		Silver
Contact Resistance	Gage	setting	max-mV*		max-mV		max- mV*	After life	max-mV	After life	max-mV*		max-mV	
Rated current (3) Amps	24	High	81	44.0 mV	54	34.5 mV	116 mV	65.0 mV	77.0 mV	56.6 mV	81	45.0 mV	54	37.5 mV
	24	Low	81	41.6 mV	54	35.6 mV	116 mV	62.5 mV	77.0 mV	55.6 mV	81	43.6 mV	54	37.0 mV
Rated current (2) Amps	26	High	96	54.0 mV	63	35.4 mV	137 mV	73.8 mV	89.0 mV	57.0 mV	96	57.0 mV	63	37.0 mV
	26	Low	96	52.0 mV	63	35.8 mV	137 mV	74.6 mV	89.0 mV	57.0 mV	96	55.0 mV	63	37.0 mV

The requirement for 24AWG Nickel Plated Copper Wire is 81mV max. and Silver Plated Wire is 54 mV max. This is a 50% difference in specified maximum voltage drop. The High Strength Nickel Plated Wire measured 44.0 mV (24AWG) after conditioning. The Silver Plated Copper Wire measured 34.5mV. This is a 27.9% difference. High Strength Nickel Plated Wire exceeds the requirement for Nickel Plated Copper Wire by a significant margin. Similar results are shown for the 26AWG wire. The crimp tool settings had negligible effect on voltage drop for both the High Strength Nickel Plated Wire and Silver Plated Copper Wire.

Similarly, the contact resistance at high temperature for High Strength Nickel Plated Wire measured significantly less than the specified maximum for Nickel Plated Copper Wire - 65.0 mV versus 116 mV (24AWG). The High Strength Nickel Plated Wire measured only 14.8% higher than Silver Plated Copper Wire – 65.0 mV versus 56.6 mV. In fact, the High Strength Nickel Plated Wire resistance at high temperature measures lower than the specified limit for Silver Plated Copper Wire – 65.0mV versus 77.0mV maximum. Crimp tool settings had negligible effect on contact resistance at high temperature.

Similar results are shown for contact resistance after high temperature measurement at 25°C. The High Strength Nickel Plated Wire passes the specification limit for both Nickel Plated Copper Wire and Silver Plated Copper Wire – 45.0mV versus 81mV max and 54mV max respectively.

Contact Resistance per MIL-DTL-22520

This contact resistance test measures contact resistance at 5 Amps across crimp barrel before and after conditioning for 1000 hours at 200°C. This test was done on High Strength Nickel Plated Wire using gold plated contacts and nickel plated contacts at high and low crimp tool settings (see Table 4). This test was designed to measure the effect of gold plating in the crimp barrel and the robustness of crimp tool settings to barrel resistance.

The results show that gold plated contact crimp joint resistance with High Strength Nickel Plated Wire is .28 milliohms average (24AWG). For nickel plated contacts crimp joint resistance is .36 milliohms average - a 28.6% increase. The low crimp tool setting (deeper indentation) lowers resistance on average by 25% - from .32 milliohms to .24 milliohms for gold plated contacts (24AWG). After temperature life testing, resistance increases on average 5.2 times from pre-conditioning resistance, from average value of 1.775 mV to 9.275 mV.

The results show that nickel plated contact crimp joint resistance with High Strength Nickel Plated Wire after temperature life conditioning is on average 14.9 times the resistance from pre-conditioning resistance. The nickel plated barrel experiences severe oxidation after conditioning. The low crimp setting on average (high indentation) shows marked improvement in barrel resistance. The high crimp setting average show a 2.63 times higher resistance after conditioning than the low crimp tool setting.

The nickel plated contact (24AWG) post-conditioning shows a very high barrel resistance (71mV) and significantly higher piece to piece variability. It was originally thought this data point should not be used. After some consideration, it was decided that this condition likely existed due to the combination of excessive oxidation of the wire and crimp barrel in combination with a high tool setting (shallow indentation). High Strength Nickel Plated Wire, in combination with a high resistance barrel is inherently a poor electrical connection.

Table 4

Gold Plated Contacts (Selectively) Average Readings			Average readings Contact Resistance after temperature Life Test.	
P/N 315-2222-103	Wire	Crimp	Nickel Plated Wire	
Contact Resistance	Gage	setting	Before	After
Rated current (5) Amps	24	High	1.6 mV	9.8 mV
Per Mil-Dtl-22520	24	Low	1.2 mV	7.2 mV
	26	High	2.2 mV	10.5 mV
	26	Low	1.9 mV	9.6 mV

Nickel Plated Contacts Average Readings			Average readings Contact Resistance after temperature Life Test.	
P/N 315-2222-103	Wire	Crimp	Nickel Plated Wire	
Contact Resistance	Gage	setting	Before	After
Rated current (5) Amps	24	High	2.0 mV	71.0 mV
Per Mil-Dtl-22520	24	Low	1.6 mV	21.5 mV
	26	High	2.7 mV	18.7 mV
	26	Low	2.0 mV	12.5 mV

Conclusion

The test results indicate that High Strength Nickel Plated Wire can be crimped into the existing standard SAE-AS39029 contact wire barrels, with the use of standard M22520 crimp tools. The standard contacts crimped with High Strength Nickel Plated Wire can meet SAE-AS39029 requirements for Axial Concentricity, Crimp Tensile Strength, Contact Resistance, Contact Resistance after Life Test, and Contact Resistance at High Temperature.

The SAE-AS39029 specification should be revised to complete the detail test requirements for High Strength Nickel Plated Wire.

The total absence of gold plating inside crimp barrels of SAE-AS39029 contacts when used in conjunction with nickel plated wire creates a high resistance connection after conditioning to the environment specified in MIL-DTL-22520.