THE EFFECT OF WIRE PLATING ON THE RELIABILITY OF CRIMPED CONTACTS

by

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In December of 1967, a major connector company was in the process of performing a full qualification test on their miniature series of crimp connectors as contracted to them by TRW. An accumulation of Contact Resistance test data early in the qualification sequence immediately pointed out high resistance (greater than 7 milliohms) across mated pairs of contacts terminated with 26 AWG wire. There were no problems with the contacts crimped with 22 AWG wire. The contact resistance was measured by passing a d.c. current of 100 milliamperes through mated contacts and measuring the voltage drop across the points shown below.

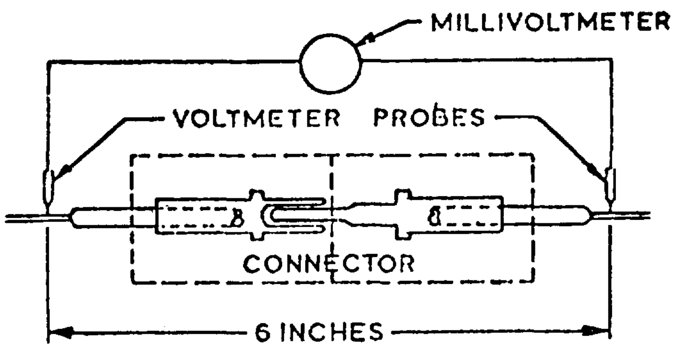

Figure 1. Contact Resistance Measurement Technique

Those who were witnessing this portion of the test found by examination that the high resistance of contacts crimped with 26 AWG stranded (7/38) wire was occurring in the crimp joints rather than at the interface between the two mating contacts. The connector and wire descriptions are as follows:

A. This connector is a high density (.080 center to center contact spacing) type of crimp connector with contacts designed to accommodate size 22, 24 and 26 AWG wire. See Figure 2.

Figure 2. Mating Connectors

B. The 22 and 26 AWG wire chosen for this connector by TRW was hot tin dipped copper wire with an irradiated extruded polyalkene insulation and an irradiated extruded polyvinylidene fluoride jacket. This particular wire was chosen for space applications because of its light weight and high resistance to radiation, abrasion and cut-through.

The qualification test was allowed to proceed despite the high resistance failures and a parallel effort was started by the connector manufacturer and TRW to determine the cause of failure and take corrective action. Attempts to reproduce the failures in our parallel effort were negative until the current cycling test in the qualification test increased the number of failures significantly. This test consisted of 100 cycles of full rated current for 30 minutes and zero current for 15 minutes through mated contacts. TRW's effort then was to temperature cycle (Thermal Shock) mated pairs of contacts between the limits of -65^{o} to $+125^{o}C$ using the same type wire mentioned previously but modified as shown below. One cycle of thermal shock consisted of 1/2 hour at $-65^{o}C$, 5 minute transition time to $+125^{o}C$, 1/2 hour at $+125^{o}C$, and 5 minutes transition time to $-65^{o}C$.

Four groups of specimens were assembled for test in the following manner:

Group A - Tin plated 26 AWG wire thermally stripped at normal temperature and contact crimped,

Group B - Tin plated 26 AWG wire mechanically stripped and contact crimped.

Group C - Tin-plated 26 AWG wire thermally stripped at excessively high temperatures (jacket and insulation charred) and contact crimped.

Group D - Silver-plated 26 AWG copper wire (19 strands of 38 AWG) thermally stripped at excessively high temperature and contact crimped.

Group A, B, C and D contacts were all crimped with the same tool and positioner to limit variables. The silver-plated wire was added to the test because previous test data accumulated by the manufacturer showed no previous contact resistance failures with 26 AWG silver-plated wire.

The results showed that all groups met the initial contact resistance requirement of 7 milliohms maximum but the Group D specimens (silver-plated wire) were the only group to meet the contact resistance requirements after 40 cycles of thermal shock. The Group D specimens had very stable contact resistance and were less than 3 milliohms throughout the test. The other groups had contact resistance values ranging from 10 milliohms to ohms. Refer to Figure 3 for graphical presentation of results.

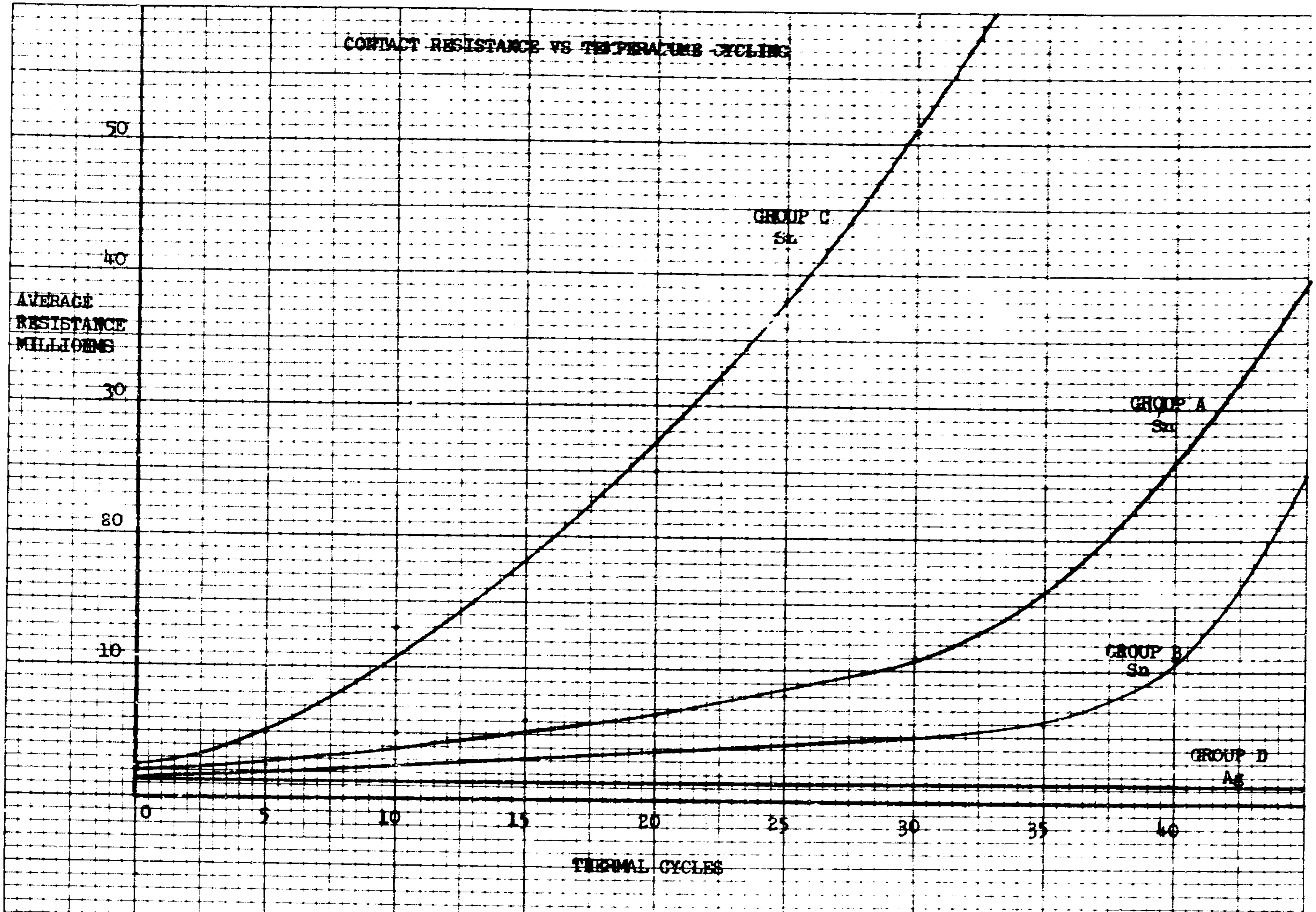
CONTACT RESISTANCE VS TEMPERATURE CYCLING
AVERAGE
RESISTANCE
MILLIOHMS
50
40
30
20
10
0
5
10
15
20
25
30
35
40
GROUP C
Sn
GROUP A
Sn
GROUP B
Sn
GROUP D
Ag
THERMAL CYCLES

FIGURE 3

Additional thermal shock testing was performed on new test specimens and the following variables were introduced:

A. Hardness of wire

B. Plating of wire

C. Stranding of wire

D. Crimp tool indentor configuration

E. Crimp depth

Each specimen was subjected to 50 cycles of thermal shock, one cycle of which consisted of 1 hour at -65°C and 1 hour at +125°C. The transition time from one temperature extreme to another was 5 minutes. The results are summarized in Table I and show that all crimped silver plated wire performed well and were less than the 7 milliohms maximum requirement. The crimped tin plated wire exceeded 7 milliohms maximum contact resistance at normal depths (.023 inch) but could perform well if the crimp depth was increased to .015 or .017 inch. Deeper crimps were felt undesirable for the following reasons:

A. Excessive growth in the outer diameter of the crimp end of contacts could occur and would prevent proper insertion and removal of contacts.

B. Work hardening of the wire strands would reduce the tensile strength of the wire and the crimp joint.

Another solution to the problem would have been to redesign the crimp barrel by reducing the inner diameter to some value slightly larger than the outer diameter of the wire. We chose to select silver plated 26 AWG wire as the most economical way for TRW to resolve high contact resistance of crimped contacts and tin plated wire.

TABLE I. SUMMARY OF THERMAL CYCLING DATA

GROUP	WIRE			CRIMP TOOL			SAMPLE SIZE	CONTACT RESISTANCE (MILLIOHMS) ±.2				
	STRANDING	PLATING	HARDNESS KNOOP ±3	MFR	TOOL PART NUMBER	CRIMP DEPTH (INCH) ±.0015		INITIAL AVERAGE	INITIAL MAXIMUM	POST THERMAL AVERAGE	POST THERMAL MAXIMUM	
1	7/34	Sn	76	Daniels	MH800	.015	8	1.1	1.4	1.1	1.3	PASS
2	7/34	Sn	76	Buchanan	612118	.015	8	1.1	1.5	1.1	1.5	PASS
3	19/38	Ag	64	Buchanan	612422	.023	8	1.2	1.5	1.2	1.6	PASS
4	7/34	Sn	76	Daniels	MH800	.017	8	1.3	1.7	1.5	2.3	PASS
5	19/38	Ag	58	Buchanan	612422	*.025	20	.7	1.1	1.5	3.1	PASS
6	7/34	Ag	59	Buchanan	612422	*.025	20	1.0	1.6	2.6	4.2	PASS
7	7/34	Sn	76	Buchanan	612636	.017	20	1.5	2.2	2.3	4.9	PASS
7 Milliohm Maximum Contact Resistance												
8	19/38	Sn	77	Buchanan	612422	.023	8	1.1	1.6	2.9	10.5	FAIL
9	7/34	Sn	60	Buchanan	612422	.023	8	1.6	1.9	5.9	20.1	FAIL
10	7/34	Sn	76	Daniels	MH800	.017	20	1.4	1.9	7.6	42.7	FAIL
11	7/34	Ni	57	Buchanan	612422	.023	8	8.8	18.5	3.5	106.5	FAIL
12	7/34	Sn	76	Buchanan	612118	.021	20	1.9	3.3	14.6	138	FAIL
13	7/34	Sn	76	Buchanan	612422	.023	20	2.7	5.3	65	452	FAIL
14	7/34	Sn	76	Buchanan	612422	*.025	20	7.1	13.8	325	1120	FAIL

* Tool not properly calibrated; should be .023

NOTES: 1. 19/38 wire has .020 conductor diameter
2. 7/34 wire has .019 conductor diameter

The cause of the high contact resistance of contacts crimped (at normal depths) with tin-plated wire is, as yet, not clearly understood. It is probably attributable to a barrier layer of tin that becomes oxidized, crazed, or powdery after thermal cycling. If the layer of tin is pierced by crimping, it is possible that the resistance of the crimp joint will be insensitive to temperature cycling.

The use of tin-plated wire in crimp type connectors although economically sound can present severe electrical-problems. It is recommended that each application of this type be carefully checked through thermal cycling tests to assure satisfactory performance. If the problem does exist, the substitution of silver-plated wire can offer an immediate solution.