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Gold Plating Study Test Report

CB-12

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ELECTRONIC INDUSTRIES ASSOCIATION

ENGINEERING DEPARTMENT

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(CB-12 was formulated under the cognizance of the EIA P-5.1 Task Group on Gold Plating.)

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INTRODUCTION

SCOPE:

The purpose of this study is to evaluate the performance characteristics of gold plating thicknesses when exposed to a severe series of environmental sequences. The sequences as established were chosen for their impact on phenomenon which could potentially cause contact interface degradation. The program is designed to stress the component system beyond normal military qualification test sequences. No pass/fail criteria was established. The data as generated is used for comparative purposes only.

PARTICIPATING COMPANIES AND BASIC REPORTING FORMAT

Three companies participated in performing the test program as established. For reporting purposes, all data is anonymous and grouped. Participating companies chose the product to be tested per the slash sheets of MIL-C-39029. Testing was performed by qualified laboratories. All said laboratories had current suitability status in effect as issued by DESC for the products involved.

Upon completion of testing, all data was submitted to an independent agency. Said agency summarized and presented the data in the format contained herein as approved by the EIA P-5.1 Task Group on gold plating. Upon completion of the report, all data was returned to the submitting companies for their own disposition. Copies of the report were submitted to each participating company only.

The data presented herein is "grouped". That is, the averages are the grand average of all data submitted from all participating companies. The maximum data point was the maximum observed from all data submitted from all participating companies.

The committee wishes to acknowledge all participating companies for their time and resources in generating the data contained herein. Companies participating in the test program were:

a) Dupont
b) Elco
c) Texas Instruments

The independent agency collating the data was Contech Research, Inc.

TEST SAMPLES AND PREPARATION

1. Unless otherwise indicated all materials were certified by the manufacturer to be in accordance with the applicable product specification.

2. The connectors as tested and submitted were certified by the manufacturer as being fabricated and assembled utilizing normal production techniques common for this type of product and inspected in accordance with the quality criteria as established for the product involved.

3. All connectors were coded and identified to maintain continuity throughout the test sequences.

4. Test lead attachment for electrical resistance monitoring was in accordance with the applicable product specification.

5. Unless otherwise specified in the test procedures used, no further preparation was performed.

6. Three different connector styles were evaluated in this study. These connectors are categorized as follows:

   a) Style A -- Pin (dia.) and socket type
   b) Style B -- Square post and contact type
   c) Style C -- Blade and dual tine stamped contact

SAMPLE SIZE

Unless otherwise specified, the number of connectors submitted to the exposures and the number of data points monitored were in accordance with the indicated test plan.

APPLICABLE DOCUMENTS

1. The following test standards were used in the performance of this evaluation.

   a) MIL-STD-1344
   b) EIA RS 364

2. The following products were submitted to the exposure in accordance with the following specifications:

   a) MIL-C-55302

TEST SELECTION

1. All test were performed in accordance with the sequences and procedures as specified herein.

2. See Test Plan Flow Diagram, Figure #1, for test sequences used.

CONTACT CODING

The contacts shall be coded as shown below as a convenience for comparative evaluation. It is important that the initial measurements for contact engagement and separation forces, crimp contact resistance, low level circuit resistance and the final measurements, be carefully recorded so that a comparison can be made between the initial and final measurements on the same contact.

Contact Type:	F - Female M - Male
Plating Thickness:	1 - 50 +9, -0 microinches 2 - 30 +9, -0 microinches 3 - 20 +9, -0 microinches
Test Sequence:	A - Unmating/Environment B - Mated/Environment C - Mated/Durability/Environment D - Mated/Durability/Vibration/Environment E - Mated/Vibration/Environment
Durability:	1 - Standard durability (500 cycles) 2 - High durability (625 cycles) 3 - Low durability (250 cycles)
Environmental Exposure:	T - Thermal cycling E - Elevated temperature S - Standard salt spray as per specification L - 240 Hour salt spray
Contract Condition:	M - Mated U - Unmated
Individual Contact Designator:	X - Substitute individual contact number without group (i.e., -2)

Example - Typical Contact Code

F2BTU-4 - Female contact 30 millionths gold, test sequence "B", thermal cycled, unmated, contact 4 within test group.

M1C2EM-2 - Male contact, 50 millionths gold, sequence "C", high durability test, elevated temperature, mated, contact 2 within test group.

CONTACT ALLOCATION

The allocation of contacts by contact code for each test sequence are shown on Table 1.

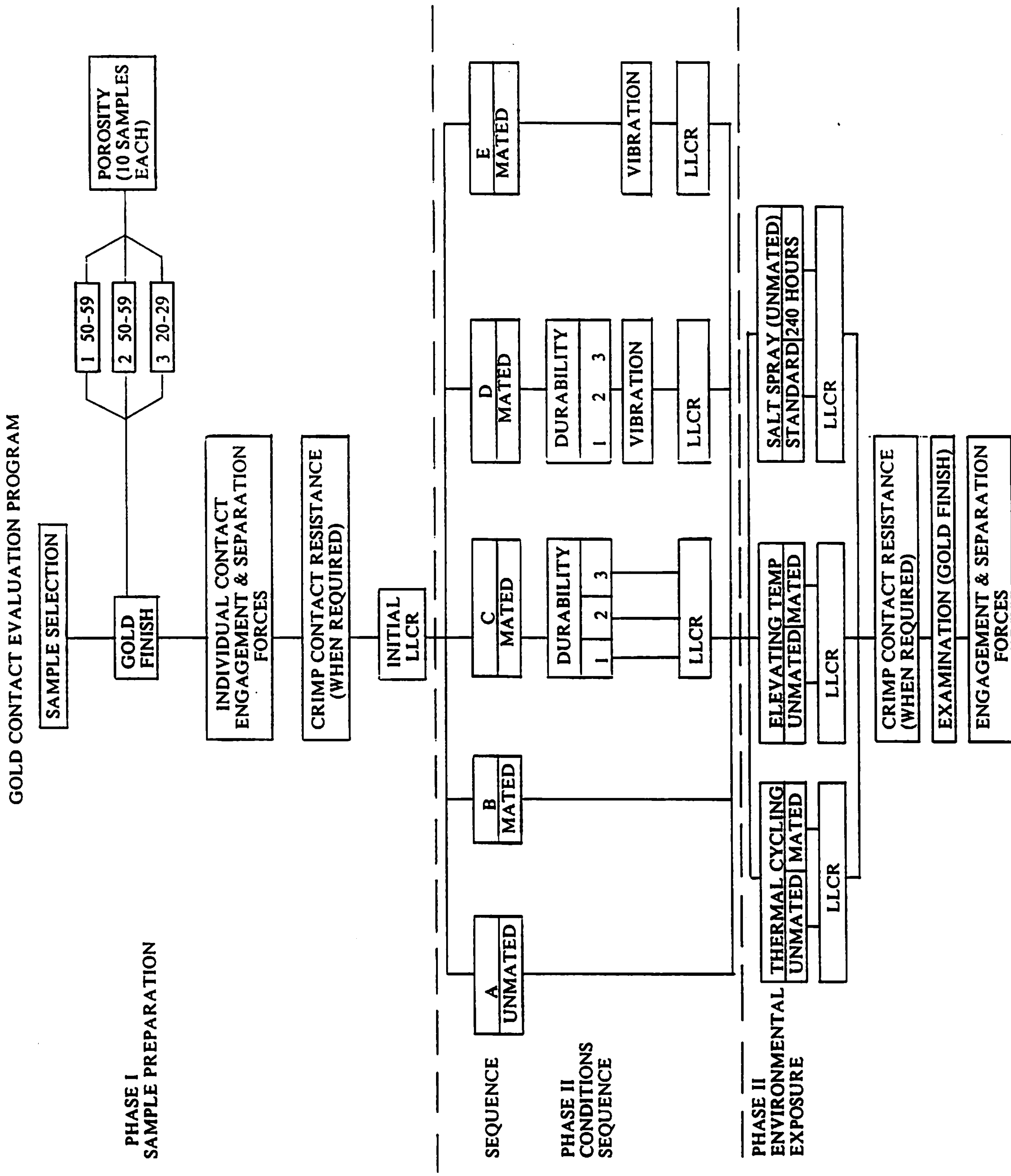
TABLE I

CONTACT REQUIREMENTS (FOR EACH TYPE, MALE, FEMALE, HERMAPHRODITIC)

(The Quantities Shown Include All Samples Subjected To The Phase II Conditioning Sequence)

Thermal Cycling 10 Each Unmated	 Mated	Elevated Temperature 10 Each Unmated	 Mated	Salt Spray Unmated 6 Each Std.	 240 Hr.
1A	1B 1C1 1D1 1E	1A	1B 1C1 1D1 1E	1A 1C1 1D1 1E	1A 1C1 1D1 1E
2A	2B 1C2 1D2 2E	2A	2B 1C2 1D2 2E	2A 1C2 1D2 2E	2A 1C2 1D2 2E
3A	3B 1C3 1D3 3E	3A	3B 1C3 1D3 3E	3A 1C3 1D3 3E	3A 1C3 1D3 3E
	2C1 2D1		2C1 2D1	2C1 2D1	2C1 2D1
	2C2 2D2		2C2 2D2	2C2 2D2	2C2 2D2
	2C3 2D3		2C3 2D3	2C3 2D3	2C3 2D3
	3C1 3D1		3C1 3D1	3C1 3D1	3C1 3D1
	3C2 3D2		3C2 3D2	3C2 3D2	3C2 3D2
	3C3 3D3		3C3 3D3	3C3 3D3	3C3 3D3
27x10 = 270 Contacts		27x10 = 270 Contacts		24x6 = 144	24x6 = 144

TOTAL CONTACTS		
	Male	828
	Female	828
	Hermaphroditic	828


GOLD CONTACT EVALUATION PROGRAM
PHASE I SAMPLE PREPARATION
SAMPLE SELECTION
GOLD FINISH
1 50-59
2 50-59
3 20-29
POROSITY (10 SAMPLES EACH)
INDIVIDUAL CONTACT ENGAGEMENT & SEPARATION FORCES
CRIMP CONTACT RESISTANCE (WHEN REQUIRED)
INITIAL LLCR
SEQUENCE
A UNMATED
B MATED
C MATED
D MATED
E MATED
PHASE II CONDITIONS SEQUENCE
DURABILITY 1 2 3
LLCR
DURABILITY 1 2 3
VIBRATION
LLCR
VIBRATION
LLCR
PHASE II ENVIRONMENTAL EXPOSURE
THERMAL CYCLING UNMATED MATED
LLCR
ELEVATING TEMP UNMATED MATED
LLCR
SALT SPRAY (UNMATED) STANDARD 240 HOURS
LLCR
CRIMP CONTACT RESISTANCE (WHEN REQUIRED)
EXAMINATION (GOLD FINISH)
ENGAGEMENT & SEPARATION FORCES

TEST RATIONALE

POROSITY

PURPOSE:

To establish the magnitude and severity of porosity and other types of imperfections present on contact surfaces utilizing gold finishes. The presence of these discontinuities may result in corrosion products being created in these areas which result from base metals or underplate exposure. These corrosion products in turn may be of sufficient magnitude to potentially spread across the contacting surfaces. Contingent on the magnitude of other design attributes (i.e., normal force, environments involved, circuit parameters, wipe, sealing effects, etc.) or lack thereof, this potential can result in electrical degradation. The establishment of the presence of porosity and other imperfections is considered a reference test and is utilized as a means to evaluate data generated from the environmental compartments in proper perspective.

TEST PROCEDURE

The test was performed in accordance with MIL-STD-1344, Method 1017 (equivalent of EIA TP-53). This is a destructive test. Contacts used in this test were not used in any other test sequence.

GOLD FINISH THICKNESS

PURPOSE:

A standard technique for measurement of the lots to be tested. The recommendation is to use contacts randomly chosen from the lots tested and measure the thickness at the contact points via X-ray fluorescence technique. This is also a reference test.

As part of the gold thickness evaluation the report should show the type of finish (overall, selective plating, inlay, etc.), the hardness of the gold used, and the underplate (and thickness) used. The gold hardness used shall be as specified in the relevant military or detailed specification sheet.

CONTACT ENGAGEMENT AND SEPARATION FORCES

PURPOSE:

This test is included to provide information as to the effect that the various stress conditions and environmental exposures will have on the contact forces.

The contact engagement and separation forces shall be measured prior to the initial low level circuit resistance test and following the final low level circuit resistance at the completion of the test. The method of measurements shall be in accordance with the relevant military specification.

LOW LEVEL CIRCUIT RESISTANCE (L.L.C.R.)

PURPOSE:

To evaluate contact resistance characteristics of the contact systems under conditions where applied voltages and currents do not alter the physical contact interface and will detect oxides and films which degrade electrical stability. This attribute is monitored throughout the test exposures. Electrical stability of the contact system is determined by analysis of the change in resistance occurring.

This test shall be performed in accordance with MIL-STD-1344, Method 3002 with a 100 milliamp test current and an open circuit voltage of 20 millivolts maximum.

The key measuring parameter is the change (positive or negative) in resistance occurring at each measurement period to each initial absolute value per contact. For this evaluation, the absolute values themselves are meaningless.

DURABILITY

PURPOSE:

This is a preconditioning sequence which is used to induce wear that may occur under normal service conditions on the contacting surfaces. Connectors are mated and unmated a predetermined number of cycles utilizing the actual mating devices. Upon completion, the test units shall be exposed to the environments as specified to assess any impact on electrical stability.

Test Conditions:

Temperature - Room
Humidity - Uncontrolled
Durability - Test Method shall be in accordance with the relevant military connector specification

- Level 1 (Standard) - The number of insertion and withdrawal cycles shall be the same as required by the military specification governing the specific contact.
- Level 2 (High) - The number of cycles shall be 25% more than required for Level 1.
- Level 3 (Low) - The number of cycles shall be 50% less than required for Level 1.

VIBRATION

PURPOSE:

1. To determine the effects of vibration within the predominant vibration frequency range and magnitudes that may be encountered during the life of the connector.

2. To determine if electrical discontinuities at the level specified exist.

3. To determine the magnitude of axial movement between mating connectors due to vibratory considerations.

4. To establish the mechanical integrity of the connector system exposed to external mechanical stresses.

5. To evaluate the impact on electrical stability of the contact system when micromotion between contacting surfaces may be induced by mechanical means (fretting corrosion).

Test Conditions:

The vibration test shall be in accordance with the relevant military specification or specification sheet. The contacts shall not be monitored for chatter during the test.

THERMAL CYCLING WITH HUMIDITY

PURPOSE:

To evaluate the impact on electrical stability of the contact system when exposed to any environment which may generate thermal/moisture type failure mechanisms such as:

a) fretting corrosion due to wear resulting from micromotion -- thermal cycling induces micromotion between contacting surfaces and humidity accelerates the oxidation process.
b) fretting corrosion of non-noble finish system.
c) oxidation of wear debris which may have become entrapped between the contacting surfaces due to induced micromotion.
d) oxidation of particulates which may have been deposited on or entrapped between the contacting surfaces from the surrounding atmosphere.
e) via the wet oxidation process, detect loss of electrical stability due to particulates which may be deposited on contacting surfaces, wear which may expose base metal or underplates of contacting surfaces, and oxidation of non-noble finish systems.

Test Conditions:

Temperature Cycle	- 5°C±1°C to 65°C±2°C
Relative Humidity	- 90±5%
Cycle Time	- 8 Hours (total) as follows:
	- 2 Hours to reach high temperature
	- 2 Hours at high temperature
	- 2 Hours to reach low temperature
	- 2 Hours at low temperature
Duration	- 150 Cycles

NOTE: The cycle time is determined to allow the R.H. factor to develop oxides or films involved. This test combines the degradation factors of thermal cycling and humidity.

TEMPERATURE LIFE (EVALUATED TEMPERATURE)

PURPOSE:

To evaluate the impact on electrical stability of the contact system when exposed to a thermal environment which may generate temperature dependent failure mechanisms such as:

a) dry oxidation of base metals and/or underplates which have reached the contacting surfaces by impurity, diffusion or pore corrosion.
b) dry oxidation and/or film formation of particulates which may have been deposited on the contacting surfaces from the surrounding atmosphere.
c) dry oxidation due to smearing of base metal and/or underplates on the contacting surfaces or exposure of same due to wear.
d) reduced normal force due to thermal relaxation.
e) dry oxidation of the contacting surface when non-noble finish systems are utilized.

Test Condition:

Temperature	- maximum rated temperature of the connector (125°C)
Relative Humidity	- uncontrolled
Duration	- 1,000 hours

SALT SPRAY

PURPOSE:

To stress the contact finish system to an environment regarded as harsh by the military. Although this environment is not common or a cause or concern by most industrial application, it has been a standard test used and recognized by the military.

Test Conditions:

MIL-STD-1344, Method 1001
Duration:

Condition 1 - 48 hours
Condition 2 - 240 hours

EXAMINATION (GOLD FINISH):

At the completion of the final low level circuit resistance test and prior to the contact engagement and separation force evaluation, two sample contacts from each test group showing the lowest contact resistance (excluding crimp resistance) and two samples from each group showing the highest contact resistance (excluding crimp resistance) shall be examined for the degree of gold remaining in the contact engagement area. These contacts shall be submerged in an alkaline polysulfide bath for (*) hours. The examination shall be made with 10X magnification.

SPECIAL NOTES

Unmated connectors are being exposed to all of the environments except vibration and durability to simulate connector sites in a system which may be exposed to the atmosphere and mated at a later period of time. The unmated connectors shall be mated for initial measurements then unmated and subjected to the tests specified. They are only to be mated again for the purpose of taking the low level contact resistance readings at the appropriate time.

SUMMARIZED TEST RESULTS

CONTACT ENGAGEMENT AND SEPARATION FORCE

Requirements per MIL-C-55302

	Engagement Force	Separation Force
Style A	12.0 oz maximum	0.5 oz minimum
Style B	6.0 oz maximum	0.75 oz minimum
Style C	Not specified	0.5 oz minimum

	Maximum Engagement Forces (Ounces)		
Plating Thickness	20	30	50
Style A			
Initial	6.6	6.6	6.0
After Thermal Cycling	6.5	6.0	7.3
After Temperature Life	4.3	5.8	3.6
After Salt Spray (48 Hr.)	4.7	6.5	3.7
After Salt Spray (240 Hr.)	4.5	5.1	4.1
Style B			
Initial	7.1	6.6	5.5
After Thermal Cycling	6.8	3.9	5.0
After Temperature Life	4.3	3.8	4.3
After Salt Spray (48 Hr.)	5.3	5.4	7.4
After Salt Spray (240 Hr.)	5.1	5.7	5.5
Style C			
Initial	3.5	2.3	3.5
After Thermal Cycling	2.9	2.5	2.9
After Temperature Life	2.5	2.6	2.8
After Salt Spray (48 Hr.)	2.9	2.7	3.0
After Salt Spray (240 Hr.)	3.4	3.2	3.4

	Maximum Separation Forces (Ounces)		
Plating Thickness	20	30	50
Style A			
Initial	1.6	1.3	1.2
After Thermal Cycling	1.2	1.1	0.8
After Temperature Life	1.0	0.9	0.8
After Salt Spray (48 Hr.)	1.4	1.0	0.8
After Salt Spray (240 Hr.)	1.6	1.2	1.0
Style B			
Initial	2.2	1.3	1.3
After Thermal Cycling	2.5	2.5	2.3
After Temperature Life	1.5	1.4	1.4
After Salt Spray (48 Hr.)	1.6	1.8	1.8
After Salt Spray (240 Hr.)	1.9	1.9	1.9
Style C			
Initial	0.7	0.7	0.7
After Thermal Cycling	0.5	0.5	0.6
After Temperature Life	0.6	0.5	0.5
After Salt Spray (48 Hr.)	0.7	0.6	0.6
After Salt Spray (240 Hr.)	0.7	0.6	0.7

ELECTRICAL RESISTANCE MONITORING

The electrical attribute monitored was changes in low level circuit resistance. The results are reflected in the grouped data tables following. Data from all participating companies were grouped resulting in the data indicating composite trends.

It is cautioned that the data be reviewed in proper perspective. The test plan was developed on a "design to fail" concept and the combination of exposures go far beyond normal specifications and sequences contained therein.

It should further be cautioned that the results may be influenced by subtle failure mechanisms such as; fretting motion, dry oxidation, wet oxidation and diffusion, or a combination thereof. These mechanisms can be influenced by normal force, contact geometry, presence of wear debris and the plating integrity. The latter factors as well as investigation of the possible failure mechanisms were beyond the scope of this project.

For a concise summary, the data as shown in the basic summary table was arbitrarily ranked as follows:

Change in LLCR	Rank
< 5.0	1
5.1 to 10.0	2
10.1 to 15.0	3
15.1 to 25.0	5
25.1 to 50.0	7
> 50.0	10

Said ranking was assigned to the maximum observation.

A) <u>THERMAL CYCLING WITH HUMIDITY</u>

	20	30	50
A	1	1	1
B	1	1	1
C -- Low	1	1	1
-- Std	1	2	1
-- High	1	2	2
D -- Low	2	1	1
-- Std	1	1	1
-- High	2	1	1
E	1	1	1
	11	11	10

B) <u>ELEVATED TEMPERATURE</u>

	20	30	50
A	1	1	1
B	1	1	1
C -- Low	1	1	1
-- Std	2	1	1
-- High	1	1	1
D -- Low	1	2	1
-- Std	1	1	1
-- High	1	1	1
E	1	1	1
	10	10	9

C) <u>SALT SPRAY 48 HOURS</u>

	20	30	50
A	1	1	1
B	1	1	1
C -- Low	1	1	1
-- Std	1	1	1
-- High	1	1	1
D -- Low	1	1	1
-- Std	1	1	1
-- High	1	1	1
E	1	1	1
	9	9	9

D) <u>SALT SPRAY 240 HOURS</u>

	20	30	50
A	1	1	1
B	1	1	1
C -- Low	1	1	2
-- Std	1	1	1
-- High	1	1	1
D -- Low	1	1	1
-- Std	1	1	1
-- High	1	1	1
E	1	1	1
	9	9	10

THERMAL CYCLING WITH HUMIDITY

Change in LLCR (Milliohms)

Plating Thickness (Microinches)	20 Avg	20 Max	30 Avg	30 Max	50 Avg	50 Max
A (Unmated)	+1.3	+4.2	+0.8	+3.3	+0.6	+2.4
B (Mated)	+0.1	+1.2	+0.6	+3.2	+0.5	+4.1
C (Durability)						
Low (250 cycles)	+0.6	+2.3	+0.7	+4.5	+0.6	+1.8
Std (500 cycles)	+0.9	+2.6	+1.3	+8.8	+1.4	+4.4
High (625 cycles)	+1.2	+4.5	+0.9	+8.7	+1.0	+8.4
D (Durability/Vibration)						
Low (250 cycles)	+1.3	+5.2	+1.0	+2.7	+1.0	+2.5
Std (500 cycles)	+1.2	+3.1	+1.0	+2.9	+1.0	+3.2
High (625 cycles)	+1.7	+5.3	+0.9	+2.7	+1.5	+5.0
E (Vibration)	+1.5	+3.0	+1.4	+2.8	+1.1	+4.4

ELEVATED TEMPERATURE

Change in LLCR (Milliohms)

Plating Thickness (Microinches)	20 Avg	20 Max	30 Avg	30 Max	50 Avg	50 Max
A (Unmated)	+0.2	+1.6	+1.1	+4.6	+0.5	+2.9
B (Mated)	+0.5	+1.9	+1.3	+4.2	+1.0	+2.9
C (Durability)						
Low (250 cycles)	+0.9	+2.0	+1.2	+4.2	+0.9	+2.3
Std (500 cycles)	+1.2	+5.4	+1.2	+4.2	+0.7	+2.0
High (625 cycles)	+1.2	+3.4	+1.3	+3.5	+0.9	+3.4
D (Durability/Vibration)						
Low (250 cycles)	+1.8	+2.7	+1.5	+6.1	+1.2	+3.1
Std (500 cycles)	+1.3	+4.1	+0.7	+2.0	+0.9	+2.7
High (625 cycles)	+1.6	+4.5	+1.0	+4.2	+1.5	+2.1
E (Vibration)	+1.1	+2.2	+1.2	+2.1	+0.8	+1.3

SALT SPRAY 48 HOURS

Change in LLCR (Milliohms)

Plating Thickness (Microinches)	20 Avg	20 Max	30 Avg	30 Max	50 Avg	50 Max
A (Unmated)	+0.0	+0.6	+0.1	+1.0	+0.3	+0.9
B (Mated)	+0.1	+0.3	+0.4	+1.7	+0.4	+1.0
C (Durability)						
Low (250 cycles)	+0.3	+2.6	+0.5	+1.8	+0.1	+1.0
Std (500 cycles)	+0.0	+2.8	+0.0	+1.6	+0.0	+1.4
High (625 cycles)	+0.6	+3.5	-0.1	+3.1	+0.3	+1.7
D (Durability/Vibration)						
Low (250 cycles)	+0.1	+1.8	+0.1	+1.1	+0.7	+1.2
Std (500 cycles)	+0.8	+3.3	+1.2	+1.6	+0.5	+1.5
High (625 cycles)	+0.4	+1.4	-0.1	+1.6	+0.2	+1.3
E (Vibration)	-0.1	+2.0	+0.1	+1.9	+0.2	+0.4

SALT SPRAY 240 HOURS

Change in LLCR (Milliohms)

Plating Thickness (Microinches)	20 Avg	20 Max	30 Avg	30 Max	50 Avg	50 Max
A (Unmated)	+0.7	+2.0	+0.6	+2.5	+0.2	+1.1
B (Mated)	+0.9	+1.9	+0.8	+2.3	+0.8	+2.1
C (Durability)						
Low (250 cycles)	+0.7	+2.0	+1.0	+2.6	+0.4	+1.4
Std (500 cycles)	+0.4	+2.5	+0.3	+2.1	+0.8	+5.1
High (625 cycles)	+0.6	+2.5	+0.5	+2.0	+0.1	+2.4
D (Durability/Vibration)						
Low (250 cycles)	+1.0	+3.9	+0.4	+2.3	+0.8	+2.1
Std (500 cycles)	+0.7	+3.4	+0.5	+1.0	+0.7	+2.5
High (625 cycles)	+0.3	+1.8	+1.0	+2.5	+0.6	+1.6
E (Vibration)	+0.7	+2.5	+0.2	+1.6	+0.4	+2.5

PLATING THICKNESS

All suppliers certified that the thickness requirements as specified were met.

POROSITY

Data as supplied indicated the following pore counts as follows:

	Average Porosity Count		
Thickness	20/29	30/39	50/59
Pin contact	6	10	3
Socket contact	10	15	5

All other plating attributes were certified as being within the specified requirements.

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EST. 1924