Report EL-2005-02-026 CR2
Evaluation of Tin Whisker Growth and Compliant Pin Resistance, FCI Lead Free METRAL® 1000 Connectors
Rev. B
2006 May 08

PURPOSE:
Lead free METRAL® 1000 connectors were tested to assess the growth of whiskers from the matte tin plating on the Baby-H style compliant pins. Standard METRAL® 1000 connectors (with tin-lead plated terminals) were included as control samples. Testing encompassed exposure to two (2) treatment environments: humid heat aging and room temperature storage. Testing was conducted according to FCI specification GS-19-028, which requires thermal shock preconditioning prior to both aging treatments. Whiskers were identified by visual examination of each tin plated pin in its plated through hole (PTH) in the printed wiring board (PWB) at approximately 100X magnification. Possible tin whiskers were verified by scanning electron microscopy (SEM) and resulting energy dispersive analysis of x-radiation (EDAX). The extent of growth of verified whiskers was evaluated by measurement of the projected whisker length in the electron microscope. Results were evaluated by comparison with the requirement for whisker length specified in FCI GS-19-028. Compliant pin resistance was measured under dry circuit conditions before and after the environmental exposures; results were assessed by comparison with the requirement of IEC specification for press fit connections, IEC 60352-5. These results are applicable to all FCI connectors with Baby-H style compliant sections on press fit (PF) pins.

CONCLUSIONS:

No whiskers were observed on the either the lead free (tin plated) or the standard (tin-lead plated) product. Consequently, the lead free test samples met the specified requirement for whisker growth (50 micrometers maximum whisker length at the end of the 6 month exposure period).

Compliant pin resistance met the requirement of 0.5 milliohm maximum change. In no case did the compliant pin resistance exceed 0.5 milliohm.

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SAMPLE DESCRIPTION:

Test sample identity is given in table 1.

Table 1. Identity of Submitted Samples

Item	Quantity	Description	Part Number	Lot	PF Plating	Received
1	2500	METRAL® 1000 Pin	55010-102LF	EPR V-2542	Sn / Ni	2005 Jan 20
2	1000	METRAL® 1000 Pin	55010-103	06/02, 07/02	Sn-Pb / Ni	2004 Dec 20
3	287	METRAL® 1000 Header	73983-1011LF	EPR V-2543	Sn / Ni	2005 Jan 20
4	200	METRAL® 1000 Header	73983-3011	YF449001	Sn-Pb / Ni	2004 Dec 29

The plating on the compliant section of the lead free press fit pins was 0.5 micrometer to 1.5 micrometers of pure matte tin over 0.5 micrometer to 3 micrometers of nickel. The plating on the compliant section of the standard press fit pins was 0.1 micrometer to 1.5 micrometers of tin-lead alloy (92 % nominal mass fraction of tin) over 1.3 micrometers minimum of nickel.

The lead free press fit product was tested in each of two (2) PTH sizes (minimum and maximum) in PWBs with each of three (3) finishes (a total of 6 sample sets) as listed in table 2.

Table 2. Identity of Sample Sets

	PWB Finish	PTH Hole Size
1	Tin-Lead	Minimum
2	Copper / OSP	
3	Tin	
4	Tin-Lead	Maximum
5	Copper / OSP	
6	Tin	

REFERENCE DOCUMENTS:

Pertinent documents are listed in table 3.

Table 3. Reference Documents

Document ID	Title	Rev. Level (Date)
FCI GS-19-028	Test Specification, Test Procedure for Tin Whisker Formation in Lead-free Connector Terminal Finishes	A (2004 Feb 09)
FCI GS-12-004	Application Standard, Specification for METRAL® Compliant Contacts	C (2001 Aug 14)
FCI EL-2004-01-032C	Test Summary, Thomas D. Moyer, Designed Experiment to Determine the Reliability of Various Commercial Plating Baths and the Key Factors Affecting Whisker Formation	(2004 Nov 24)
IEC 60352-5	Solderless connections – Part 5: Press-in connections – General requirements, test methods and practical guidance	Ed. 2.1 (2003 Dec)
ASTM E766	Standard Practice for Calibrating the Magnification of a Scanning Electron Microscope	98 (2003)

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TEST SEQUENCE:

The tests were performed in accordance with the humid heat aging and room temperature storage environments specified in FCI GS-19-028 sections 5.4.1.2 and 5.4.1.3, respectively, after preconditioning by thermal shock exposure per FCI GS-19-028 section 5.2.2. Aging in dry heat (FCI GS-19-028 section 5.4.1.1) was not performed since this environment has previously been shown to be benign with respect to whisker growth (FCI test summary EL-2004-01-032C). The applied test sequence is given in table 4

Table 4. Sequence of Applied Tests by Test Group

		Sequence	
		Group C	Group D
		Humid Heat Aging	Room Temperature Storage
Test Description	Condition	40 Terminals	40 Terminals
Terminal Insertion		1	1
Compliant Pin Resistance	Initial	2	2
Whisker Evaluation	Initial	3	3
Thermal Shock	Preconditioning	4	4
Whisker Evaluation	after T Shock	5	5
Compliant Pin Resistance	after T Shock	6	6
Humid Heat Aging	250 hr	7	
Room Temperature Storage	250 hr		7
Whisker Evaluation	at 250 hr	8	8
Humid Heat Aging	+ 480 hr	9	
Room Temperature Storage	+ 480 hr		9
Whisker Evaluation	at 1 Month	10	10
Humid Heat Aging	+ 1 Mo	11	
Room Temperature Storage	+ 1 Mo		11
Whisker Evaluation	at 2 Months	12	12
Humid Heat Aging	+ 1 Mo	13	
Room Temperature Storage	+ 1 Mo		13
Whisker Evaluation	at 3 Months	14	14
Humid Heat Aging	+ 1 Mo	15	
Room Temperature Storage	+ 1 Mo		15
Whisker Evaluation	at 4 Months	16	16
Humid Heat Aging	+ 1 Mo	17	
Room Temperature Storage	+ 1 Mo		17
Whisker Evaluation	at 5 Months	18	18
Humid Heat Aging	+ 1 Mo	19	
Room Temperature Storage	+ 1 Mo		19
Whisker Evaluation	Final (at 6 Mo)	20	20
Compliant Pin Resistance	Final	21	21

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TEST PROCEDURES:

Terminal Insertion

In normal usage, the METRAL® 1000 connector is applied to the PWB as a connector assembly, but application of the entire connector precludes observation of the press fit (tin plated) area of the terminal. Consequently, this test was conducted using individual unassembled terminals. Each terminal was affixed to a tensile/compression test instrument using a probe (insertion tool MF258.1) with a hole in the end to accommodate the mating end of the terminal and a spring member to hold the terminal in place. Insertion proceeded to the nominal insertion depth for terminals in connectors (4.3 mm from the top of the PWB to the tip of the press fit end of the pin) at a rate of 12 millimeters per minute. Forty (40) terminals were tested for each combination of test group, terminal plating, PWB finish, and PTH size.

Compliant Pin Resistance

Low level compliant pin resistance was measured in accordance with EIA-364-23B, option 1. This is a four point measurement method with separate connections for current flow and voltage sensing on each side of the compliant interface. Thermal offsets were compensated automatically by the measuring instrument by means of null measurements during pulsed application of the test current. Measurement of contact resistance across the separable interface was performed using parallel connections. The negative sides of the current supply and voltage probe were connected to a pair of I/O pins on the PWB; each of these pairs was connected in parallel to a PTH. The positive side of the current supply was connected to the mating end of the METRAL® header terminal through a single row of a METRAL® receptacle connector. The positive side of the voltage probe was connected to the press fit end of the METRAL® header terminal through a single row of a METRAL® receptacle connector modified to permit mating with the short tail protruding through the PWB. Individual contact pairs were measured by automated switching of individual pin connections for all circuit elements except the positive side of the current supply, which was connected to all pins in parallel. Consequently, the measured compliant pin resistance values included the effects of the compliant interface of the header pin, a segment of the header PWB plated through hole (PTH), and minimal bulk resistance within the press fit feature of the header pin.

Whisker Evaluation

The presence of whiskers was evaluated by visual observation using a binocular optical microscope at approximately 100X magnification. Samples with possible whiskers identified by visual observation were examined by electron microscopy. Qualitative elemental analysis by electron induced x-ray emission was employed to verify the identity of these features.

The area of observation included the press fit terminal and the PTH including the interior surface as far down into the PTH as visibly accessible from both the front (entry) and rear (opposite) sides of the PWB.

Examination for whiskers was conducted after terminal insertion, after preconditioning, and monthly during the six (6) month environmental treatments; an examination was also conducted after 250 hours of treatment to check for rapid initial whisker growth.

Whisker Measurement

Verified whiskers (if any) were measured for length from secondary electron images obtained by SEM.

The geometry of the sample surface being investigated (inside a PTH containing a press fit pin) imposes severe restrictions on the orientation from which a whisker can be viewed, which prevents the use of stereographic imaging. Accordingly, whisker measurement was performed at the optimal orientation for whisker visibility as adjudged by the operator.

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Thermal Shock
The test samples (compliant pins in PWBs) were preconditioned by exposure to repetitive thermal cycling between temperature extremes of –55 °C and 85 °C in accordance with section 5.2.2 of FCI test specification GS-19-028; 500 cycles of 20 minutes each were applied.

Humid Heat Aging
The test samples (compliant pins in PWBs) were subjected to aging under conditions of humid heat at 52 °C ± 5 °C and 90 % ± 5 % relative humidity in accordance with section 5.4.1.2 of FCI test specification GS-19-028.

Room Temperature Storage
The test samples (compliant pins in PWBs) were subjected to room temperature storage under ambient conditions (23 °C ± 5 °C with humidity uncontrolled) in accordance with section 5.4.1.3 of FCI test specification GS-19-028.

REQUIREMENTS:

Whisker Growth
The requirement for whisker length was 50 micrometers maximum in accordance with FCI test specification GS-19-028.

Compliant Pin Resistance
The requirement for compliant pin resistance was 0.5 milliohm maximum change from initial values in accordance with IEC 60352-5, section 5.2.3.1 a).

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TEST RESULTS:

Compliant Pin Resistance

The results of low level compliant pin resistance measurement are summarized in tables 5 and 6. The estimated values of expanded uncertainty at coverage factor 2 (approximately 95 % confidence level) are 0.05 milliohm and 0.06 milliohm, respectively, for low level compliant pin resistance measurement and change in low level compliant resistance. All samples met the specified requirement for low level compliant pin resistance.

Table 5. Statistical Summary of Test Results, Low Level Compliant Pin Resistance

		Measured Low Level Compliant Pin Resistance / milliohm			
		Initial (Groups C & D)	after Thermal Shock (Groups C & D)	after Aging in Humid Heat (Group C)	after Storage at Room Temp. (Group D)
Lead Free (Sn Plated) Pins All PWB Types	Count	240	239 †	120	120
	Average	0.025	0.049	0.047	0.052
	Std. Dev.	0.009	0.021	0.025	0.022
	Minimum	0.01	0.00	0.01	0.01
	Maximum	0.05	0.10	0.16	0.11
Standard (Sn-Pb Plated) Pins All PWB Types	Count	240	240	120	120
	Average	0.029	0.039	0.047	0.048
	Std. Dev.	0.014	0.029	0.055	0.065
	Minimum	0.01	0.00	0.00	0.00
	Maximum	0.09	0.20	0.44	0.41

† 1 reading was missed due to experimental mishap.

Table 6. Statistical Summary of Test Results, Change in Low Level Compliant Pin Resistance

		Change in Low Level Compliant Pin Resistance / milliohm		
		after Thermal Shock (Groups C & D)	after Aging in Humid Heat (Group C)	after Storage at Room Temp. (Group D)
Lead Free (Sn Plated) Pins All PWB Types	Count	239 †	120	120
	Average	0.024	0.021	0.028
	Std. Dev.	0.023	0.028	0.024
	Minimum	-0.04	-0.04	-0.03
	Maximum	0.09	0.14	0.08
	# > Spec. Max.	0	0	0
Standard (Sn-Pb Plated) Pins All PWB Types	Count	240	120	120
	Average	0.010	0.017	0.020
	Std. Dev.	0.033	0.053	0.065
	Minimum	-0.06	-0.05	-0.06
	Maximum	0.18	0.41	0.36
	# > Spec. Max.	0	0	0

† 1 reading was missed due to experimental mishap.

Whisker Evaluation and Measurement

No whiskers were observed on any of the test samples under any of the applied treatment conditions.

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EQUIPMENT:

Item Description	Manufacturer (Model)	Equip. ID #	Cal. Due Date
Microscope	Bausch & Lomb (StereoZoom 5)	VG6613	Not Calibrated
Microscope	Wild (M8)	VG7088	Not Calibrated
Micro-Ohmmeter	Keithley (Model 580, SN 318354)	VG6106	2005 Aug
Micro-Ohmmeter	Keithley (Model 580, SN 362834)	VG6905	2006 Oct
Scanner	Keithley (Model 7002, SN 0601955)	VG7145	Not Calibrated
Climate Monitor	Fischer Scientific (SN 230011236)	VG7813	2005 Apr
Climate Monitor	Fischer (11-661-7D, SN 51018297)	VG7961	2007 Apr
Tensile/Compression Tester	Instron (Model 1122, SN 4664)	VG6464	2005 Jul
Thermal Shock Chamber	Cincinnati Sub-Zero (Model VTS-1.5-105-105-S/AC)	VG7403	2005 May
Humidity Chamber	Blue M (FR-251B-MP1, SN F1-169)	VG6474	2006 May
Humidity Chamber	Thermotron (Model SE-300-2, SN 31938)	VG7888	2005 May 2006 May
Humidity Chamber	Espec (PRA-3GP, SN 00119002)	S56130	2006 Apr
Humidity Chamber	Espec (ESX-3CA, SN 015530)	VG7930	2006 Apr
Scanning Electron Microscope X-ray Analyzer	Philips (XL30 ESEM TMP, SN E159/D6886) EDAX (SUTW PV7760/77 ME, SN 8837-60770 ME)	VG7782	Cal. Before Use
Cu and Al Reference Sample	Ernest F. Fullam (10800)	VG7943	Cal. Not Required

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REVISION RECORD

Rev. #	Revision Date	Page(s)	Description
–	2005 Nov 14	All	Original Issue
A	2006 Apr 03	1	Updated Corporate Logo
B	2006 May 08	1	Repositioned Corporate Logo

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