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**Report EL-2004-12-003 CR**

Evaluation of Tin Whisker Growth by the iNEMI Method, FCI Lead Free METRAL® (EON) Headers  
Rev. C  
2006 Jun 12

**PURPOSE:**

Lead free METRAL® header connectors were tested to assess the growth of whiskers from the matte tin plating on the compliant pins. Standard METRAL® header connectors (with tin-lead plated terminals) were included as control samples. Testing was conducted in accordance with the requirements of the iNEMI (International Electronics Manufacturing Initiative) document “Tin Whisker Acceptance Test Requirements” and test procedures defined in JEDEC standard JESD22A121. Testing encompassed independent exposure to four (4) treatment stresses: ambient storage, humid heat aging, thermal cycling, and electrical bias (under ambient conditions). Whiskers were identified by visual examination of each plated pin in its plated through hole (PTH) in the printed wiring board (PWB) at approximately 100X magnification. Any sample with a possible tin whisker (as identified optically) was examined by scanning electron microscopy (SEM) and resulting energy dispersive analysis of x-radiation (EDAX) for authentication of whisker identity. The extent of whisker growth was evaluated by measurement of the projected whisker length in the electron microscope. Tin whisker growth on the lead free samples was assessed relative to the requirements for whisker length specified in the iNEMI document, by comparison with whisker growth on standard (tin-lead plated) product, and by comparison with the results of previous testing (FCI US Product Test Laboratory report EL-2004-12-002) using a battery of applied stress treatments in accordance with per FCI specification GS-19-028. These results are applicable to all FCI connectors with eye-of-needle (EON) style compliant sections on press fit (PF) pins.

**CONCLUSIONS:**

No whiskers were observed on either the lead free (tin plated) or the standard (tin-lead plated) product. Therefore, the lead free METRAL® header pins met the iNEMI requirements for both product Classes 2 and 3.

In contrast to the iNEMI method, evaluation using the FCI test protocol yielded substantial whiskering on both lead free and standard pins (26 whiskers of 38 micrometers average length and 2 whiskers of 35 micrometers average length, respectively). Consequently, the FCI test procedure is substantially more severe than that specified by the iNEMI test requirements.

**SAMPLE DESCRIPTION:**

Test sample identity is given in table 1. The test specimens were obtained by sampling product submitted for testing under US Product Test Laboratory number EL-2004-12-002, which included whisker evaluation by the FCI method (per FCI GS-19-028).

**Table 1. Identity of Submitted Samples**

| Item | Quantity | Description        | Part Number | Lot                       | PF Plating | Received    |
|------|----------|--------------------|-------------|---------------------------|------------|-------------|
| 1    | 2500     | METRAL® Header Pin | 60047-102LF | EPR V-2482<br>2004 Oct 26 | Sn / Ni    | 2004 Oct 29 |
| 2    | 2500     | METRAL® Header Pin | 60047-102   | Unknown                   | Sn-Pb / Ni | 2004 Sep 27 |

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 0.5 micrometer to 1.5 micrometers of tin-lead alloy (92 % nominal mass fraction of tin) over 0.3 micrometer minimum of nickel.

This testing was conducted using minimum and maximum size plated through holes in printed wiring boards approximately 1.6 mm thick. To avoid confusion by whisker growth from the PWB finish, only boards with copper (OSP) finish were used in this testing. Previous testing (FCI EL-2004-12-002) showed that whisker formation was much more prevalent with copper (OSP) than with other PWB finishes (tin or tin-lead). The sample sets are listed in table 2.

**Table 2. Identity of Sample Sets**

|   | Plating on Press Fit Pin | PTH Size |
|---|--------------------------|----------|
| 1 | Tin-Lead                 | Minimum  |
| 2 | Tin (Lead Free)          |          |
| 3 | Tin-Lead                 | Maximum  |
| 4 | Tin (Lead Free)          |          |

**REFERENCE DOCUMENTS:**

Pertinent documents are listed in table 3.

**Table 3. Reference Documents**

| Document ID         | Title   | Rev. Level (Date) |
|---------------------|---|-------------------|
| iNEMI               | Tin Whisker Acceptance Test Requirements  | (2004 Jul 28)     |
| JEDEC JESD22A121    | Measuring Whisker Growth on Tin and Tin Alloy Surface Finishes  | (2005 May)        |
| FCI GS-12-180       | Product Specification, Converged METRAL® Header   | B (2002 Aug 27)   |
| FCI GS-20-073       | Application Specification, Application Guide for Converged METRAL® Vertical Press Fit Signal Headers and Shrouds  | B (2004 Jun 08)   |
| FCI 58351           | Customer Drawing, Printed Circuit Board Information   | B (2004 Jul 20)   |
| FCI EL-2004-12-002  | Evaluation FCI Lead Free METRAL® Header Pins with EON Compliant Sections  | (2005 Sep 14)     |
| FCI GS-19-028       | Test Specification, Test Procedure for Tin Whisker Formation in Lead-free Connector Terminal Finishes   | A (2004 Feb 09)   |
| 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)     |
| ASTM E766           | Standard Practice for Calibrating the Magnification of a Scanning Electron Microscope   | 98 (2003)         |

**TEST SEQUENCE:**

The tests were performed in accordance with the iNEMI test requirements. No preconditioning was applied in accordance with instructions for testing of compliant pins per section 15.4 of the iNEMI document. Whisker growth evaluation comprised four (4) test groups, each consisting of a separate environmental treatment: ambient storage, aging in humid heat, thermal cycling, and application of voltage bias (under ambient conditions). Sampling for each test group consisted of 92 individual pins in accordance with the iNEMI requirement of 90 leads minimum. The applied test sequence is given in table 4.

**Table 4. Sequence of Applied Tests by Test Group**

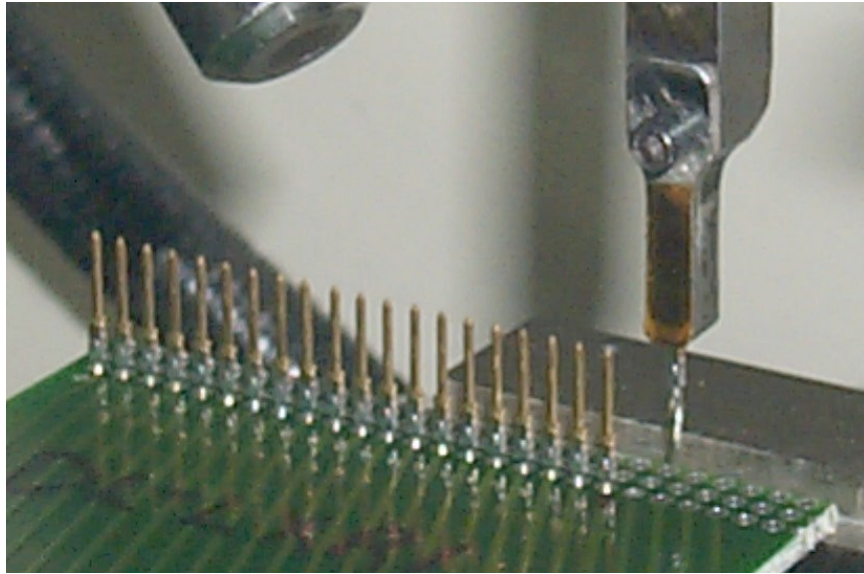
| Test Description        | Condition    | Test Sequence    |                 |                 |              |
|-------------------------|--------------|------------------|-----------------|-----------------|--------------|
|                         |              | Group 1          | Group 2         | Group 3         | Group 4      |
|                         |              | Humid Heat Aging | Ambient Storage | Thermal Cycling | Voltage Bias |
|                         |              | 92 Terminals     | 92 Terminals    | 92 Terminals    | 92 Terminals |
| Terminal Insertion      |              | 1                | 1               | 1               | 1            |
| Whisker Evaluation      | Initial      | 2                | 2               | 2               | 2            |
| Temp/Humidity Treatment | 1000 hr      | 3                |                 |                 |              |
| Ambient Storage         | 1000 hr      |                  | 3               |                 |              |
| Thermal Cycling         | 500 cycles   |                  |                 | 3               |              |
| Voltage Bias Treatment  | 1000 hr      |                  |                 |                 | 3            |
| Whisker Evaluation      |              | 4                | 4               | 4               | 4            |
| Temp/Humidity Treatment | + 1000 hr    | 5                |                 |                 |              |
| Ambient Storage         | + 1000 hr    |                  | 5               |                 |              |
| Thermal Cycling         | + 500 cycles |                  |                 | 5               |              |
| Voltage Bias Treatment  | + 1000 hr    |                  |                 |                 | 5            |
| Whisker Evaluation      |              | 6                | 6               | 6               | 6            |
| Temp/Humidity Treatment | + 1000 hr    | 7                |                 |                 |              |
| Ambient Storage         | + 1000 hr    |                  | 7               |                 |              |
| Thermal Cycling         | + 500 cycles |                  |                 | 7               |              |
| Voltage Bias Treatment  | + 1000 hr    |                  |                 |                 | 7            |
| Whisker Evaluation      |              | 8                | 8               | 8               | 8            |
| Temp/Humidity Treatment | + 1000 hr    | 9                |                 |                 |              |
| Ambient Storage         | + 1000 hr    |                  | 9               |                 |              |
| Thermal Cycling         | + 500 cycles |                  |                 | 9               |              |
| Voltage Bias Treatment  | + 1000 hr    |                  |                 |                 | 9            |
| Whisker Evaluation      | Final        | 10               | 10              | 10              | 10           |

In addition to the minimum treatment durations, the iNEMI procedure has provision (under certain conditions) for extended exposure to the treatment environments until whisker growth stops. Extended exposures are to be applied if whisker growth on the lead free (tin plated) samples exceeds that on the control (standard tin-lead plated) samples.

## **TEST PROCEDURES:**

### **Terminal Insertion**

In normal usage, the METRAL® header is applied to the PWB as a connector assembly. However, application of the entire connector precludes observation of the press fit (tin plated) area of the terminal. Consequently, individual pins were inserted into PWBs. For insertion, each pin was affixed to the moving crosshead of a tensile/compression test instrument in a probe with a spring member to hold the terminal (insertion tool 258.1) with the press fit end projecting downward. Insertion proceeded under machine control by pushing the pin(s) into the PWB at a rate of 12 millimeters per minute 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) as illustrated in figure 1 (derived from FCI EL-2004-12-002).



**Figure 1. Test Setup for Insertion of Individual Pins in PWBs (from EL-2004-12-002)**

### **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.

Examination for whiskers was conducted initially, after each 500 cycles of thermal cycling, and after each 1000 hours of other treatments (humid head aging, ambient storage, and voltage bias)

### **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.

### **Humid Heat Aging**

The test samples (compliant pins in PWBs) were subjected to aging under conditions of humid heat at  $60\text{ }^{\circ}\text{C} \pm 5\text{ }^{\circ}\text{C}$  and 85 % to 90 % relative humidity in accordance with the requirements of JEDEC standard 22A121 (Section 6.4, Table 4).

### **Ambient Storage**

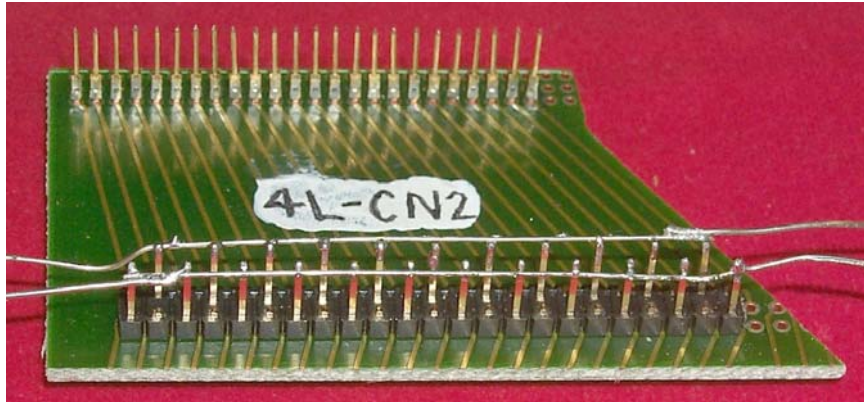
The test samples (compliant pins in PWBs) were subjected to storage under ambient laboratory conditions.

### **Thermal Cycling**

The test samples (compliant pins in PWBs) were subjected to thermal cycling between  $-55\text{ }^{\circ}\text{C}$  and  $85\text{ }^{\circ}\text{C}$  at a rate of 3 cycles per hour in accordance with the requirements of JEDEC standard 22A121 (Section 6.4, Table 4).

### **Voltage Bias**

A voltage bias of 5 volts was applied between adjacent pins on the test samples (compliant pins in PWBs) under ambient conditions in accordance with section 16.1 of the iNEMI document. The individual pins (23 per PWB) were placed into individual PTHs at the nominal spacing between terminals in assembled connectors (2 mm between pin centerlines). To facilitate whisker evaluation, all pins were placed in a single row of PTHs. Alternating pins were connected electrically via PWB traces. Electrical potential was applied between these two (2) isolated, interspersed sets of connected pins thereby producing voltage bias between all adjacent pairs of pins. Figure 2 shows an example of a test board wired for application of voltage bias.



**Figure 2. Example of Test Board Wired for Application of Voltage Bias**

### **REQUIREMENTS:**

In accordance with the iNEMI document (Section 18, Table 3), the requirements for whisker length were 40 micrometers maximum for Class 2 devices (high reliability business applications) and 50 micrometers maximum for Class 3 devices (consumer products) in high frequency applications.

### **TEST RESULTS:**

#### **Whisker Evaluation**

No whiskers were observed on any of the samples at any of the treatment durations. Consequently, the lead free pins met the requirements of whisker growth for both Class 2 and Class 3 applications.

Since the lead free and standard pins exhibited equivalent performance through the standard treatment durations, extension of the treatments was not required.

## **COMPARISON WITH FCI TEST METHOD:**

The same pins were previously tested (FCI EL-2004-12-002) for whisker growth in the same PWBs using a different set of test conditions in accordance with FCI specification GS-19-028.

The main differences between the iNEMI and FCI test methods are as follows. The FCI method applies thermal cycling (500 cycles) as a preconditioning to the other environmental exposures rather than as a separate test group (for 2000 cycles minimum in the iNEMI method); temperature extremes and cycling frequency are equivalent. The FCI humid heat aging uses slightly lower temperature (52 °C) and slightly wider tolerance on relative humidity (85 % to 95 %) than the iNEMI test (60 °C, 85 % to 90 % RH). The exposure durations are slightly longer for the FCI method (6 months or approximately 4380 hours) than the minimum durations of the iNEMI test (4000 hours). Although aging in dry heat is also indicated (FCI GS-19-028 section 5.4.1.1), it was not performed since this environment has previously been shown to be benign with respect to whisker growth (FCI EL-2004-01-032C).

Under the FCI test protocol, whiskers of substantial length (longer than 10 micrometers) were observed after 3 months of treatment duration. Throughout the full test, a total of 28 whiskers were observed with an average length of 38 micrometers. This included two (2) whiskers from standard (tin-lead plated) pins with an average length of 35 micrometers.

This large disparity in observed whisker growth indicates that the FCI test method is substantially more severe than that specified by the iNEMI test requirements.

**EQUIPMENT:**

| <b>Item Description</b>                        | <b>Manufacturer (Model)</b>  | <b>Equip. ID #</b> | <b>Cal. Due Date</b> |
|--|--|--------------------|----------------------|
| Microscope                                     | Wild (M8)  | VG7088             | Not Calibrated       |
| Microscope                                     | Olympus (SZH)  | VG7399             | Not Calibrated       |
| Tensile/Compression Tester                     | Instron (Model 1122, SN 4471)  | VG7171             | 2005 Jul             |
| Humidity Chamber                               | Thermotron (SM-3.5S, SN 20022-S)   | VG6475             | 2006 May             |
| Humidity Chamber                               | Espec (ESX-3CA, SN 015530)   | VG7930             | 2005 May<br>2006 Apr |
| Thermal Shock Chamber                          | Cincinnati Sub-Zero (VTS-1.5-105-105-S/AC,<br>SN 88-11078)                           | VG7403             | 2005 May<br>2006 May |
| Power Supply                                   | Sorensen (QRE 7.5-10, SN 443)  | VG6148             | Not Calibrated       |
| Multimeter                                     | Extech (380202, SN 638619)   | VG7154             | 2005 Dec             |
| Multimeter                                     | Extech (380202, SN 638607)   | VG7155             | 2005 Aug             |
| Scanning Electron Microscope<br>X-ray Analyzer | Philips (XL30 ESEM TMP, SN E159/D6886)<br>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    |

REVISION RECORD

| <b>Rev. #</b> | <b>Revision Date</b> | <b>Page(s)</b> | <b>Description</b>  |
|---------------|----------------------|----------------|---|
| -             | 2005 Nov 03          | All            | Original Issue  |
| A             | 2006 Apr 03          | 1              | Updated Corporate Logo  |
| B             | 2006 May 08          | 1              | Repositioned Corporate Logo   |
| C             | 2006 Jun 12          | 1, 6           | Modification of Statistical Statements regarding Whisker Growth under FCI Test Method |
|               |                      |                |   |
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