Tin Whiskers – A Long Term RoHS Reliability Problem

Presented by:

Robert J. Landman, President, SM IEEE
H&L Instruments, North Hampton, NH

Author: Section 10, Power Systems Components,
Standard Handbook for Electrical Engineers,
14th Ed., Fink & Beaty, McGraw-Hill, 2000

Tin Whiskers

- Tin whiskers grow in the absence of lead in solder and pose a serious reliability risk to electronic assemblies.
- Tin whiskers have caused system failures in both earth and space-based applications as well as missile systems.
- At least three tin whisker-induced short circuits resulted in complete failure of on-orbit commercial satellites.

Source Material References

http://nepp.nasa.gov/WHISKER/

Dr. Henning Leidecker, Jay Brusse
Metal Whiskering Group at Goddard Space Flight Center (GSFC)

Dr. Gordon Davy at BMPCOE (Best Management Practices Center of Excellence)

Bill Rollins, Raytheon Missile Systems, Tucson AZ

Steve Smith, Consulting Scientist, Smith & Co.

Ignorance of the Problem

"It's not what you don't know;
it's the things you know, that are not so,
that really get you."

"Publically" Reported Whisker Failures (partial listing)

- 1942-43 Aircraft Radio Corporation electrical problems
- 1946 American Electroplaters' Society *The Monthly Review*
- 1951 Conference of the National Assoc of Corrosion Engineers
- 1956 Convention of American Electroplaters Society
- 1974 20 Years of Observation - Trans. Inst. of Metal Finishing
- 1986 Pacemaker FDA Class 1 recall total failure crystal short
- 1989 Phoenix air-to-air missile failures
- 1991 Raytheon Patriot missile intermittent mis-fire problems
- 1998 Galaxy IV & VII (PanAmSat)
- 2002 Relay Failure Caused by Tin Whiskers
- 2005 Millstone Unit 3 nuclear reactor shutdown
- 2006 Galaxy IIIR (PanAmSat)

2002 Grumman Northrup Relay Failures

3 Relay failures from a Military Aircraft -- approximately 10 years old. Failed in 1998. Rated at 25 amps/115 Vac/3 phase

Figure 1 – Failed relay

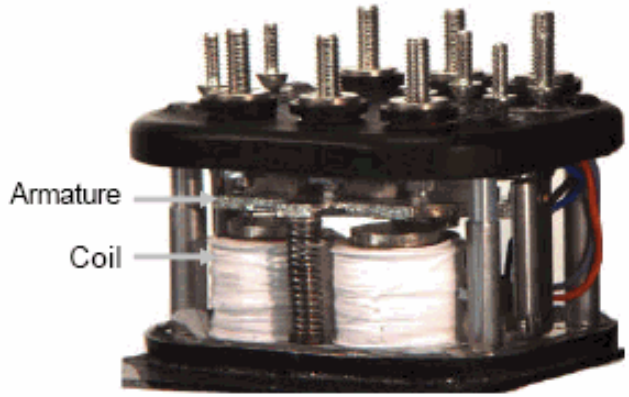

Figure 2 – Opened un-failed relay

NASA Space Shuttle OV-105

- Challenger explodes in 1986 tragically killing its crew

- Congress authorizes funding for replacement shuttle OV-105 Endeavor

- Expense to dispose of waste lead plating bath; Honeywell proposes to "go green" provided pure tin-plated card guides

- During 2006, NASA found 100 to 300 million tin whiskers growing on these card guides; whiskers had lengths between 0.2 mm and 25 mm.

NASA Videos

NASA asks: Why are so many people ignorant of tin whisker risks?

Most people think, "If it hasn't happened to me, then I don't care about it" not realizing that it is happening to them.

Most people address problems that they know they have had before. They do not recognize a steady drizzle of problems caused by metal whiskers. It's hard to "see" whiskers even when whiskers are present.

Do all tin, zinc or cadmium coatings produce whiskers?

- Not all of these coatings produce whiskers within the time of use of the equipment.

- NASA inspected 100 walnut-sized tin plated relays, stored for at least 5 years (no contacting that might rub off whiskers). About 20% were growing whiskers.

- No one yet understands how to predict the whiskering proclivities of a given tin coating.

Not all whiskered surfaces cause circuit malfunctions!

- Bridge to another conductor at a different voltage
- Low voltage melts the whisker open, escaping logged fault
- Event is able to latch an enduring fault
- ~1V, evaporates entire whisker
- >15V, metal vapor plume forms plasma arc
- ≥50V, at ≥30A, post-identification damage obvious
- Size and geometry can increase risk more than six orders of magnitude

Not all whisker-induced failures can be identified

- Failure analysis can cost $300 to $3000 per job
- Most commercial equipment is junked, repaired without analysis
- Typically only military and space communities carry out the analysis needed to locate the problem
- Very few analysts correctly identify whisker-induced problems

Not all cases of whisker-induced failures are reported!

- NASA has logged, in 5 years, 3 to 5 reports a month of tin whisker infestation that required urgent help

- Very few have allowed NASA to document their problems in detail or share results publicly

- Fear of lost sales, warranty claims, punitive damages, injuries, embarrassment and no desire to share solutions to problems with competitors

NASA Estimate of the Problem

"The hundreds of cases we have documented scale to roughly a few million to a few hundred million cases of whiskering problems over the last fifty years --- this seems about right to me."

-Dr. Henning Leidecker

Goddard Space Flight Center

Do suppliers give us what we order?

- If you specify 3% leaded-tin coating, will you be certain that you receive it?

- NASA found “pure tin coatings” 1.5 to 3% of the time (month to month) even when the contract and Certificate of Compliance says “contains X% lead”

- Believing the "Certificate of Compliance" contributed to a multi-billion dollar event (not to NASA; rather, to a commercial fleet) caused by whiskering-induced shutdowns in spacecraft.

Are there mitigations?

- Conformal electrical insulating coatings to block any loose whiskers from shorting

- A whisker-tough coating (there is none yet) which contains whisker growth

- Re-plating with tin-lead solder

Corfin Industries - Salem NH
www.corfin.com

- Robotic Hot Solder Dip (RHSD) – for Tin Whisker Mitigation US Navy-qualified process removes 100% of the pure tin and replaces it with SnPb (tin-lead)
- Robotic Hot Solder Dip (RHSD) – for RoHS compliance removes the SnPb and replaces it with SAC305 (tin silver copper) or any other specified alloy
- BGA Reballing for conversion to Tin-Lead or RoHS-compliance
- Flushes all balls and alloy residue on the pads and replaces balls of Sn63, SAC305 or any other specified alloy.
- XRF – X-Ray Fluorescence Analysis – Used to determine Lead (Pb) content of Termination Finishes and Plating Thickness.

Hi-Rel Services

Tin Whisker Mitigation - Adding Lead to Chip Size Components with Pure-Tin Terminals

Issues facing Hi Rel Product Manufacturers

- Traditional solder terminals with >3% lead is not prone to whiskering
- Tin Whiskers tend to grow on pure-Tin terminated surfaces
- Whisker growth in Pure Tin Terminated components are unpredictable, and there is no accepted accelerated method to test for whiskering propensity
- Pure-Tin Terminated leaded components can be hot Sn-Pb Solder Dipped (though not always 100% effective)
- Pure-Tin terminated chip size components cannot be hot Tin-Lead Solder Dipped because of their very small sizes

UNACCEPTABLE

Tin whisker growth in Commerical Pure-Tin terminated chip-size component after 45 Thermal Cycles (MIL STD 202, Method 107)

Exclusive AEM Processes to add Lead to COTS Pure-Tin Terminals:

- Part of our AEM regular process of terminating chip size passive components to include capacitors, inductors, resistors, ferrite chip beads and fuses
- Processed components will be Up-screened (Groups A & B) and QCI performed
- Up screening and QCI can be per MIL STD 202, SCD, MIL Spec, etc.
- Processed and fully up-screened components will be warranted as AEM products
- Applicable to most multi-layer chip-size components. Other components may be processed subject to construction constraints

Summary

For high reliability electronics, such as for NASA, military, aerospace or medical, specify "no pure tin, or zinc, or cadmium plating" on your equipment or at least try to mitigate whiskers with conformal coatings.

Check your incoming materials at the document-level and use explicit assays.